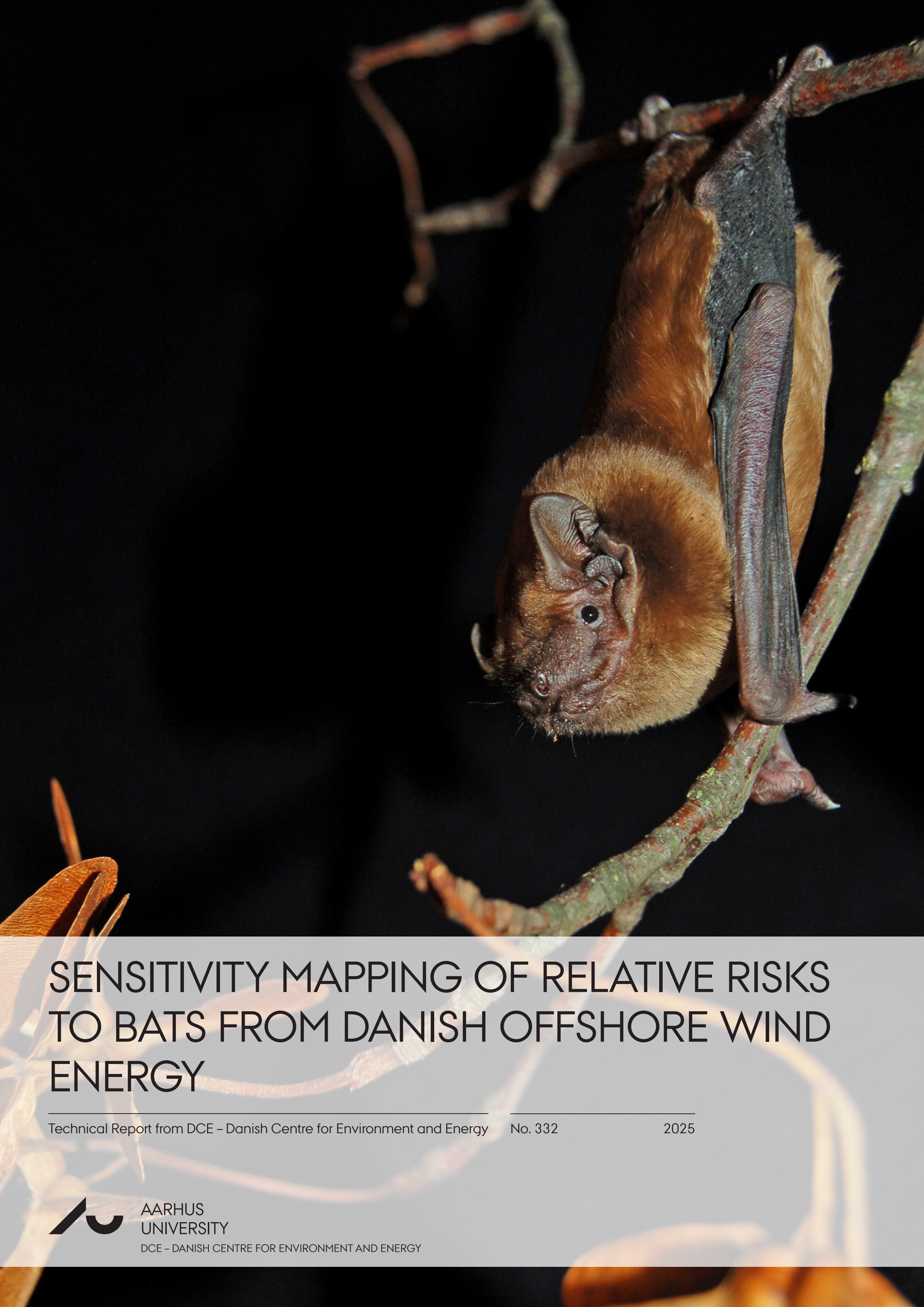

SENSITIVITY MAPPING OF RELATIVE RISKS TO BATS FROM DANISH OFFSHORE WIND ENERGY

Technical Report from DCE – Danish Centre for Environment and Energy No. 332 2025

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Abstract: The data and information available for bats from environmental investigations and independent studies in Danish offshore areas is scarce and data collection has not been systematically planned or repeated on a large scale over time and space. The sensitivity map for bats presented in this report is therefore based on expert evaluations and a cautionary principle as it was not possible based on current knowledge to develop an objective and quantitative spatial model to predict species occurrence, abundance and risk of impact. Until a more robust database is established, bats are predicted to be overall most sensitive within a 20 km distance of the entire Danish coastline and throughout the Baltic Sea and Belt area. From 20 to 40 km offshore the sensitivity is assessed as medium. Further offshore, the sensitivity of bat populations to wind turbines in the North Sea is assessed as low, while the sensitivity in the Skagerrak and the Kattegat is assessed as medium. The report highlights methodological challenges and significant knowledge gaps.

Keywords: Bats, Nathusius' pipistrelle, offshore wind farm, sensitivity analysis, risk assessment

Front page photo: Noctule (*Nyctalus noctula*), a long-distance migratory bat species. Photo by Signe MM Brinkløv.

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Contents

Preface

Background for the report and relation to other activities

This report contributes to the project "*Environmental mapping and screening of the offshore wind potential in Denmark*" initiated in 2022 by the Danish Energy Agency. The project aims to support the long-term planning of offshore wind farms by providing a comprehensive overview of the combined offshore wind potential in Denmark. It is funded under the Finance Act 2022 through the programme "Investeringer i et fortsat grønnere Danmark" (Investing in the continuing greening of Denmark). The project is carried out by NIRAS, Aarhus University (Department of Ecoscience) and DTU Wind.

The overall project consists of four tasks defined by the Danish Energy Agency (https://ens.dk/energikilder/planlaegning-af-fremtidens-havvindmoelleparker)

1. Sensitivity mapping of nature, environmental, wind and hydrodynamic conditions.
2. Technical fine-screening and assessment of the overall offshore wind potential based on the sensitivity mapping and relevant technical parameters.
3. Assessment of potential cumulative effects from large-scale offshore wind development in Denmark and neighbouring countries.
4. Assessment of barriers and potentials in relation to coexistence.

This report addresses one component of Task 1: sensitivity mapping. Specifically, it provides an overview of areas within Danish offshore regions that are likely to be particularly vulnerable to offshore wind farm development regarding bats. Other subjects within Task 1 – such as fish, birds, marine mammals, benthic habitats, wind and hydrodynamics and ecosystem modelling – will be presented in separate reports in late 2024 and early 2025. A synthesis of all topics under Task 1 will be published in 2025.

The project has relied predominantly on historical data, with minimal new data collection. As a result, the sensitivity mapping is largely dependent on the availability and accessibility of pre-existing data across specific subject areas. From the outset, significant effort was made to incorporate all relevant data to comprehensively address the task requirements. However, certain existing datasets could not be accessed. Section 3.1 specifies the information used in the sensitivity mapping for bats. It is important to recognise that sensitivity mapping serves as a dynamic tool, which can be updated as new data becomes available.

The project management teams at both AU and NIRAS have contributed to the description of the background for the report and the relation to other activities in the preface. The report and the work contained within are solely the responsibility of the authors.

Sammenfatning

I forbindelse med screeningen af havvindspotentialet i danske farvande har flagermuseksperter fra Aarhus Universitet udarbejdet følsomhedskort for flagermus på baggrund af eksisterende videnskabelig litteratur om flagermustræk og resultaterne af flagermusundersøgelser i konsulentrapporter i forbindelse med marine baseline-undersøgelser og miljøkonsekvensvurderinger i forbindelse med vindmølle- og andre anlægsprojekter.

Overordnet eksisterer der kun få offshore undersøgelser af flagermus over danske farvande, og datagrundlaget er derfor utilstrækkeligt til modelbaserede følsomhedskort. Følsomhedskortet for flagermus er derfor baseret på ekspertvurderinger og bør betragtes som et dynamisk redskab, der løbende opdateres i takt med at nye undersøgelser tilføjes.

Rapporten sammenfatter desuden en række af de usikkerheder, der dels er forbundet med den hyppigst anvendte metode, passiv akustisk overvågning, og dels opstår i forbindelse med varierende eller manglende detaljegrad i afrapporteringen og manglende krav hertil.

Dette er afspejlet i følsomhedsvurderingen, der derfor tager udgangspunkt i, at der kan forventes eller, indtil et mere robust og bredere geografisk datagrundlag opnås, ikke kan udelukkes flagermustræk over hele de indre danske farvande. Desuden må der forventes regelmæssig forekomst af flagermus gennem sommeren kystnært op til mindst 20 km fra kysten langs samtlige danske kyststrækninger og over de indre danske farvande og Østersøen.

Summary

As part of the national screening of the potential for offshore wind energy in Danish waters, bat experts from Aarhus University have prepared a sensitivity map for bats based on existing scientific publications and consultancy reports, describing bat migration and the results of bat surveys conducted as part of marine baseline investigations for environmental impact assessments related to offshore wind and other infrastructure projects.

Overall, only few investigations exist of bats over Danish waters and of bats offshore in general. Consequently, the data foundation is insufficient to allow model-based sensitivity analyses. The resulting sensitivity map for bats is therefore based on expert assessments and should be considered as a dynamic tool and be continuously updated with the results of further research and surveys.

The report also summarizes data uncertainties partly inherent to passive acoustic monitoring, the most common and accessible method used in bat surveys offshore and partly introduced with the variable and deficient degree of detail included when results of those surveys are reported and missing standards for methodology and reporting such surveys.

This is reflected in the evaluation of sensitivity and the resulting sensitivity map for bats, which currently, and based on a precautionary principle until more robust data becomes available, assumes that bat migration activity is likely throughout the entire inner Danish waters. Regular activity of bats throughout the summer season up to at least 20 km from shore is also predicted along coastal areas country-wide and over inner Danish waters, including the Baltic Sea.

1 Introduction

As part of the political strategy for sustainable energy, the Danish Energy Agency has initiated a screening of Danish waters to map the potential for offshore wind development and guide long-term planning efforts on a national scale. Sensitivity assessments and associated offshore sensitivity maps for a range of species will feed into the screening. The present report concerns the species group bats.

1.1 Aim

The overall purpose of this report is to review available studies on bats from offshore and coastal areas. In this introductory chapter, we first briefly summarize background knowledge on bat migration over Danish and associated offshore areas. Next, we introduce each of the bat species known from Denmark and documented over marine areas and follow up with information about their international conservation status. The introduction is concluded with a description of bat survey techniques, with specific focus on passive acoustic monitoring.

In the subsequent chapters, we compile and review information and data for bats from scientific studies and consultancy reports. We provide an overview of the duration and geographic coverage of surveys, the types and settings of equipment used, and the degree of detail reported. The information is then used to 1) evaluate and map bat sensitivity to potential offshore wind development in the collective Danish offshore area and 2) identify significant knowledge gaps to be addressed in future assessments of the consequences and cumulative effects of large-scale wind development on bats. In this context, we problematize the extent of information disclosed for bat surveys in general in relation to their applicability for the sensitivity assessment.

The resulting sensitivity map identifies areas where bats are considered at low, medium or high risk of being affected by offshore wind development. For data deficient areas, the expert evaluation of sensitivity is instead guided by a precautionary principle.

It is not within the scope of this report to discuss efforts to mitigate the potential effect of wind turbines on bat populations.

1.2 Bat migration

European bat species move between distinct summer and winter habitats, with some species embarking on long-distance migrations of up to 2,200 km (e.g., Hutterer et al. 2005, Kruszynski et al. 2020, Alcalde et al. 2021). Known long-distance migrants include Nathusius' pipistrelle, the noctule, the particoloured bat and Leisler's bat.

The spring migration of most European bat species happens during April and May where the bats arrive at breeding sites in Northern Europe. The returning autumn migration to Central and Southwestern Europe happens from late-August to October (Lagerveld et al. 2021, Pētersons 2004, Voigt et al. 2012a, Rydell et al. 2014, Seebens-Hoyer et al. 2021). Bats are thought to fly at low height during long distance flights (Ahlén et al. 2007) but migrating bats may fly at heights above 1,000 m (O'Mara et al. 2019, 2021, Voigt et al. 2024a) and bats have been recorded at nacelle height or higher on offshore wind turbines (Hatch et al. 2013, Brabrant et al. 2019).

Commuting and migrating bats do not always fly in straight lines but may meander and approach environmental or anthropogenic features that provide richer acoustic information (Goldshtein et al. 2024). Wind turbines or other structures offshore could serve as beacons for migrating bats (Horn et al 2010, Cryan et al. 2014), consequently increasing the risk of collisions.

Movement patterns and migration distances of a given species may vary with the geography and knowledge from one area of Europe is therefore not reliably transferable to other areas (Hutterer et al. 2005, Lehnert et al. 2018). There is in general little quantitative knowledge on bat migration, and despite an increasing focus over recent years, the existing survey effort for bats is not enough to fill this gap.

1.2.1 The Baltic and Belt Sea

Bats migrate in large numbers from breeding sites in Denmark, the Scandinavian peninsula and Finland to hibernation sites in Central and Western Europe, moving through Denmark and crossing the Belt Sea and Danish parts of the Baltic enroute (Ahlén 1997, Hutterer et al. 2005, Rydell et al. 2014, Gaultier et al. 2020, Kruszynski et al. 2020, Seebens-Hoyer et al. 2021). The species recorded most regularly include Nathusius' pipistrelles, noctules and soprano pipistrelles. These species as well as Daubenton's bat, common pipistrelle, serotine, northern bat, pond bat, and brown long-eared bat may also use the Baltic and the belt areas as foraging habitats during the summer and autumn (e.g. Ahlén et al. 2007).

1.2.2 The Kattegat and the Skagerrak

Knowledge on migration and foraging activities in the Kattegat and the Skagerrak areas is incidental and no systematic studies exist. Bats are occasionally found on islands in the Kattegat during late-summer and autumn (Baagøe 2001, NIRAS 2021, Elmeros et al. 2024). Species recorded on Læsø, Anholt, Hirsholmene and Hjelm include Daubenton's bat, noctule, Nathusius' pipistrelle, soprano pipistrelle, serotine and parti-coloured bat. Bat activity has also been documented across all seasons from a PAM (passive acoustic monitoring) station on the beach near Grenen, Skagen (Johansen & Johansen 2020).

1.2.3 The North Sea

Most of the North Sea like the Skagerrak represents a 'black box' with no information about offshore bat activity (Brinkløv et al. 2024b). Bat migration is documented across the southern parts of the North Sea (e.g., Bach et al. 2022, Lagerveld et al. 2019, Seebens-Hoyer et al. 2021). Species records from the North Sea include: Nathusius' pipistrelle (the species most frequently recorded for the area), northern bat, Leisler's bat, noctule, parti-coloured bat, common pipistrelle, and the serotine (Petersen, A et al. 2014, Brabant et al. 2019, Lagerveld et al. 2019, Lagerveld et al. 2021, Seebens-Hoyer et al. 2021). Records from the northern North Sea stem mostly from non-systematic observations of bats on structures (e.g., oil rigs) and vessels (Petersen, A et al. 2014) and are not useful for estimating activity, migration routes and patterns offshore.

1.3 Bats in Danish offshore areas

Eighteen species of insectivorous, vespertilionid bats have been recorded in Denmark, including a recent record of the grey long-eared bat, *Plecotus austriacus* (Baagøe 2007, Elmeros et al. 2024, arter.dk). All European bat species are strictly protected on Annex IV of the Habitats Directive (eur-lex.europa.eu). Three species occurring in Denmark are also listed on Annex II. All bat species that occur in Denmark have been found dead under onshore wind turbines (Rodrigues et al. 2015, EUROBATS 2017). Fatality surveys have not been performed and are not feasible for offshore wind turbines, but bat species that are at risk at onshore wind turbines must be expected also to be at risk at offshore wind turbines until studies have proven otherwise.

Presently, 11 of the 18 species that occur in Denmark have been documented foraging at varying distances to the coast or migrating over marine areas (e.g., Ahlén et al. 2007, Petersen, A et al. 2014, Seebens-Hoyer et al. 2021). The following paragraphs introduce these 11 bat species in taxonomic order. The relative fatality rates included in the species descriptions are derived from reported numbers of dead bats found under wind turbines (Rodrigues et al. 2015). These EUROBATS guidelines are applicable both on- and offshore but the fatality estimates stem from studies of wind turbines on land. It is not feasible to recover and estimate bat fatalities directly from offshore wind turbines.

Bats also forage during migration, i.e., the two behaviours are not strictly differentiated in time and space (Voigt et al. 2012b, 2024b). Most studies of individual bat migration distances rely on banding, but in recent years small tags have been deployed to follow individual bats (Hutterer et al. 2005, Taylor et al. 2017, O'Mara et al. 2019, 2021, Bach et al. 2022). These methods do not account for the potential migration distances covered prior to the banding or tagging, and distances covered after recapture or the last point of data reception, e.g., by a radio-receiver (migration and methods are explained further in section 1.2 and 1.3).

1.3.1 Species introductions

Pond bat (*Myotis dasycneme*)
The pond bat occurs in most of Jutland and Southern Zealand, incl. Lolland-Falster, and is occasionally recorded on Funen and Bornholm (Elmeros et al. 2024). It is also found in Southern Sweden, in the Baltic countries, and in Germany, Poland, and the Netherlands (Haasma 2023).

Pond bats forage almost exclusively on aquatic insect prey seized from water surfaces, or the airspace above them (Haasma 2023). Foraging often occurs over marine areas (fjords, belts, inlets, e.g., Ahlén et al. 2007) where pond bats often emit characteristic echolocation calls of maximum energy at 30-35 kHz.

The pond bat is a medium-range migrant with documented movements of up to 300 km (Hutterer et al. 2005, Haasma 2023). Most of the Danish population hibernates underground in limestone pits in Central and Northern Jutland (Elmeros et al. 2022) but the catchment area and migration routes for pond bats hibernating in these sites are not well documented. A pond bat ringed in Northern Germany has been recorded hibernating in mid-Jutland and later found hibernating near Kiel (Andersen et al. 2019), indicating long-distance movements and exchange between national populations. The hibernation sites and migration routes for the population in Eastern Denmark and Southern Sweden are unknown, but the species has been recorded over Fehmarn Belt during the autumn migration period (FEBI 2013). The pond bat is expected to occur regularly over coastal waters around Jutland and Southern Zealand and Lolland-Falster but may also occur further than 10 km from the coastline migrating across The Baltic Sea and belts (Ahlén et al. 2007, FEBI 2013, Elmeros et al. 2024 and references therein).

Daubenton's bat (*Myotis daubentonii*)

Daubenton's bat is widespread and common throughout Denmark and all neighbouring countries (Encarnação & Becker 2020, Elmeros et al. 2024).

This species typically hunts over waterbodies, including marine areas, feeding on a variety of aquatic insects (Encarnação & Becker 2020) and occasionally small fish (Siemers et al. 2001). It is smaller than the pond bat, typically forages over more calm water surfaces than pond bats and uses echolocation calls with a higher peak frequency at 40-45 kHz.

Daubenton's bat has been recorded hunting up to 35 km offshore over the Baltic Sea and belts (e.g., Ahlén et al. 2007, Hällqvist et al. 2021). It is considered a short to medium-range migratory species. Migration distances up to 300 km have been logged for some individuals but are usually below 150 km between summer and winter habitats (Hutterer et al. 2005, Encarnação & Becker 2020). Thousands of Daubenton's bats hibernate in the limestone pits in Central and Northern Jutland and migrate there from the whole of Jutland (summarised in Elmeros et al. 2022), but there are numerous smaller hibernation sites across Denmark. Migration routes over Danish marine areas are unknown, but Daubenton's bats have been observed across multiple years leaving the southern coasts of Sweden and the Danish isles in late summer and autumn (Ahlén 1997, Ahlén et al. 2007, Baagøe 2011, Baagøe & Fjederholt 2014). They have also been recorded over Fehmarn Belt (FEBI 2013). Daubenton's bats are expected to forage regularly over inner Danish water and migrate across the Baltic Sea and belts.

Nathusius' pipistrelle (*Pipistrellus nathusii*)

Nathusius' pipistrelle is widespread and relatively common across most of Denmark (Elmeros et al. 2024). Breeding populations are also found in Southern Norway, Sweden and Finland, in the Baltic countries and further east (Russ 2022).

Nathusius' pipistrelle is an aerial hawking species (Russ 2022) and has often been recorded foraging over brackish waters in fjords, belts and the Baltic Sea (Ahlén et al. 2007, Elmeros et al. 2018, Seebens-Hoyer et al. 2021). It is among the species recorded most numerously as fatalities under wind turbines (e.g., Rodrigues et al. 2015, EUROBATS 2017). Characteristic echolocation calls of Nathusius' pipistrelle have a peak-energy at 35-40 kHz.

Nathusius' pipistrelle is a long-distance migrant with numerous distance records > 1000 km, including some >2000 km (Hutterer et al. 2005, Alcalde et al. 2021). Nathusius' pipistrelle from the breeding populations in Northeastern Europe migrate across inner Danish marine waters to Central and Southwestern Europe in late summer and early autumn to hibernate (Ahlén 1997, Pētersons 2004, Ahlén et al. 2007, Voigt et al. 2012a, 2012b, Kruszynski et al. 2020, Seebens-Hoyer et al. 2021). Migration from Jutland to Germany and the Netherlands during autumn has also been documented (Brinkløv et al. 2024b, Elmeros et al. unpublished). Whether these individuals were transient migrants from the Norwegian breeding population is unknown. The spring migration patterns of Nathusius' pipistrelle across Denmark and marine areas are not documented as well as the autumn migration. The migration behaviour of Nathusius' pipistrelles from the Danish breeding population is unknown, but the species has only rarely been recorded hibernating in Denmark (Baagøe 2001).

Nathusius' pipistrelle is one of the most likely species to occur regularly offshore in the Baltic Sea and belts and, but less regularly, over the North Sea, the Skagerrak and the Kattegat (Ahlén et al. 2007, Petersen, A et al. 2014, Seebens-Hoyer et al. 2021, Brinkløv et al. 2024b).

Soprano pipistrelle (*Pipistrellus pygmaeus*)
The soprano pipistrelle is widespread and common in Denmark apart from Western Jutland (Elmeros et al. 2024). It also occurs widely in Southern Sweden and Norway and in Eastern Germany, Poland and the Baltic countries (Jones & Froidevaux 2020).

The soprano pipistrelle is an aerial hawking bat and hunts at low to medium heights and distances to surfaces and clutter (Jones & Froidevaux 2020). Soprano pipistrelles are common among bat fatalities found under wind turbines (e.g., Rodrigues et al. 2015, EUROBATS 2017). The echolocation calls of the soprano pipistrelle typically have the peak energy at 50-55 kHz.

Foraging soprano pipistrelles are often recorded over brackish waters in fjords, belts and the Baltic Sea (e.g., Ahlén et al 2007, Seeben-Hoyer et al. 2021). The soprano pipistrelle is often presented as a stationary species that only migrates short distances between summer habitats and hibernation sites. However, parts of the populations migrate longer distances and some individuals have been recaptured >500 km from the marking site (Hutterer et al. 2005, Jones & Froidevaux 2020). Genetic studies also indicate that there are seasonal migrations in European populations (Racey et al. 2007). Individuals from the breeding populations in Scandinavia and Northeastern Europe presumably migrate to Central and Western Europe during late summer and early autumn (Ahlén et al. 2007, Jones & Froidevaux 2020, Seeben-Hoyer et al. 2021). The spring migration patterns of flyway populations through Denmark and offshore, and the migration patterns of soprano pipistrelle from the Danish breeding population are unknown.

Common pipistrelle (*Pipistrellus pipistrellus*)
The common pipistrelle occurs most frequently in Southern and Central Jutland, on Zealand and Bornholm (Elmeros et al. 2024). It is widespread and relatively common throughout Europe apart from most of Scandinavia and Finland (Mathews et al. 2022). Common pipistrelle and soprano pipistrelle were only differentiated as separate species a few decades ago (Jones & Barratt 1999). For this reason, historical data, including banding studies, confound the two species that do exhibit similar behaviour.

The common pipistrelle hunts at medium heights and distances to surfaces and clutter (Mathews et al. 2022). It is one of the species with the highest number of known fatalities from wind turbines (Rodrigues et al. 2015, EUROBATS 2017). The species' echolocation calls have a maximum energy at frequencies around 44-47 kHz, intermediate between the peak frequencies typically used by the soprano and Nathusius' pipistrelles.

Seasonal migration distances for the common pipistrelle are usually less than 20 km (Hutterer et al. 2005, Mathews et al. 2022), and genetic analysis suggests that the common pipistrelle is more stationary than the soprano pipistrelle (Racey et al. 2007). However, there seem to be regional variations in migration patterns, and long-distance migrations of 700-1000 km occur (Hutterer et al. 2005). In Scandinavia, vagrant common pipistrelles have been observed far from the breeding areas during the summer, and the species has occasionally been found on platforms in the North Sea (Racey et al. 2007). Common pipistrelles occur in smaller numbers around the southern coast of Sweden and foraging over the Baltic Sea and Øresund (Ahlén 1997, Ahlén et al. 2007, Rydell et al. 2014).

Leisler's bat (*Nyctalus leisleri*)

Leisler's bat is a rare species in Denmark and Sweden but widespread and common further south in Europe and on The British Isles (Boston et al. 2020, Elmeros et al. 2024). Records from Denmark are possibly vagrants, but Leisler's bat has been recorded increasingly in recent years, primarily in Eastern Denmark, and small breeding colonies might be present.

Leisler's bat feeds on a diverse diet and is a fast-flying, aerial hawking species (Boston et al. 2020) with frequent fatalities at wind turbines (e.g., Rodrigues et al. 2015, EUROBATS 2017). Characteristic echolocation calls from Leisler's bat alternate between peak frequencies at 25-27 kHz and 21-25 kHz. The lower-frequency call can be relatively long (up to 20 ms) with almost constant frequency.

Leisler's bat is a long-distance migrant covering large distances up to >1000 km between summer habitats and hibernation areas (Hutterer et al. 2005, Boston et al. 2020). Individuals have been found on the Faroe Islands, isles north of Scotland and on ships and platforms in the North Sea (Petersen, A et al. 2014). Leisler's bat is expected to occur irregularly foraging and migrating over the Baltic Sea and the belts.

Noctule (*Nyctalus noctula*)

The noctule is relatively common in most of Denmark except in the western part of Jutland (Elmeros et al. 2024). It is widespread in the Central and Western Europe with breeding populations in Denmark, Southern Sweden, Norway and Finland and in the Baltic countries (Lindecke et al. 2023).

The noctule is a fast-flying, aerial hawking bat (Lindecke et al. 2023). The flight and hunting behaviour of noctule presents a high risk for collisions at wind turbines, and numerous fatalities has been recorded under wind turbines (e.g., Rodrigues et al. 2015, EUROBATS 2017). The noctule often echolocates with alternating calls with peak-energy at 22-26 kHz and 19-22 kHz, respectively. The low-frequency call type is often relatively long (up to 28 ms) and of almost constant frequency.

The noctule is a long-distance migrant and may commute, forage and migrate at heights of up to several hundred meters over land (Roeleke et al. 2016, O'Mara et al. 2019). The breeding populations in Northern and Eastern Europe migrate between summer habitats and wintering areas in Central and Western Europe (Ahlén 1997, Ahlén et al. 2007, Hutterer et al. 2005, Lindecke et al. 2023, Seebens-Hoyer et al. 2021). Noctules within a population may migrate over highly variable distances up to more than 1,000 km (Hutterer et al. 2005, Lehnert et al. 2018).

Noctules have been found on ships and platforms in the North Sea and the isles north of Scotland (Petersen, A et al. 2014). It is unknown if wintering individuals in Denmark are migrants from elsewhere in Scandinavia or Northeastern Europe. The species is expected to occur regularly foraging and migrating over the Baltic Sea and the Belt Sea (Ahlén et al 2009). Migration may occur less regularly over the Kattegat, the Skagerrak and the North Sea. Noctules have been recorded foraging 18 km offshore and at heights up to 1,000 m (e.g., Ahlén et al 2007, Lagerveld & Mostert 2023).

Northern bat (*Eptesicus nilssonii*)
The northern bat is a rare species in Denmark except on the island of Bornholm (Elmeros et al. 2024). It is also recorded regularly in Elsinore but elsewhere the species is only found sporadically. The species is widespread and common in Sweden, Norway, Finland and its distribution range also include most of Eastern and Central Europe (Suominen et al. 2022). Northern bats occur at several islands in the Baltic Sea (Ahlén 2004) and have apparently established a breeding population on Bornholm during the last decades (Elmeros et al. 2024).

The northern bat is an aerial hawking species, typically hunting at relatively low heights below 10 m above the ground (Suominen et al. 2022). It is frequently recorded hunting along the coasts in Southern Sweden and over the Baltic Sea (Ahlén et al. 2007, 2009). The northern bat is recorded in relatively low numbers as fatalities at wind turbines (Rodrigues et al. 2015, EUROBATS 2017). Echolocation calls with a peak frequency at 26-29 kHz are common for northern bats in open environments.

The species is relatively stationary and generally only migrates short distances between breeding habitats and hibernation sites, but a few individuals have been recorded migrating up to 450 km (Hutterer et al. 2005, Suominen et al. 2022). Vagrant individuals have also been recorded far from the normal distribution area, e.g. on platforms in the North Sea and the Faroe Islands (Petersen, A et al. 2014). The northern bat is expected to occur foraging and migrating over the Baltic Sea and belts, but vagrant individuals may occur throughout the Danish offshore area.

Serotine (*Eptesicus serotinus*)
The serotine is widespread and relatively common in most of Denmark (Elmeros et al. 2024) and in Europe further south, while it is only rarely found in Southern Sweden (Martinoli et al.2020).

The serotine is an aerial hawking bat, typically flying and foraging at heights below 10 m (Martinoli et al. 2020). Like other aerial hawking species, the serotine is at relatively high risk of collisions at wind turbines, and fatalities are regularly recorded under wind turbines (Rodrigues et al. 2015, EUROBATS 2017). It is a food generalist and flexible depending on prey availability. The serotine emits echolocation calls with a frequency of maximum energy at 23-27 kHz.

The serotine is relatively sedentary and typically migrates less than 50 km seasonally, but some individuals may migrate more than 300 km (Hutterer et al. 2005, Martinoli et al. 2020). Despite the generally short migration distances, there is high gene flow between populations in Europe apart from across the English Channel (Martinoli et al. 2020). The serotine has been documented leaving the coast in Southern Sweden over the Baltic Sea, and it has also been observed foraging over the Baltic Sea and Øresund (Ahlén et al. 2007).

Parti-coloured bat (*Vespertilio murinus*)
The parti-coloured bat is common in Northern Zealand, but also occurs widespread on the rest of Zealand, much of Jutland and on Bornholm (Elmeros et al. 2024). The distribution range outside of Denmark covers Southern Sweden and Norway and most of Central and Eastern Europe (Safi 2020).

The parti-coloured bat forages over open landscapes and often high above productive waterbodies, including brackish waters (Ahlén et al. 2007, Safi 2020). The flight behaviour of the parti-coloured bat makes it prone to collision risks at wind turbines and high numbers of fatalities have been recorded (e.g., Rodrigues et al. 2015, EUROBATS 2017). Species characteristic echolocation calls of parti-coloured bats have a peak-energy at frequencies at 22-25 kHz, but the species is not always easily distinguished from, e.g., noctules or serotines.

Parti-coloured bats from the breeding populations at the species' northern and eastern ranges migrate to Central and Western Europe for hibernation, while populations in Central Europe may migrate at a regional scale (100-200 km) between summer and wintering habitats (Hutterer et al. 2005, Safi 2020). The maximum migration distance recorded for a parti-coloured bat is >1,500 km. The parti-coloured bat is known to hunt and migrate over the Baltic Sea and the belts (Ahlén 1997, Ahlén et al. 2007). Individuals have also been found at platforms in the North Sea, on the isles north of Scotland and on the Faroe Islands in the North Atlantic (Petersen, A et al. 2014). Rare island records from late summer and autumn also suggest some migration across the Kattegat.

Brown long-eared bat (*Plecotus auritus*)
The brown long-eared bat is found in most of Denmark except for Western and Northern Jutland (Elmeros et al. 2024). It is also widespread in most of Europe (Ancillotto & Russo 2020).

Brown long-eared bats forage by gleaning prey off vegetation or other surfaces but is also capable of catching flying insects usually while hunting close to clutter (Ancillotto & Russo 2020). The echolocation calls of brown long-eared bat are of low intensity, with detection ranges <10 m, making this species difficult to monitor acoustically. Consequently, it is likely underrepresented in acoustic surveys.

Although brown long-eared bats usually hunt near or in vegetation (Ancillotto & Russo 2020), the species may forage over the open sea over Øresund and the Baltic Sea (Ahlén et al. 2007). The hunting behaviour renders the long-eared bat at low risk for collisions from wind turbines, but a few fatalities have been documented (Rodrigues et al. 2015, EUROBATS 2017).

The brown long-eared bat is a mostly sedentary species with short migration distances between its summer habitats and wintering sites (Hutterer et al. 2005, Dietz et al. 2009). Known migration distances for the brown long-eared bat are typically <30 km, the longest recorded migration is 90 km (Hutterer et al. 2005, Ancillotto & Russo 2020).

1.4 Conservation status of marine foraging or migrating bats

All European bat species are strictly protected by national implementation of the EU Habitats Directive. International legislation thus prescribes that disturbances and incidental killings of bats must be monitored, prevented and limited to ensure that bat populations maintain a favourable conservation status. The national conservation status for most of the common Danish bat species is generally assessed as favourable, but due to limitations in the monitoring methods, this assessment does not include empirical data on population sizes and trends (Fredshavn et al. 2019). Furthermore, offshore sensitivity assessments for bats need to also consider flyway populations of the migratory species that cross country borders and biogeographic regions as well as species foraging offshore. The conservation status of most bat species found foraging or migrating over Danish waters is generally unfavourable or unknown at a European level (Table 1.1, see also https://nature-art17.eionet.europa.eu/article17/).

Bats are long-lived and reproduce at slow rates, a combination which leaves them sensitive to increased mortality rates (e.g., Altringham 2011). Even small changes in annual mortality rates may have significant impact on the status of bat populations (Frick et al. 2017, Voigt et al. 2012a, 2024a). Collisions with rotating turbine blades lead to an increase in mortality within bat populations, and it is likely that such an increase in mortality can have a negative effect on the conservation status of bat populations (e.g. EUROBATS 2015, Voigt and Kingston 2015, Voigt et al. 2024a). Especially for bat species that migrate at medium- or long-range distances, the cumulative effect of wind turbines may have significant impact on the status of populations, although bat mortality per turbine may appear insignificant (Frick et al. 2017, Friedenberg & Frick 2021). Onshore wind turbines result in habitat loss (e.g., Millon et al. 2018, Reusch et al 2022, Leroux et al. 2024) and displacement effects of offshore wind turbines have been shown for birds (Petersen, IK et al. 2014, Petersen et al. 2018, Scott-Hayward et al. 2024). To what extend this may also apply to bat activity offshore is unknown.

Offshore wind turbines are expected to pose a risk to the same bat species as onshore wind turbines, especially to the populations of long-distance migrators (e.g., to and from Sweden) and the species most commonly found foraging and migrating at sea, Nathusius' pipistrelle, noctule, parti-coloured bat, soprano pipistrelle, Daubenton's bat, and pond bat (e.g., Ahlén 1997, Ahlén et al. 2007, Petersen, A et al. 2014, Seebens-Hoyer et al. 2021). There is a significant information gap on population sizes and dynamics at a national and international or fly-way population level, and a lack of suitable methods to assess conservation status at flyway-population level (Voigt et al. 2012a, 2024a).

Table 1.1. Migratory behaviour of bat species known to occur offshore in Denmark (see references in text under species descriptions). Also given for each species is their listing on the Habitats Directive (HD Annex) and current conservation status in the most relevant biogeographic regions (https://www.eea.europa.eu) bats might forage and migrate to and from across Danish waters. ATL: Atlantic biogeographic region, CON: Continental biogeographic region, BOR: Boreal biogeographic region. FV: Favourable, U1: Unfavourable-Inadequate, U2: Unfavourable-Bad, XX: Unknown (https://nature-art17.eionet.europa.eu/article17/, accessed 31/09/2024).

Scientific Name	Common Name	Migratory behaviour	HD Annex	EU Conservation status		
				ATL	CON	BOR
Myotis dasycneme	Pond bat	Medium	II + IV	U1	U1	U1
Myotis daubentonii	Daubenton's bat	Short - Medium	IV	U1	U1	FV
Pipistrellus nathusii	Nathusius' pipistrelle	Long	IV	XX	U1	U1
Pipstrellus pygmaeus	Soprano pipistrelle	Short - Medium	IV	FV	U1	XX
Pipistrellus pipistrellus	Common pipistrelle	Short - Medium	IV	U1	U1	XX
Nyctalus leisleri	Leisler's bat	Long	IV	U1	U2	XX
Nyctalus noctula	Noctule	Long	IV	XX	U1	U1
Eptesicus nilsonii	Northern bat	Short - Medium	IV	XX	U1	FV
Eptesicus serotinus	Serotine	Short - Medium	IV	U1	U1	XX
Vespertilio murinus	Parti-coloured bat	Medium - Long	IV	XX	U1	FV
Plecotus auritus	Brown long-eared bat	Short	IV	U1	U1	FV

1.5 Bat survey techniques

Danish bats are nocturnal, flying mammals and use ultrasonic echolocation, an orientation system that is short-range and inaudible to the human ear without special aids. Their cryptic lifestyle presents a major challenge for surveying and monitoring, and for compiling adequate knowledge for informed species management. The principle of echolocation involves emitting sound to interrogate the environment and listening for the returning echoes of the emitted sound to guide orientation and, in the case of most bats, foraging (Griffin 1958, Galambos & Griffin 1942). Bats use echolocation in air, where the range of ultrasound is short because the produced sound waves attenuate (lose energy) rapidly (Bass 1995, Goerlitz 2018, Ratcliffe & Jakobsen 2018). This has major implications for acoustic monitoring which is one of the main methods used to gain information about the occurrence, distribution and activity levels of bats (Lawrence & Simmons 1982, Ratcliffe & Jakobsen 2018, Russo et al 2018).

Available techniques to survey bats offshore include radar, video, tagging and tracking, and acoustic monitoring. Radar and video techniques are typically not cost-efficient enough for large-scale surveys and are not widely used for bat monitoring. Parallel to bird ringing, individual bats have traditionally been caught and banded to gain information about their movements but the use of this method to provide data on bat migratory paths requires successful re-capture or recovery of the same individual to be useful (Rodrigues et al. 2015). The method may be ethically problematic, as bands may cause injuries to the bats (Baker et al. 2001). With modern tracking methods, a variety of tags, e.g., VHF- or GPS-transmitters, can be attached to animals to collect different types of information (e.g. Taylor et al. 2017, Bach et al. 2022, Wild et al. 2023, Goldshtein et al. 2024). The main limitation of this method are the size and weight-bearing capacity of the animal carrying the tag (Meierhofer et al. 2024), and the need to retrieve tags with onboard data storage.

1.5.1 Acoustic monitoring of bats

Passive acoustic monitoring (PAM) by autonomous recorders programmed and deployed to record the echolocation activity of bats at night over weeks, months or even years is a valuable, low maintenance method to gain information about bat presence, absence and activity levels (Blumstein et al. 2011, Marques et al 2013). PAM is cost-effective, enables species identification to a large degree, and is used extensively in bat studies and investigations worldwide. Unfortunately, the limitations of PAM are rarely pointed out in consultancy reports. In this context, it should be stressed that the acoustic detection range covered even by numerous PAM stations offshore is minute compared to the overall size of the offshore survey or project area. Consequently, the number of bats recorded underestimates, and does not equal, the number of bats present in the project area. This is rarely declared in consultancy reports that may even claim that all bats are recorded in extensive project areas with a limited number of detectors. The estimated number of bats missed by the monitoring effort is, however, equally important to consider.

A range of commercial and custom-made recorders are used for bat surveys, e.g., the Wildlife Acoustics SongMeter range (SM2, SM4BAT, SM mini, etc.), AudioMoth, SeaBat (customized AudioMoth), AnaBat, Pettersson bat detectors, and more. There are, however, no standard equipment requirements or minimum standards for the degree of detail that should be reported for equipment specifications or acoustic analyses used in environmental bat surveys that include acoustic monitoring. In addition, no up-to-date formal and quantitative comparison has been published between the different types of equipment to quantify and directly compare the performance of different detector types that are often used in offshore surveys (Brinkløv et al. 2023), although several reports describe them as being in ‘general good agreement’.

Many factors influence the detection range for ultrasonic bat calls, including the properties of the call itself, the characteristics of the emitter (the calling bat), the characteristics of the receiver (the recorder), and the physical properties of the medium (air) through which the call is transmitted (Jakobsen et al. 2013, Adams et al. 2012, Voigt et al. 2021). Echolocation calls of lower intensity and higher frequency do not reach as far and are easier missed by recorders than high-intensity, lower frequency calls, because higher frequencies attenuate more. Bats do not emit omnidirectional echolocation calls that travel with equal intensity in all directions. Rather, they focus the energy of their calls in a directional forward beam like an ‘acoustic flashlight’ with a species dependent diameter. This means that the orientation or flight direction of the bat in space relative to the recorder also affects the detection range and probability of detecting the emitted calls. Similarly, ultrasonic microphones are rarely equally sensitive to sound received from all angles of incidence or to sound across all relevant frequencies, and microphone sensitivity can change significantly over time or with changing ambient conditions (e.g., if the acoustic membrane is exposed to rain). Further, detection range is affected by ambient temperature and humidity (Voigt et al. 2021), which contribute to the frequency-dependent attenuation of sound, and by noise, both inherent to the recording system, and ambient noise, e.g., from wind, waves, rain, vessels, and electrical sources (Madsen & Wahlberg, 2007, Darras et al. 2020, Brinkløv et al. 2023). Realistic estimates of detection range are ca. 30 m for Nathusius' pipistrelle (call peak frequency: 35-40 kHz) and ca. 50 m for the noctule (call peak frequency: 20-25 kHz) (Voigt et al. 2021). For species like long-eared bats that echolocate at low intensity, the detection range is even shorter (ca. 10 m).

1.5.2 Acoustic species identification

Many bat species emit echolocation calls with species-specific characteristics (e.g., Ahlén & Baagøe 1999, Barataud 2015). Bats echolocation is, however, dynamic and even the echolocation call structure of an individual is often flexible and changes on a call-to-call basis to optimise the echo information extracted from the environment. Consequently, echolocation calls can often only be reliably classified to species pairs, groups or complexes (Barclay 1999, Biscardi et al 2004, Russo et al 2018). Several commercial and open-source software options are available for automated detection and species identification of bat calls (Rydell et al. 2017, Obrist & Boesch 2018, Thomas & Davison 2020, Goodwin & Gillam 2021, Brinkløv et al. 2023), but their approach is often not fully transparent (e.g., commercial solutions that do not disclose the input data the software was trained on), and the output of such automated approaches is often reported without any comments on whether or how the results were validated.

The limitations described above are inherent to passive acoustic studies of bats but rarely reported as uncertainties in impact assessments. The use of multiple detectors increases the chance of recording bat presence, but bats still go unnoticed if they pass outside the detection range of the recorders (see section 1.3.1) or pass by during the off-phase where recorders are inactive if running on a specified on/off recording duty-cycle (see discussion).

Statistical approaches, such as distance sampling, can account for variations in detection probability and the potential number of bats missed by the PAM effort, based on knowledge or assumptions about the properties of bat calls, the recording equipment and environmental variables. Such tools have proven highly useful, e.g., for density index estimation and distribution in bird and marine mammal surveys (Marques et al. 2013, Buckland et al. 2015, Fregosi et al. 2022), but are rarely considered in bat surveys and have to date not been used in any consultancy report on bats as part of a Danish environmental impact assessment (EIA).

2 Methods

To carry out the expert assessment and sensitivity mapping of bats in Danish offshore areas, we compiled information from a review of scientific literature and environmental surveys for the impact assessments of offshore wind projects and the Fehmarn Belt fixed link infrastructure project. The information input was primarily from Danish surveys, supplemented with studies from Sweden and Germany. The assessment is based on the reported results and meta-data only. Raw data from the surveys, including sound recordings from manual or passive acoustic monitoring of bats, were not accessible.

'Grey literature', e.g., reports and notes from consultants carrying out the baseline surveys and not peer-reviewed and searchable from a collective database, represents a significant portion of the existing and potentially relevant information for the assessment of bat sensitivity offshore. Additional information about study designs were requested on behalf of Aarhus University and NIRAS by The Danish Energy Agency from relevant consultants, private and public energy companies to complement information included in the reports and support the sensitivity mapping.

The limited existing surveys and studies of bats at sea and along the coastlines do not include broad, long-term systematic mapping and monitoring in Danish waters and neighbouring seas. Consequently, the quality and volume of information available on the occurrence, activity and movements of bats offshore gives sparse input to inform a sensitivity map for bats. The sensitivity map for bats reflects expert assessments based on the available information, which is not sufficient to enable spatial modelling of the sensitivity of bat populations to offshore wind development.

The assessment of the quality and applicability of studies for inclusion in the sensitivity mapping was based on information on monitoring periods, the number and density of acoustic recorders in the project area, the recorder and microphone type used, the recorder settings, the approach to data analyses and species identification, and the level of detail reported. This knowledge is essential for cross-study comparisons and for obtaining comparable data for future surveys and monitoring. A comparative overview and considerations of the relevance of level and differences in reporting detail between surveys was not part of a recent note on bats and wind turbines (Christensen & Hansen 2023).

The survey descriptions and sensitivity assessments below are organized according to five sections of the Danish offshore area: the North Sea, the Skagerrak, the Kattegat, the Belt Sea and the Baltic Sea. Each of these sections or subareas within them are scored according to categories of high, medium or low sensitivity. The sensitivity assessment considers information from the surveys done for each section of the Danish offshore and scientific studies of bat migration in The Netherlands, Germany and Sweden.

3 Results

The descriptions below and the information in table 3.1-3.7 summarize published or supplemented details from offshore or coastal bat surveys for environmental assessments, primarily in Denmark. Even with the details gained from our request for further information to supplement the description in the survey reports, the database does not by itself substantiate the sensitivity assessments or allow quantitative modelling of bat occurrence offshore in Denmark.

3.1 Review of existing surveys

In this review section, we outline the survey effort and results of each survey in brief descriptions. Wherever species are listed in the descriptions, they appear in order from most to least commonly recorded. We also establish an overview of the number and type of detectors used, the geographical extent and time frame of the survey, the number of bat recordings and species identified from the survey, and the methods used for call analysis and species identification.

Figure 3.1 maps the pre-investigation areas for offshore wind farms (OWFs) that are either existing or in the planning phase. Of the 17 currently established OWFs in Danish waters (https://ens.dk/ansvarsomraader/vindmoeller-paa-hav/etablerede-havvindmoelleparker, accessed 15-11-2024), bat surveys were only part of the pre-investigations for Kriegers Flak (Figure 3.1). Bat surveys are included for most of the OWFs that have been or are currently in the planning phase but are not yet operational. Some of these only include land-based and no offshore monitoring efforts (Figure 3.2).

As part of the expansion of renewable energy in Germany, a geographically broad offshore monitoring project (Batmove) was carried out between 2016 and 2019 (Figure 3.3), with data collection from multiple PAM stations throughout the North Sea, the Belt Sea and the Baltic Sea (Seebens-Hoyer et al 2021). For the sake of overview, the results from the BatMove project are presented along with additional surveys below under each of the geographical areas they are relevant for.

The species identifications indicated below reflect the results reported for each survey and were only carried out by Aarhus University for the North Sea I first year surveys.

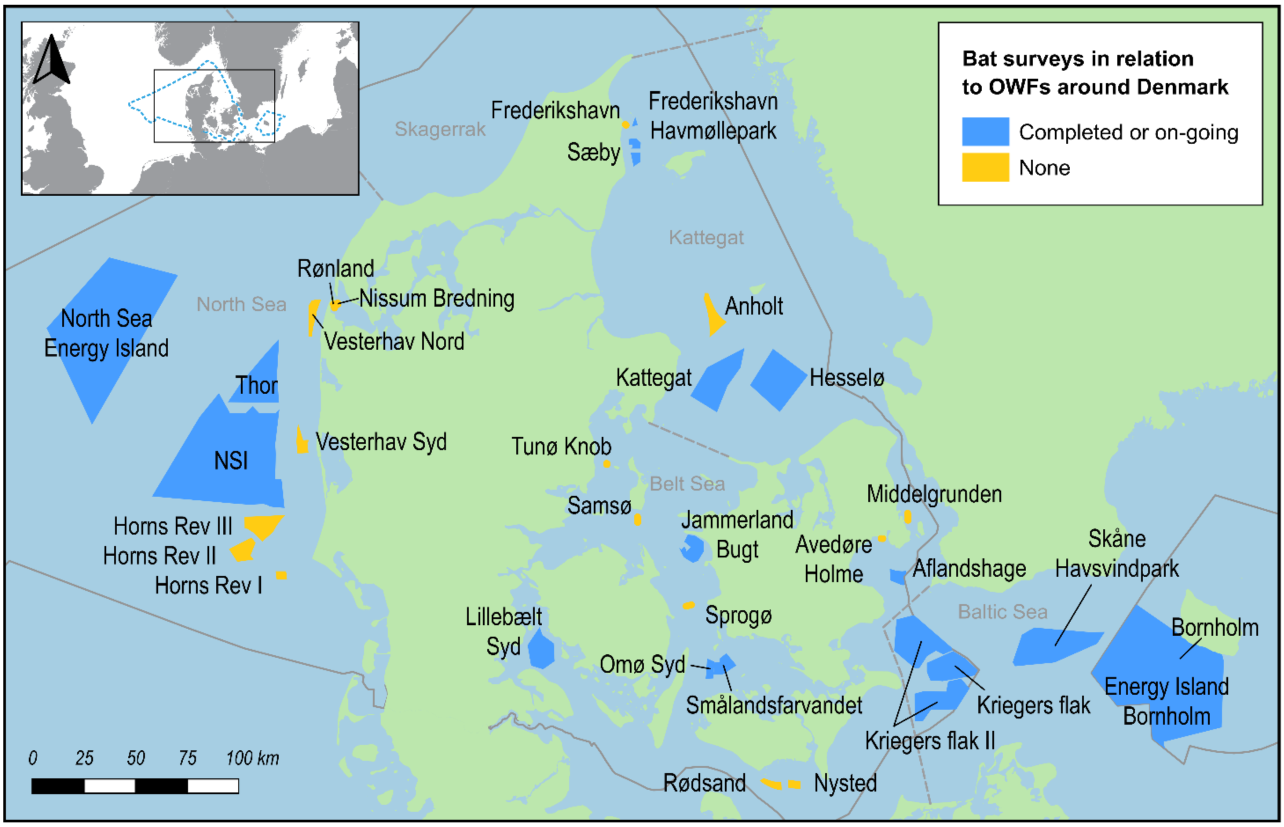

Figure 3.1. Map of offshore wind farm (OWF) areas in Danish waters (outlined in solid grey) that are either existing or in the planning stage. Each project area shown is based on the coordinates from the pre-investigation permit. Bat surveys are included as part of the pre-investigations for areas shown in blue. Bat surveys were not included in the pre-investigations for areas shown in yellow. Grey dashed lines separate the different sections of the Danish offshore area that are considered separately for the overall sensitivity assessment: the North Sea, the Skagerrak, the Kattegat, the Belt Sea and the Baltic Sea. OWFs from adjacent areas in Sweden and Germany are only shown if bat surveys were part of the pre-investigations.

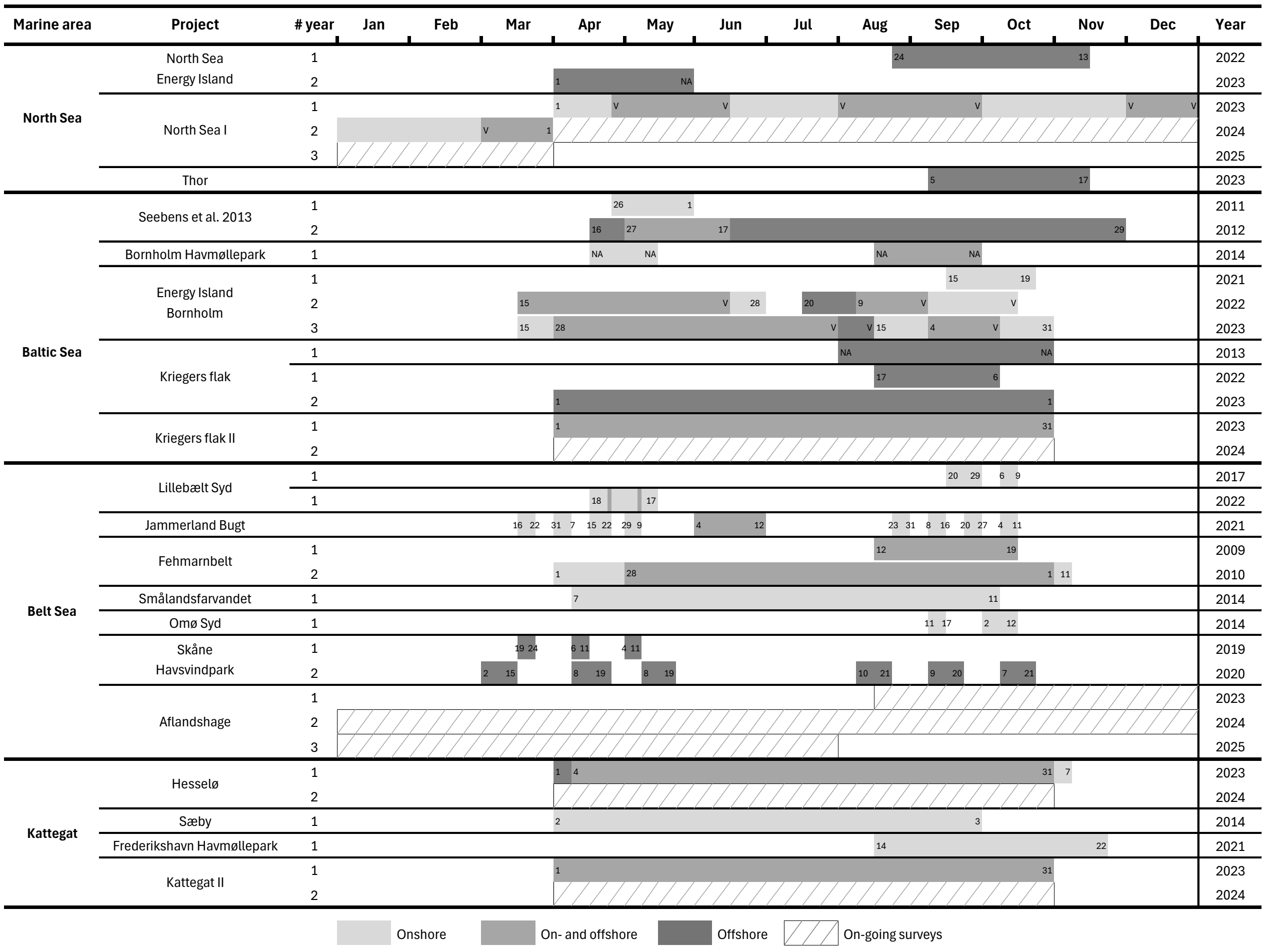

Figure 3.2. Timeline for existing and ongoing bat surveys conducted in relation to OWF and construction projects. It is indicated in the figure whether the surveys are ongoing and unpublished and whether a survey only includes land-based PAM or both on- and offshore survey efforts. Numbers in the timeline indicate exact start and end dates of the surveys. V: start and end date variable between PAM stations, depending on servicing schedule and battery. NA: exact start and end date for survey not reported.

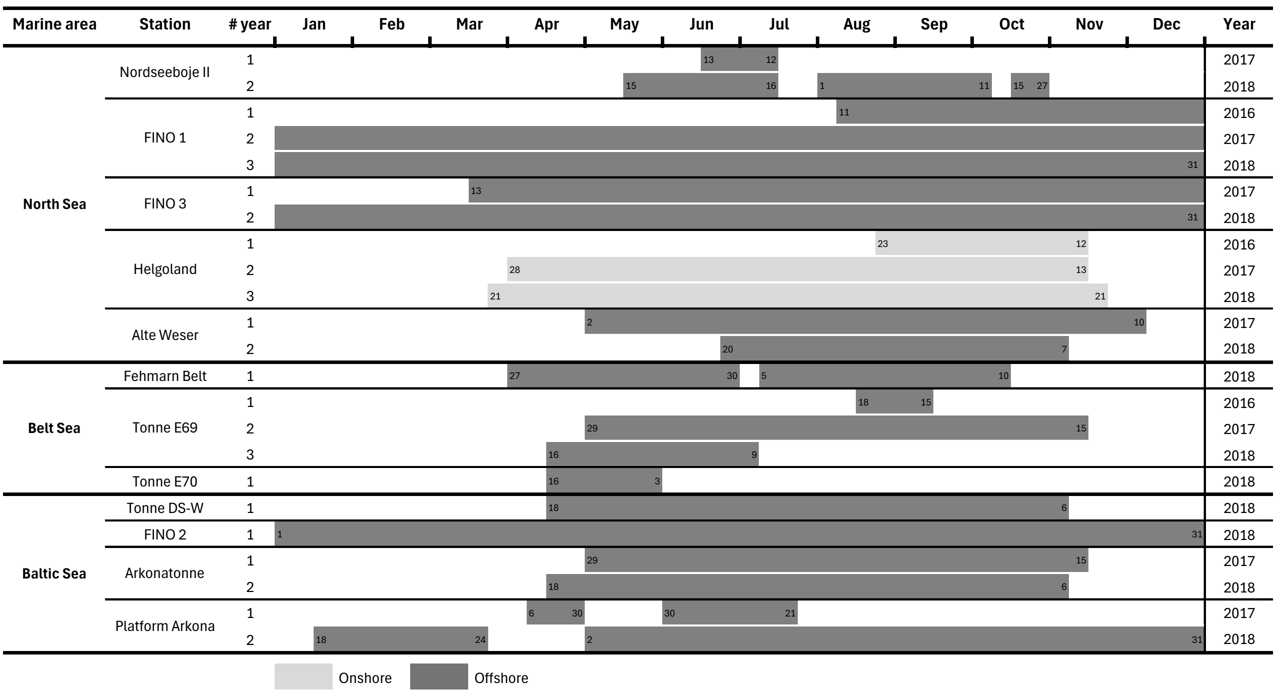

Figure 3.3. Timeline for bat monitoring conducted as part of the German BatMove project reported in Seebens-Hoyer et al 2021. Numbers in the timeline indicate exact start and end dates of the surveys.

3.1.1 The North Sea

The Danish part of the North Sea currently has five OWFs in operation: Horns Rev I, II and III, Vesterhav Syd and Vesterhav Nord. More (including Thor OWF and areas for North Sea I and the North Sea Energy Island) are in the planning stage or under construction. Dedicated bat pre-investigation surveys including static offshore PAM stations have only been performed for North Sea I and the North Sea Energy Island. Post-construction bat monitoring is underway to provide data for the requalification process for Horns Rev I but will not be considered further in this report due to a lack of any additional information.

No bat surveys were conducted during the planning process of two existing small sites with operational wind turbines in the western Limfjord (Rønland and Nissum Bredning; Ringkøbing Amt 2001, Orbicon 2011).

Monitoring stations in the North Sea were included in the German BatMove project (Seebens-Hoyer et al 2021).

Tables 3.1 and 3.2 give an overview of bat surveys conducted in the Danish part of the North Sea. A timeline for the surveys is provided in Figures 3.2 and 3.3.

Table 3.1. Overview of methodology and findings from bat surveys conducted in the Danish part of the North Sea. [1]Maximum number of nights surveyed (in bold if inside offshore project area including buffer zones for North Sea Energy Island and North Sea I). [2]External microphone type shown as w/ type if reported. [3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings. *Information gained upon request. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, MYOsp: species in genus *Myotis*, Mdau: Daubenton's bat.

Project area	Station type (#)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
North Sea Energy Island	Offshore buoys (8)	None	**46**	SM4BAT FS w/ SMM-U2	12 dB trigger Sunset-sunrise	Raven Lite	0
North Sea I	Land (11)	Pnat, ENVsp, Ppyg, MYOsp	313	SM4BAT FS w/ SMM-U2	12 dB trigger Sunset-sunrise	Raven Lite AnimalSpot	>290,000
	Offshore buoy (22)	Pnat (68), ENVsp (20), Ppyg (1), MYOsp (1)	**203**				90
	Offshore turbine (10)	Pnat (85), ENVsp (1)	**45**				86
	Offshore vessel (1)	ENVsp (27)	62				27
Thor	Offshore vessel (2)	Pnat, Mdau	73	SM4BAT FS w/ SMM-U2	*12 dB trigger Sunset-sunrise	BatSound	126

Table 3.2. Overview of methodology and findings from the BatMove project conducted in the German part of the North Sea (Seebens-Hoyer et al 2021). [1]Maximum # of nights surveyed. [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Reported in study as minute intervals occupied by bats. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, PIPsp: species in genus *Pipistrellus*, Ppip: pygmy pipistrelle, Nlei: Leisler's bat, Nnoc: noctule, Enil: northern bat, Eser: serotine, Vmur: parti-coloured bat.

Study area	Station type (ID)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
North Sea	Offshore buoy (Nordseeboje II)	ENVsp (2), Pnat (2)	322	AnaBat SD2	NA	AnaLook	4
	Offshore lighthouse (Alte Weser)	Pnat (375), ENVsp (33), PIPsp (8), Ppip (4), Nlei (3), Nnoc (2)	362				425
	Offshore platform (FINO 1)	Pnat (38), Nlei (18)	872	UltraSound-Gate /w FG-DT50	Sunset to sunrise	BatSound	56
	Offshore platform (FINO 3)	Pnat (4)	658				4
	Island (Helgoland)	Pnat (2,239), Enil (49), Nlei (47), ENVsp (47), PIPsp (44), Ppip (40), Nnoc (21), Ppyg (19), Eser (15), Vmur (7)	556				2,528

North Sea Energy Island

The baseline surveys of bats for the North Sea Energy Island were limited to one year (Figure 3.2). They included passive acoustic monitoring (PAM) in autumn 2022 and in spring 2023 from eight offshore buoy stations (Table 3.1) located either within the ca. 2,500 m² pre-investigation area or a surrounding 15 km buffer area (Brinkløv et al. 2024a). No bats were recorded on any of the eight PAM stations during the two surveys.

Two Lidar buoys were also deployed in the pre-investigation area by Fugro for a total period of two years to collect physical (wind and wave) data. Both included an SM4BAT FS recorder. The recordings were analysed with Wildlife Acoustics Kaleidoscope software but although a preliminary note indicated that bats (including three new species records for Denmark) may be present in these data (Fugro, 2024), follow-up validation concluded that acoustic data from the Lidar buoys included noise at bat call frequencies but no bat calls (Energinet 2024).

North Sea I

Bat baseline surveys are concluded for the first year of pre-investigations for the ca. 2,160 km² North Sea I area (Brinkløv et al. 2024b) and are ongoing for a second year. The first-year surveys were conducted between April 2023 and April 2024 (Figure 3.2). The main component of the bat baseline surveys is PAM from: a) 22 buoys within the project area and a 20 km buffer zone around it, b) the transition piece platform on existing wind turbines in Horns Rev III OWF (10 deployments during the first year of the pre-investigations, c) 11 land-based PAM stations along the western coast of Jutland (Table 3.1). In addition, radio-tracking with Motus receivers and tags (https://motus.org) was part of the survey programme during the first year.

Results from the first-year surveys in the Norths Sea I and buffer area included 90 recordings of bats from a total of 11 out of 22 buoy stations. Only one of the bat recordings from buoys was from spring 2024, the other 89 were all recorded in autumn 2023. In addition, 86 bat passes were recorded on four out of 10 PAM stations on the wind turbines in Horns Rev III OWF. In contrast to the findings from the buoy stations, most (80) bat recordings from the wind turbines were from late spring 2023, and only six of them were from autumn 2023. Offshore records included Nathusius' pipistrelle, species identified to the *Eptesicus/Nyctalus/Vespertilio* complex, soprano pipistrelle and one *Myotis* species. Except for a single record approximately 80 km from the coastline, all other bats recorded offshore were within 40 km of the coast. Two Nathusius' pipistrelles tagged with VHF-transmitters in northwestern Denmark (Thy), were later recorded by receivers on land near the Wadden Sea in Schleswig-Holstein.

Thor OWF

No bat surveys were initially conducted for the ca. 290 km^2 pre-investigation area for Thor OWF, but a supplementary investigation of bats was carried out in autumn (September to November) 2023 (Figure 3.1) in response to the increasing focus on bats in relation to offshore wind energy. This included PAM with a single recorder installed ca. 8 m above sea level on each of two vessels conducting geophysical surveys in the area (NIRAS 2023). The surveys recorded a total of 12 bats (six per vessel) in September 2023, ca. 25 km off the coast. The records included two species: Nathusius' pipistrelle and Daubenton's bat (Table 3.1).

Thor OWF is located just north of the North Sea I project area and is partially overlapped by the 20 km buffer zone included in the North Sea I survey area and results from the North Sea I pre-investigations in this area of overlap therefore serve as empirical data for both projects (Energistyrelsen 2023).

Seebens-Hoyer et al 2021

The German BatMove project did not focus on a specific OWF or infrastructure pre-investigation area and was carried out between 2016 and 2019 (Figure 3.3). It included relatively long survey periods from four static PAM stations in the German part of the North Sea: Nordseeboje II (120 km offshore), FINO 3 (70 km offshore), FINO 1 (45 km offshore), and the lighthouse Alte Weser (14 km offshore). Additionally, one station was located on the island of Helgoland 57 km off the German coast. Most bat activity was found at the offshore lighthouse and on Helgoland; primarily of Nathusius' pipistrelle, but also northern bat, Leisler's bat, common pipistrelle, noctule, soprano pipistrelle, serotine and parti-coloured bat. Stations further offshore recorded primarily Nathusius' pipistrelle in small numbers (Table 3.2).

3.1.2 The Skagerrak

No published bat surveys have been identified for the Skagerrak area. Bat surveys are ongoing in relation to OWFs in Swedish and Norwegian waters, but no results have been published.

3.1.3 Kattegat

Anholt OWF and wind turbines at Frederikshavn harbour are presently operational in the Kattegat section of the Danish offshore area but did not include pre-investigation surveys for bats. Bat surveys have been conducted for four OWFs in the planning stage: Sæby, Frederikshavn, Kattegat II and Hesselø.

Table 3.3 gives an overview of bat surveys conducted in Kattegat. A timeline for the surveys is provided in Figures 3.2.

Table 3.3. Overview of methodology and findings from bat surveys conducted in the Danish part of the Kattegat. [1] Maximum number of nights surveyed (in bold if inside offshore project area). [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings; may differ from summed species records if some records were not further described/identified in reports. [5]Surveys from Hesselø Syd and Kattegat II report on the same land- and island-based survey. *Reporting unclear, our interpretation. **Estimated from figure. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, MYOsp: species in genus *Myotis*, Mdau: Daubenton's bat, Nnoc: noctule, Eser: serotine, Vmur: parti-coloured bat, Mdas: pond bat, UIsp: unidentified bat species, Paur: brown long-eared bat.

Project area	Station type (#)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
Hesselø[5]	Offshore vessel (1)	NA	NA	SeaBat 2.0 (Audiomoth)	DC 5s on/10s off Sunset to sunrise	**Kaleido-scope** BatSound	NA
	Offshore buoys (2-6)	*Nnoc/Vmur (8), Ppyg (1), Pnat (1)	**213**				**14
	Island (2)	Pnat, Nnoc, Vmur, Mdau, Ppyg	217				NA
Kattegat II[6]	Land (11)	Pnat, Ppyg, Vmur, Nnoc					
	Offshore vessel (1)	NA	NA				NA
	Offshore buoys (3-8)	*Nnoc/Vmur (52), Pnat (4), Ppyg (1)	**213**				**110
Sæby	Island (1)	Pnat (2,097), Eser (74), Ppyg (60), Mdau (18), Mdas (14), MYOsp (14), Nnoc (12), Mdau/Mdas (1), UIsp(13)	119	SM2+ w/ SMX-US	NA	**Kaleido-scope**	2,303
	Land (1)	Ppyg (4,628), Nnoc (936), Eser (553), Pnat (123), Mdau (20), ENVsp (47), Vmur (9), MYOsp (9), Mdau/Mdas (5), Mdas (3), Paur (1), UIsp (207)	184				6,541
Frederik-shavn	Island (1-2)	Mdau (46), Ppyg (39), Eser (36), Pnat (21), Nnoc (4), Vmur (3)	96	Pettersson D500X SM4BAT FS	Sunset to sunrise	**Kaleido-scope** BatSound	149

Hesselø

Baseline surveys of bats for this ca. 170 km² project area off the island of Hesselø were done to facilitate preliminary risk assessments for bats in relation to OWF development in the southern Kattegat (WSP 2024d). The PAM survey lasted from start April 2023 to start November 2024 (Figure 3.2), and included two island-based stations, 11 land-based stations and at most six offshore buoy stations. Only two buoy stations were active in the first four months of the survey. On Hesselø, bat activity was highest during spring and autumn, where five species were registered: Nathusius' pipistrelle, noctule, parti-coloured bat, Daubenton's bat and soprano pipistrelle. During September, noctule/parti-coloured bat, Nathusius' pipistrelle and soprano pipistrelle were recorded in the offshore survey area, primarily on buoy stations close to the coast of Hesselø (Table 3.3). Details of the land-based survey are not reported, but all species found on Hesselø except Daubenton's bats were also registered from land, and 'clear migration patterns' are reported for Nathusius' pipistrelle. A vessel-based survey is also outlined, but results are not reported.

Kattegat II

About 20 km west of the Hesselø project area, bat surveys have been conducted for the planned Kattegat II OWF situated between Hesselø and the coast of Djursland (WSP 2024e). This PAM survey included at most eight offshore buoy stations in the pre-investigation area, five of which were inactive for the initial four months of the survey. Island and land-based monitoring is also reported but is based on the same data as the above Hesselø survey. Situated closer to the coast of Djursland than Hesselø, bats were more common in the Kattegat II area (Table 3.3). Records were spread evenly across the buoy PAM stations at distances 10-40 km from the nearest coast and were primarily of noctules/parti-coloured bat and a few Nathusius' and soprano pipistrelles. As for the Hesselø OWF survey, a vessel-based survey is also outlined, but results are not reported.

Sæby OWF

This survey was done near the planned 60 km^2 Sæby OWF project area (Žydelis et al. 2015). This PAM survey did not include offshore monitoring and was conducted between April and October 2014 with two stations: one on the island of Hirsholm more than 5 km north of the project area and one on the coast south of Sæby. Seven bat species were recorded: pond bat, Daubenton's bat, Nathusius' pipistrelle, soprano pipistrelle, noctule, serotine, parti-coloured bat and brown long-eared bat (Table 3.3).

Frederikshavn Havmøllepark

A land-based PAM survey was conducted between August and November 2021 (Figure 3.2) to confirm the results of the pre-investigation survey done in 2014 for Sæby OWF (NIRAS 2021). This island-based only PAM survey on Hirsholmene initially used one recorder type on one station, which was later replaced due to technical difficulties with two other recorder types at two other locations. Six species of bats were recorded: Daubenton's bat, soprano pipistrelle, serotine bat, Nathusius' pipistrelle, noctule and parti-coloured bat (Table 3.3).

3.1.4 The Belt Sea

There are seven operational OWFs in the Danish Belt Sea: Samsø and Tunø Knob north of Funen, Sprogø in the Great Belt, Rødsand and Nysted south of the island of Lolland, and Middelgrunden and Avedøre Holme in the Sound off Copenhagen (Øresund). None of these included pre-investigations of bats. For Nysted and Middelgrunden, post-construction bat surveys have been initiated as part of the requalification of these OWFs but we are unaware of any additional details regarding the timeline, methodology and spatial coverage of these surveys and they are not considered further in this report.

Six more OWFs have been or are planned: Jammerland Bugt, Omø, Smålandsfarvandet, Lillebælt Syd and Aflandshage. Bat surveys have been conducted for the first four. For Aflandshage bat surveys are ongoing, but unpublished.

A bat survey also exists for the Fehmarn Belt fixed link infrastructure project (FEBI 2013). A general study of the presence of bats over the western Baltic Sea by the German coast is published (Seebens et al. 2013) and bat monitoring stations in the Belt Sea were included in the German BatMove project (Seebens-Hoyer et al 2021).

Tables 3.4 and 3.5 give an overview of bat surveys conducted for the Belt Sea. A timeline for the surveys is provided in Figures 3.2 and 3.3.

Table 3.4. Overview of methodology and findings from bat surveys conducted in the Danish part of the Belt Sea. [1]Maximum number of nights surveyed (in bold if inside offshore project area). [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings; may differ from summed species records if some records were not further described/identified in reports. [5]Offshore survey area not dedicated to OWF. *Estimated from figure. **Report refers to '# bat calls', which is interpreted as '# records' here. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, MYOsp: species in genus *Myotis*, PIPsp: species in genus *Pipistrellus*, Ppip: pygmy pipistrelle, Mdau: Daubenton's bat, Nlei: Leisler's bat, Nnoc: noctule, Eser: serotine, Vmur: parti-coloured bat, Mdas: pond bat, UIsp: unidentified bat species, Paur: brown long-eared bat, Bbar: Barbastelle's bat.

Project area	Station type (#)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
Seebens et al. 2013[5]	Offshore platform (1)	Pnat (21), Nnoc (7), Ppyg (5), Eser (4), Ppip (4), Mdau (1)	**10**	Batcorder	Sunset -1 hr to sunrise +1 hr	BatSound Avisoft-SASLab	42
	Offshore ferry (1)	Nnoc, Pnat	**212**	Avisoft	Sunset -½ hr to sunrise +½ hr	NA	NA
	Island (1)	Pnat (8,432), Ppip (3,928), Nnoc (1,873), Eser (671), Ppyg (398), Paur (33), Mnat (4), Nlei (4)	**87**	Pettersson D500x	NA	BatSound Avisoft-SASLab	15,343
	Manual detection	Mnat, Nnoc, Nlei, Ppip, Ppyg, Pnat, Vmur, Eser, Paur	**4**	Batbox Griffin			NA
Fehmarn Belt[6]	Offshore vessel (2)	*Pnat (135), Ppyg (36), Nnoc (12), PIPsp (10), ENVsp (10) Ppip (4), Eser (3), Mdas (1)	73	Pettersson D240x AnaBat SD1	NA	BatSound AnaLook	**214
	Manual detection (9)	Ppyg (357), Pnat (200), Ppip (179), PIPsp (110), Nnoc (70), MYOsp (41), ENVsp (18), Eser (16), Mdau (7), Bbar (3), Nlei (1), Vmur (1)	**29**				**1,003
	Offshore ferry (2)	ENVsp (36), Pnat (19), Nnoc (6), Ppyg (1), Ppip (1), MYOsp (1)	**262**	AnaBat SD1		AnaLook	**62
	Island (6)	Ppyg (36,232), Pnat (32,232), Ppip (18,090), PIPsp (10,328), ENVSp (1,645), Nnoc (1,614), MYOsp (1,524), UIsp (145), Bbar (33), Nlei (5), Eser (2)	**291**				102,532
Jammerland Bugt	Island/Land (12)	Pnat, Ppyg, Nnoc, Vmur, Eser, Mdau	**58**	Audiomoth	Sunset -½ hr to sunrise +½ hr	**Kaleido-scope** BatSound	~60,000
	Offshore turbine (4)	Pnat, Ppyg, Nnoc, Vmur	34				NA

Lillebælt Syd	Land (2)	Pnat, Ppyg, Nnoc	**9**	Pettersson D500x	Sunset +4 hrs	**Kaleido-scope** BatSound	NA
	Manual detection (2)	NA	3	Pettersson D240x Edirol R-09HR	Manual trigger Sunset +2-4 hrs		
	Offshore vessel (1)	None	2	BatLogger A+ BatLogger M2 Pettersson D240x	Manual trigger Sunset to 00:00	**BatExplorer** BatSound	0
	Manual detection (1)	Ppyg, Pnat, Ppip, Eser, Nnoc	5	BatLogger M2 Pettersson D240x			NA
	Island (3)	Ppyg (8,497), Mdas, Mdau, Nnoc, Eser, Ppip, Pnat	25	BatLogger A+	Sunset to <4 am		15,898
Omø Syd	Manual detection: On land (2) From vessel (1)	Ppyg, Pnat, Eser, Nnoc, Mdau Pnat, Nnoc	3 2	Pettersson 1000x Pettersson D240x	Manual trigger Sunset +4 hrs	NA	NA
	Island (1)	Ppyg, Pnat, Nnoc, Eser, MYOsp, PIPsp	26	Pettersson D500x	Sunset +4 hrs		
Smålands-farvandet	Island (2)	Ppyg (6,595), Pnat (430), Eser (387), Nnoc (86), Bbar (12), Vmur (9), Mdau (8), ENVSp (5), Paur (1)	**187**	SM2+	NA	NA	7,533

Table 3.5. Overview of methodology and findings from the BatMove project conducted in the German part of the Belt Sea (Seebens-Hoyer et al 2021). [1]Maximum number of nights surveyed (in bold if inside offshore project area). [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings, reported in study as minute intervals occupied by bats; may differ from summed species records if some records were not further described/identified in reports. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, MYOsp: species in genus *Myotis*, Ppip: pygmy pipistrelle, Nlei: Leisler's bat, Nnoc: noctule, Eser: serotine, Vmur: parti-coloured bat.

Study area	Station type (ID)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
Belt Sea	Offshore buoy (Fehmarn Belt)	Pnat (92), Ppyg (10), Nnoc (10), ENVsp (8), Eser (1), MYOsp (1)	195	AnaBat SD2	NA	AnaLook	122
	Offshore buoy (Tonne E69)	Pnat (164), Ppyg (26), Nnoc (14), Nlei, Ppip, Vmur, Eser	312	AnaBat SD2 Batcorder		AnaLook BatIdent	231
	Offshore buoy (Tonne E70)	Pnat (19), Ppyg (1)	48				20

Jammerland Bugt

Jammerland Bugt was surveyed in 2021 (Figure 3.2) to map potential disturbance effects of planned OWFs on bat migration over the belt between Funen and Zealand (WSP 2024c). The survey used PAM over multiple seven-day periods (3-4 per season) in spring and autumn from 12 land-based stations around the ca. 30 km^2 project area (two each at Fyns Hoved and Stavreshoved on Funen, and at Asnæs and Reersø on Zealand, plus four on the island of

Sprogø). Four PAM stations were also installed during the summer on wind turbines near Sprogø, ca. 20 km south of the project area. Both on land and offshore, four species were registered: Nathusius' pipistrelle, soprano pipistrelle, noctule and parti-coloured bat (Table 3.4). High activity of migratory bat species by the shore indicated that the northern part of the Great Belt and perhaps across Sprogø could be possible migration routes for bats. During summer, some bat activity was found around offshore wind turbines.

Lillebælt Syd

Two surveys were performed for the ca. 25 km² Lillebælt Syd pre-investigation area, respectively in autumn 2017 and spring 2022, to monitor the activity during migration periods in the belt between Northern Als and Southern Funen (COWI 2023). The autumn survey covered three blocks of three nights (Figure 3.2), selected for favourable weather conditions (low wind speeds and high temperatures), with two PAM stations, one on Helnæs and one on Als. Three bat species were recorded: Nathusius' pipistrelle, soprano pipistrelle and noctule. Manual detection was done on two nights on Helnæs and one night on Als, however, it is unclear which species were found (Table 3.4).

The spring survey was done on Northern Als with land-based PAM using a different detector type than the autumn survey. Additionally, for two nights a recorder was installed on a vessel drifting with the current in an area 1-2 km west of the project area. Another two types of handheld detectors/recorders were used for manual detection on both the vessel and on the coastline of Als. From a total of 15,898 recordings, the survey effort on Als included six species of bats: soprano pipistrelle, pond bat, Daubenton's bat, noctule, serotine, common pipistrelle and Nathusius' pipistrelle. Manual detection onshore also found the Nathusius' pipistrelle, whereas no bats were recorded during the two nights at sea.

Smålandsfarvandet

Pre-investigations for a 65 km² area for a near-shore windfarm in Smålandsfarvandet south of Zealand included a survey in 2014 (Figure 3.2) to estimate the prevalence of migratory bat species (Rambøll 2015). The survey was island-based (Table 3.4) with one PAM station on each of the islands of Lolland and Omø, setup to record throughout spring, summer and autumn (Figure 3.2). Three migratory bat species were commonly registered: soprano pipistrelle, Nathusius' pipistrelle and noctule. Since these species were found in high numbers on coastal areas during April and September, these findings could indicate migratory behaviour. Furthermore, recordings included parti-coloured bat, serotine, Daubenton's bat, brown long-eared bat and western barbastelle.

Omø Syd

In 2014 a bat baseline survey was done to assess the presence of bats in a 44 km² pre-investigation area south of Omø (Figure 3.2). The survey combined a single island-based PAM station, and manual detection on the coast and by vessel in the project area (Orbicon 2016). Five bat species were recorded on land: soprano pipistrelle, Nathusius' pipistrelle, serotine bat, noctule and Daubenton's bat. Only the two migratory species Nathusius' pipistrelle and noctule were recorded offshore from a vessel (Table 3.4).

Aflandshage

Bat surveys are ongoing for the Aflandshage OWF project area (Figure 3.2) but have not been published yet.

Fehmarn Belt

This baseline survey was done for the environmental risk assessment of a fixed transportation link between Denmark and Germany across the Fehmarn Belt (FEBI 2013). If the resulting fixed link is constructed as a tunnel, potential disturbance of bats is likely limited to the construction phase. However, bat surveys were completed to assess the degree of migration by bats across the belt and was based on PAM conducted during autumn, 2009 and in spring-summer-autumn, 2010 (Figure 3.2). The onshore surveys consisted of six island-based PAM stations (three on Lolland, Denmark, and three on Fehmarn, Germany), Also, 28 nights of manual detection was done on these same islands (14 nights on Fehmarn and 14 on Lolland). The offshore PAM was done partly from a vessel conducting bird radar surveys at two anchor positions and partly from two active Scanline ferries crossing the belt (Table 3.4). Six species were registered from vessels: Nathusius' pipistrelle, noctule, soprano pipistrelle, serotine, pond bat and Daubenton's bat. The land-based survey revealed high concentrations of the same species, including three additional species: Leisler's bat, particoloured bat and western barbastelle. Nathusius' pipistrelles, noctules and soprano pipistrelles were the most common.

Seebens et al. 2013

In 2011 and 2012, the German NABU (Nature and Biodiversity Conservation Union) completed a pilot survey to establish a baseline for bat presence over the Baltic Sea by the northern coast of Germany. The study included one station of island-based PAM and manual listening on Greifswalder Oie in the Bay of Pomerania over two periods (April to June) in both 2011 and 2012 (Figure 3.2). Automatic PAM devices were also setup on a trans-Baltic ferry operating from April and throughout November. Additionally, PAM devices were mounted from mid-May to mid-June on an offshore research platform located 2.2 km off the coast by Rostock, however, due to technical difficulties these recorders only ran for two weeks in June. The offshore surveys (ferry and platform) registered: Nathusius' pipistrelle, noctule, soprano pipistrelle, serotine, common pipistrelle and a single Daubenton's bat. Most of these detections (12 out of 14) were made within 25 km of the coast. The island-based PAM found a long list of species common to Germany, but Nathusius' pipistrelle, common pipistrelle, noctule, serotine and soprano pipistrelle were especially common (Table 3.4). Detections of Nathusius' pipistrelles were pronounced in early May and noctules in mid-May, perhaps indicating migratory behaviour.

Seebens-Hoyer et al 2021

The German BatMove project did not focus on a specific OWF or infrastructure pre-investigation area and was carried out between 2016 and 2019 (Figure 3.3). Monitoring in the Belt Sea was focused on the months of summer and autumn and was based on three offshore buoy stations: Fehmarn Belt (8 km offshore), Tonne E69 (20 km offshore) and Tonne E70 (25 km offshore). Just under 400 bats were registered during the survey period, primarily Nathusius' pipistrelle, but also soprano pipistrelle, noctule and common pipistrelle (Table 3.5).

3.1.5 The Baltic Sea

Kriegers Flak is the only currently operational OWF in the Danish part of the Baltic Sea. Bat surveys were completed in the pre-construction phase for Kriegers Flak (Skov et al. 2015). A post-construction bat survey has also been done from the wind turbines in Kriegers Flak (WSP 2024a).

Kriegers Flak II and the project area of Bornholm Energy Island are in the planning stage and results of the ongoing bat surveys have been published for the first year (WSP 2024b, WSP 2025). A second year of surveys is underway for both areas. A small bat survey was also completed as part of the planning for Bornholm OWF (Amphi Consult 2015).

In Swedish waters northwest of Bornholm, another small bat survey was completed as part of the planning stage for Skåne Havsvindpark (Hällqvist et al. 2021).

Bat monitoring stations were included for the Baltic Sea in the German BatMove project (Seebens-Hoyer et al 2021).

Tables 3.6 and 3.7 give an overview of bat surveys conducted in the Danish parts of the Baltic Sea. A timeline for the surveys is provided in Figures 3.2 and 3.3.

Table 3.6. Overview of methodology and findings from bat surveys conducted in and near the Danish part of the Baltic Sea. [1]Maximum number of nights surveyed (in bold if inside offshore project area). [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings; may differ from summed species records if some records were not further described/identified in reports. *DC = Duty cycling. **Estimated from figure. ***Incomplete, four migratory species selected for reporting. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, MYOsp: species in genus *Myotis*, Ppip: pygmy pipistrelle, Mdau: Daubenton's bat, Mnat: Natterer's bat, Mbra: Brandt's bat, Mmys: whiskered bat, Nnoc: noctule, Eser: serotine, Vmur: parti-coloured bat, UIsp: unidentified bat species, Paur: brown long-eared bat.

Project area	Station type (#)	Species (#)	# nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
Skåne Havsvindpark	Offshore vessel (1)	Mdau (6), Pnat (4)	**62**	NA	NA	BatSound	10
Kriegers Flak	Offshore platform (2)	Pnat (245), Nnoc (19), Vmur (17), Eser (3), ENVsp (1), UI sp (2)	**NA**	SM2 w/ SMX-US	NA	**Kaleido-scope**	287
	Offshore turbine (5-10)	Nnoc (1,033)/Vmur (771), Pnat (129), Ppyg/Ppip (125)	**266**	SeaBat 2.0 (Audiomoth)	*DC 5s on/10s off 18.30-07.00	**Kaleido-scope** BatSound	2,058
Kriegers Flak II	Offshore buoy (10-16)	Nnoc (763), Vmur (160), Pnat (46), Ppyg/Ppip (10), Mdau (2)	**213**	SeaBat 2.0 (Audiomoth)	DC 5s on/10s off Sunset -30 min to sunrise +30 min	**Kaleido-scope** BatSound	**979
	Offshore vessel (1)	NA	**NA**				NA
	Island/Land (NA)	Pnat, Nnoc, Vmur, Ppyg	NA	MAM-model (Audiomoth)			NA
Energy Island Bornholm	Offshore buoy (15)	Nnoc (36), Vmur (29), Pnat (24), Mdau (4), Eser/Vmur (3), Ppyg (1)	**416**	SeaBat 2.0 (Audiomoth)	DC 5s on/10s off + amplitude trigger Sunset-sunrise	Kaleidoscope	97
	Offshore vessel (1)	None	**NA**				0
	Island/Land (14)	***Pnat (27,296), Ppyg (20,355), Nnoc (4,344), Vmur (558)	455				NA
Bornholm Havmøllepark	Manual detection	Nnoc, Pnat, Mdau, Mnat, Ppyg, Eser, Mbra/Mmys	23	Pettersson D1000x	Manual trigger	NA	NA
	Island (6)	Pnat, Nnoc, Mnat, Eser, Ppyg, Mdau, Mbra/Mmys, Paur, MYOsp	16	Pettersson D500x	Sunset-sunrise		
	Offshore vessel (1)	Mdau, Nnoc, Pnat	**6**	Pettersson D1000x Pettersson D500x	Manual trigger Sunset-sunrise		

Table 3.7. Overview of methodology and findings from the BatMove project conducted in the German part of the Baltic Sea (Seebens-Hoyer et al 2021). [1]Maximum number of nights surveyed (in bold if inside offshore project area). [2]External microphone type shown as w/ type if reported.[3]Analysis software, in bold if used for automated species identification. [4]Total number of bat recordings; may differ from summed species records if some records were not further described/identified in reports. Species abbreviations: Pnat: Nathusius' pipistrelle, ENVsp: *Eptesicus*/*Nyctalus*/*Vespertilio* species complex, Ppyg: soprano pipistrelle, PIPsp: species in genus *Pipistrellus*, Ppip: pygmy pipistrelle, Nlei: Leisler's bat, Nnoc: noctule, Vmur: parti-coloured bat,.

Study area	Station type (ID)	Species (#)	# Nights[1]	Recorder[2]	Schedule	Software[3]	# Bat records[4]
Baltic Sea	Offshore buoy (Tonne DS-W)	Pnat (28), Ppyg (2), Nlei (1)	202	Batcorder	NA	BatIdent	31
	Offshore platform (FINO 2)	Pnat (212), Ppip (45), Nnoc (11), ENVsp (11), PIPsp (8), Ppyg (1)	364	UltraSoundGate /w FG-DT50	Sunset-sunrise	BatSound	289
	Offshore buoy (Arkona Tonne)	Pnat (59), ENVsp (6), Nnoc (4), Vmur (3), Nlei (2), Ppip (2), Ppyg (2)	402	AnaBat SD2 Batcorder	NA	AnaLook BatIdent	78
	Offshore platform (Arkona)	Pnat (5), Nnoc (1)	384				6

Kriegers Flak

Bat baseline surveys were conducted for Kriegers Flak OWF in 2013 from two PAM stations from the edge of the ca. 250 km^2 pre-investigation area (Figure 3.2, Table 3.6) (Skov et al. 2015). Both were located on the research platform FINO 2 at the southeastern edge of the project area. Bats were recorded over 17 nights between August and November, and identified as Nathusius' pipistrelle, noctule, parti-coloured bat and serotine.

After Kriegers Flak OWF became operational in 2021, another survey was done from 10 of the Kriegers Flak wind turbines in 2022 and 2023 (WSP 2024a). Due to technical difficulties, only 5 PAM stations were active from April to August 2023. The post-construction survey yielded 2,058 recordings of bats from the offshore wind turbines, including: noctule/parti-coloured bat, Nathusius' pipistrelle and soprano pipistrelle/common pipistrelle.

Kriegers Flak II

For the planned Kriegers Flak II OWF consisting of an area north and one south of the existing Kriegers Flak OWF, only the results of the first out of two years of bat baseline surveys are reported (WSP 2024b) and surveys are ongoing in 2024 (Figure 3.2). From April to November 2023, at most 16 offshore PAM stations were deployed on buoys in the 172 km^2 pre-investigation area, but only 10 of these were actively recording from April to mid-August. This was supplemented with land-based PAM stations on the surrounding islands and coastal areas and a recorder on a research vessel surveying the area (Table 3.6). Offshore stations recorded five species: noctule, parti-coloured bat, Nathusius' pipistrelle, soprano pipistrelle and Daubenton's bat. Except the latter, the same species were also recorded for the coastal areas. The results from vessel-based PAM are not reported.

Energy Island Bornholm

The pre-investigations of bats for this ca. 650 km² area were conducted in 2021-2023 (Figure 3.2) and included up to 15 offshore PAM stations on buoys in the pre-investigation area > 15 km from the coast. The buoy recordings were supplemented with coastal stations and a detector on board a survey vessel (WSP 2025). The survey reports 97 bats from the offshore PAM stations, including five species: noctule, Nathusius' pipistrelle, parti-coloured bat, soprano pipistrelle and Daubenton's bat. Few records were reported of the latter two. It is noted in the technical report, without further explanation, that the number of bat recordings from 2023 (80) is likely more representative than the very low number recorded in 2022 (17). No bat recordings were found in the data from the detector on board the survey vessel (Table 3.6).

The coastal surveys collected data from September 2021 to October 2023 with 14 detectors in total at seven locations on or around Bornholm: two coastal reference locations (Rügen and Skåne), two islands between Bornholm and Sweden (Christiansø and Utklippan) and three on Bornholm itself (Hammeren, the Southwestern coast of Bornholm and the Southeastern coast of Bornholm). A complete list of species found is not given, since analysis was narrowed down to four migratory focus species (Nathusius' pipistrelle, noctule, parti-coloured bat and soprano pipistrelle). These were all found on coastal stations during migration periods.

Bornholm OWF

In 2014, bat surveys were completed in the 45 km² pre-investigation area of Bornholm Havmøllepark to determine the presence of bats off the western coast of Bornholm. Surveys were done in Spring and Autumn (Figure 3.2), with PAM from six recorders placed on the island coast (Amphi Consult, 2015). In both migration periods, this was supplemented with 23 nights of manual detection on the coastal stations and, on six nights in Autumn, from an offshore vessel doing area transects (Table 3.6). On the coastal stations, eight (maybe nine) species were registered: Nathusius' pipistrelle, noctule, Daubenton's bat, Natterer's bat, soprano pipistrelle, serotine, Brandt's bat/whiskered bat and brown long-eared bat. During vessel surveys which were only possible in favourable weather, three species were found: Daubenton's bat, noctule and Nathusius' pipistrelle (Amphi Consult, 2015).

Skåne Havsvindpark

Surveys for this Swedish OWF were conducted in spring 2019 and 2020, and during autumn 2020 (Figure 3.2), with a single unspecified PAM detector with unknown settings on an anchored boat near the centre of the ca. 533 km² project area (Hällqvist et al. 2021). Only two out of 62 nights had registrations of bats, both were from spring 2020 and identified as a Daubenton's bat and a Nathusius' pipistrelle (Table 3.6).

Seebens-Hoyer et al 2021

The German BatMove project did not focus on a specific OWF or infrastructure pre-investigation area and was carried out between 2016 and 2019 (Figure 3.3). Monitoring in the Baltic Sea was focused on the months of summer and autumn, but a few stations covered the entire year. The monitoring effort included four offshore stations: Arkona Tonne (15 km offshore), DS-W (25 km offshore), FINO 2 (29 km offshore), and Platform Arkona (35 km offshore).

Most activity was found on the research platform FINO 2 located on the edge of the then pre-investigation area for Kriegers flak OWF. Bat records were primarily Nathusius' pipistrelle, but also included common pipistrelle, soprano pipistrelle, noctule, parti-coloured bat and Leisler's bat (Table 3.7).

3.2 Sensitivity mapping

3.2.1 General considerations

The existing knowledge about bat migration and foraging behaviour over Danish waters and coastlines comes from sporadic observations, small-scale research projects (e.g., Ahlén 1997, Ahlén et al. 2007, Seebens-Hoyer et al. 2021), and the environmental surveys reviewed above. The existing or ongoing bat surveys reviewed here for Denmark along with additional surveys from Sweden and Germany document the presence of bats for all Danish offshore areas except the Skagerrak, which is completely data deficient. It is apparent from the surveys that the number of bat recordings per night of monitoring effort is generally much higher on land than offshore (Tables 3.1-3.7), and that offshore activity of bats, including potential foraging bouts from shore, is generally higher close to the coast (Brinkløv et al., 2024b, WSP 2024a, WSP 2024b). These observations demonstrate that land-based monitoring can serve as a point of reference, but not a replacement, for offshore monitoring. Furthermore, they motivate the assessment that buffer zones of high and medium sensitivity up to 20 km and 20-40 km from the coast should be imposed along the entire Danish coastline, except for islands in the Kattegat (see section 3.2.4).

However, the bat surveys are not compatible for detailed comparisons as they are scattered, vary widely in temporal and geographical coverage, in the equipment, settings and analytical methods used, and in the level of detail reported for these. The surveys were conducted by a range of consultants and rely on a plethora of recording schedules, equipment types (ranging across at > 10 different detector models) and analysis software (Table 3.1-3.7). Recorders, and specifically the microphone type used, vary in sensitivity and internal noise levels. The sensitivity and frequency response of recorders is a) not always available from the manufacturer, b) almost never tested/verified by the user, c) rarely tested or calibrated over time for consistency, and d) potentially changed by user customizations of the recorder. This means that the number of bats detected is not directly comparable between recorder types, and the numbers of bats reported from acoustic surveys are likely a gross under-estimate of actual bat occurrence offshore. This is further elaborated in section 1.3.1 and the discussion.

3.2.2 Sensitivity assessment – North Sea

The assessment is based on studies of bat migration over the Dutch and German North Sea (e.g., Brabrant et al. 2019, Lagerveld et al. 2021, Seebens-Hoyer et al. 2021) and three bat surveys available for OWF project areas in the Danish North Sea: The North Sea Energy Island, North Sea I and Thor (Energistyrelsen 2023, Brinkløv et al. 2024a, Brinkløv et al. 2024b).

Surveys for the North Sea I and Thor areas both document offshore bat occurrence in the Danish North Sea but predominantly up to 40 km from the coast and with the highest occurrence on the three North Sea I stations nearest to shore. Notably, 99% of the activity around the buoy PAM stations was from autumn with a single record from spring, but PAM stations located on wind turbines in Horns Rev 3 in contrast recorded most activity in spring. The results are not directly comparable as the monitoring effort was not equal between the wind turbine and buoy stations but if the second year of surveys indicate a similar pattern, this highlights the need to map activity of bats systematically across both time and space and the need for post-construction monitoring. All the bat recordings from wind turbines in the Horns Rev 3 area from the first year of the North Sea I survey were from distances beyond 20 km to the coast, as were 17% of the bat recordings from buoys in the North Sea I area (Brinkløv et al. 2024b).

Only one bat survey exists from far offshore (> 80 km) in the Danish part of the North Sea, where data from ten static PAM stations on buoys in the survey area did not document any bat activity (Brinkløv et al. 2024a, Energinet 2024). Combined with the sporadic findings of bats from the North Sea (Petersen, A et al. 2014) and the distances to the nearest coastlines of Denmark, Norway, England and Scotland, this forms the empirical basis for the low sensitivity assessed for the far-offshore part of the North Sea.

Land-based PAM stations along the coast of Western Jutland show much higher and more consistent bat activity with peaks during the autumn migration period (Brinkløv et al. 2024a). Whether bat activity is concentrated at specific parts along the West Coast remains unclear. The few documented southbound long-distance flights of Nathusius' pipistrelles (Brinkløv et al. 2024b) show migration along the coast of Western Jutland but are insufficient to exclude bat migration across the Danish Wadden Sea.

Both resident and migrating bats may forage over coastal waters, including the North Sea (e.g. Lagerveld & Mostert 2023, Brinkløv et al. 2024) and the high and medium sensitivity buffer is therefore upheld for this section also.

3.2.3 Sensitivity assessment – The Skagerrak

No bat surveys were accessible for the sensitivity assessment of the Skagerrak area, which is therefore based entirely on a principle of caution. Potential crossing distances to and from Norway and Sweden are more like those across the Kattegat than the distances involved in crossing the North Sea. Several bat species in Northern Europe migrate to hibernation areas in Central and Western Europe (Pētersons 2004, Hutterer et al. 2005, Kruszynski et al. 2020). A few Nathusius' pipistrelles tagged in Finland (under the project Baltic Sea Motus Network: deployment ID# 49631 and 29575, Hellström 2020) appear to have crossed the Gulf of Bothnia in the Baltic Sea moving southwest through Sweden to Southern Norway, where their tag signals were picked up by receivers at Sandefjord and near Kristiansand, respectively. If the migration pattern from the north towards hibernation areas further south-west holds for breeding populations in Norway, northern Sweden and Finland as is indicated by the movement tracks documented by the Motus tags, then OWF development in the Skagerrak, particularly near the outposts of Hirtshals and Hanstholm, could increase their sensitivity, which is accordingly assessed as medium.

3.2.4 Sensitivity assessment – The Kattegat

The limited number of offshore bat records from Kattegat stem from two of the four bat surveys reported for this area (WSP 2024d, WSP 2024e). The other two were based solely on island/land-based survey efforts (Žydelis et al. 2015, NIRAS 2021). At least three species, including long-distance migrants, are documented offshore, and more bats were recorded for the Kattegat II area closer to shore than for Hesselø South further offshore, based on a comparable buoy PAM survey effort using the same equipment over the same number of nights (Table 3.3).

Potential migration activity is hard to evaluate based on the limited data from the Danish part of the Kattegat and without data from the Swedish part of the Kattegat. Crossing distances for the Kattegat between Sweden and Denmark are shorter than across the North Sea but longer than those required to cross any of the belts in the inner Danish waters. Following the same reasoning as for the Skagerrak, the sensitivity for bat populations to OWF development in the Kattegat is assessed as medium.

Bat occurrence on Læsø and Anholt is limited during summer (Baagøe 2001), and there are probably no regular breeding populations on these islands. Therefore, no coastal buffers zones were added around Læsø and Anholt.

3.2.5 Sensitivity assessment – The Belt Sea

The distances involved for bats crossing any of the belts in the inner Danish waters are small and crossing can be completed in a few hours or less. Bats also forage over the Belt Sea (e.g. Ahlén et la 2007). Several bat surveys have been conducted or are underway for the Belt Sea but only few include offshore survey efforts beyond short term (a few days) monitoring from vessels (Table 3.4). Vessel surveys included for the Fehmarn fixed link infrastructure with better temporal coverage documented six species over the Fehmarn Belt. Both offshore and land-based PAM and manual monitoring efforts indicate a high species diversity for the coastal area in the Belt Sea relative to the North Sea. The short distances between coasts within this area, combined with the nationwide coastal buffer zones, which already include most of the Belt Sea, results in the assessment of high sensitivity for bats in the Belt Sea.

The geography of both the Belt Sea and the Baltic Sea is suggestive of potential bat migration from Finland and the Scandinavian Peninsula, given the North-East to South-West migration vector observed for several species in autumn (Pētersons 2004, Hutterer et al. 2005, Kruszynski et al. 2020).

3.2.6 Sensitivity Assessment – The Baltic Sea

Along with the Belt Sea, the Baltic represents the highest offshore species diversity of bats documented for any of the Danish marine sections (Tables 3.1-3.7). This was expected from its geographic location interspersed between Finland and the Scandinavian Peninsula on one side and mainland Europe on the other. Regular and high activity, also of foraging bats, over the Baltic is also apparent from a range of studies from the last three decades (Ahlén 1997, Ahlén et al. 2007, Hutterer et al. 2005, Rydell et al. 2014, Gaultier et al. 2020, Kruszynski et al. 2020, Seebens-Hoyer et al. 2021).

Bornholm is also of special focus in the sensitivity assessment for the Baltic. Bornholm represents a potential stopover site for bats crossing the Baltic between Sweden and mainland Northern Europe (Baagøe 2011, Baagøe & Fjederholt 2014). It also represents an ecological site where Bechstein's bat, Brandt's bat, whiskered bat and Natterer's bat; several of the *Myotis* species reported for Denmark, occur exclusively, near-exclusively or are encountered more commonly than elsewhere in the country (Elmeros et al. 2024). None of those species are considered long-distance migrants but dispersal flights related to population exchange could place vagrants from such local breeding populations at high sensitivity for offshore wind development in this area.

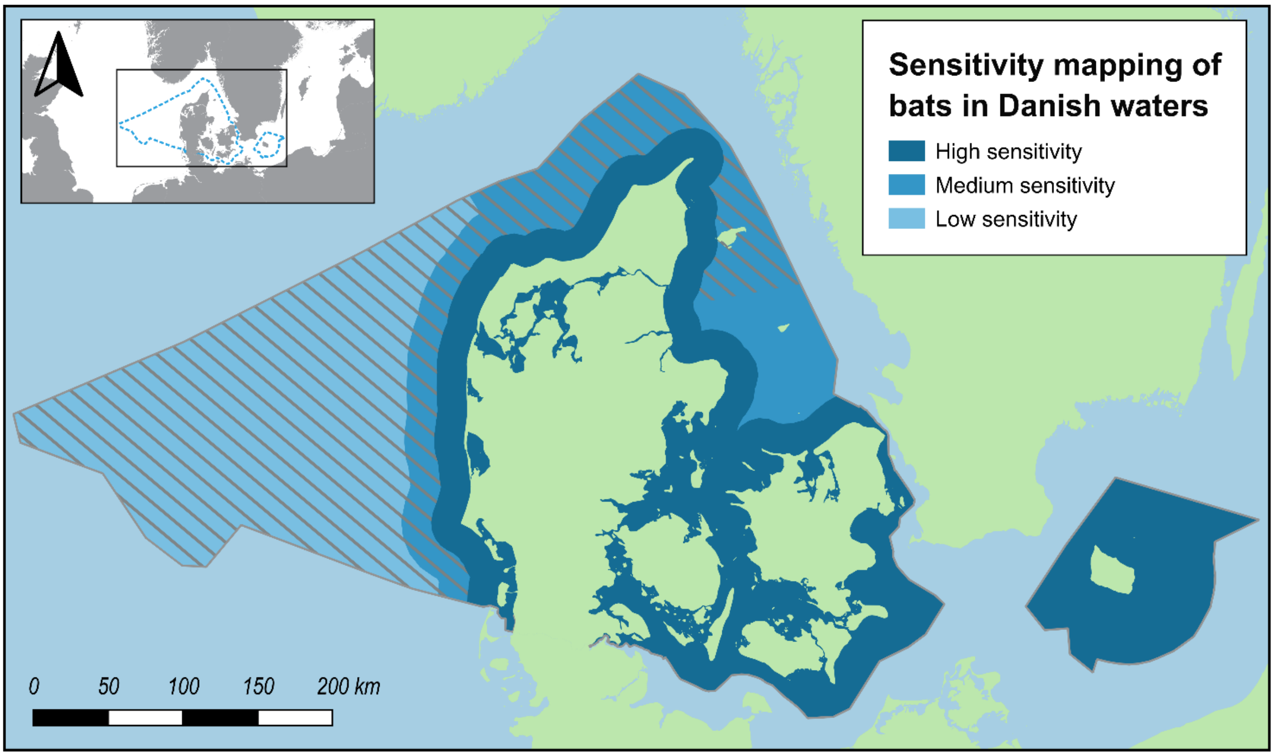

Figure 3.3. Sensitivity map for bats in the Danish offshore area based on expert assessments of available background information from scientific literature and reports describing the results from environmental surveys. Five sections of the overall Danish offshore area were evaluated separately to produce the overall sensitivity map, including categories of high, medium and low sensitivity: the North Sea, the Skagerrak, the Kattegat, the Belt Sea and the Baltic Sea. The map includes a high sensitivity buffer zone of 0-20 km offshore and a 20-40 km offshore medium sensitivity buffer for the entire Danish coastline except for the islands of Anholt and Læsø, located in the Kattegat. The rest of the North Sea is assessed as low sensitivity, the Skagerrak and the Kattegat as medium sensitivity, and the Belt Sea and Baltic Sea as areas of high sensitivity for bats. The hatched area is particularly data deficient.

4 Discussion

4.1 Current knowledge status

It is evident from the knowledge summarised in this report that the number of offshore bat surveys for Danish and adjacent marine areas is severely limited. Existing surveys are too sporadic and non-systematic to enable detailed informed planning of, and mitigation strategies for, offshore wind energy, but indicate where offshore wind turbines may cause conflicts with bat conservation on different levels based on the limited available knowledge. The sensitivity map cannot replace pre-construction surveys and post-construction monitoring for specific projects, offshore monitoring and research on bats is needed to feed into and update the sensitivity map over time, adding to its robustness and use as a dynamic tool over time.

Moreover, the surveys reviewed and summarised here vary widely in the extent of detail they report for the survey design and analyses methods used. Only recent surveys from 2022 and onwards have included static PAM stations able to record bat activity in the offshore project area over prolonged time periods. Consequently, there are insufficient data for bats offshore to predict bat activity, risks of collision and habitat displacement (i.e., lower use of foraging areas due to disturbance from wind turbines which is well described onshore (e.g. Millon et al. 2018, Reusch et al. 2022, Leroux et al. 2024)) and to model the impact of these parameters on bat populations, overall and at the species-specific level. Knowledge about population sizes and dynamics, including for flyway populations that cross national borders and biogeographical regions, is also highly limited and further hinders modelling of population effects from single wind turbine farms and cumulatively from offshore as well as onshore wind turbines.

This underlines the importance of dedicated bat surveys in offshore environmental investigations to add onto current knowledge and build a robust database to inform sensitivity maps and more. Additional and standardised bat surveys are of general relevance across all three relative sensitivity categories (low – medium – high) until enough empirical evidence is compiled to validate the expert assessment of 'low risk' offshore areas, rather than relying on assumptions of low bat activity for areas where empirical data do not exist.

4.2 Limitations of existing surveys

It should be noted in this context that no established monitoring programme currently exists offshore, e.g., parallel to the Danish national monitoring programme for aquatic environment and nature (NOVANA). Further, no official set of guidelines or standards are in place to refer to when designing and conducting offshore bat investigations in Denmark, as e.g., in Germany (BHS 2013). Consequently, there are no formal requirements for the number of nights and monitoring stations that should be part of the survey design or even one that specifies that monitoring must be done from within the actual area of investigation. This complicates or may even hinder 'umbrella' analyses and modelling efforts across broader geographic and temporal scales. Another important point is that raw data from surveys of this nature are typically not per default disclosed or may not even be stored for transparency and future use/re-analyses. Official guidelines are, however, in the process of being established and are urgently needed.

Most knowledge of bat activity offshore in Danish waters comes from acoustic monitoring, which has inherent limitations as described further in section 1.3.1. These should always be disclosed but are often not considered in areas with higher bat occurrence, as focus tends to be on reporting registrations without considerations of potential bats missed by the monitoring effort. Further, acoustic monitoring results in point registrations of bats and cannot by themselves map migration routes of individual bats.

The surveys are scattered in space and time and vary widely in geographical and temporal coverage. Most are conducted in narrowly defined project areas for offshore or coastal wind turbines or other infrastructure projects (Figure 3.1). Only recent surveys (since 2022) include multiple static PAM stations dispersed within the offshore project area, and only rarely has the survey effort been replicated over multiple years or seasons (Figures 3.2 and 3.3). The surveys are typically of a limited time scope of one year or less. The timelines in Figures 3.2 and 3.3 indicate start and end dates for each survey where these are specified but it is not always clear whether all nights are effectively monitored within this scope or whether data was only collected during some of it, e.g., due to reasons such as duty cycling or equipment failure.

The reports often contain no methods description of how bats were detected in the recordings and the bat species identified. Unless raw data is also provided, this leaves no way to verify results. This is concerning since some of the species recorded offshore can be difficult or even impossible to tell apart acoustically and if a conservative approach (e.g., the use of species complexes) is not used, it will introduce a bias for species level analysis and interpretation of the results.

Recorders can be programmed to follow custom or automatic schedules, telling them to e.g., be active from sunset to sunrise, for 24 hrs a day or from a set number of hours/minutes before or after sunset to a set number of hours/minutes before or after sunrise. This information is also rarely specified but information about the scheduling is not redundant. Schedules are often described as 'recorded continuously' but this rarely equals continuous data collection. It is often not specified whether recorders are simply activated and able to record at any time but will only save data files if a certain trigger setting/threshold is passed, if the recorders run on a duty cycle or if they are continuously saving data. Duty cycling entails that recordings are only saved for a certain percentage of time, e.g., 5 s on, 10 s off, as is employed in some of the reviewed surveys. However, it is highly speculative that a simple linear extrapolation accurately accounts for the number of bats missed during off-periods of duty cycling when, e.g., the recorder is only able to record for 33% of the survey period, especially if duty cycling is also combined with the use of a trigger (see next section).

It is typically not feasible for offshore data collection to use continuous recording where files are saved back-to-back as the demands on power and storage space are too high and would cause batteries to drain and memory cards to fill up too quickly, increasing the already significant cost of servicing equipment at sea. Essentially, however, this means that data are filtered out already at the PAM station and are not available for later review. The trigger settings must be considered carefully as the degree of conservative versus liberal settings decide the signal-to-noise ratio that bat recordings can have and still be saved on the device. A higher trigger setting means that good signal-to-noise ratio recordings are saved but also that bat recordings are potentially not saved if they have poor signal-to-noise ratio.

For most of the reports evaluated here, such information was not specified, and any data gaps were not mentioned, or simply explained with 'due to technical challenges' that make it impossible to evaluate the consequence of such gaps. Such details are necessary to enable cross-study comparisons and for obtaining comparable data for future surveys and monitoring but were not considered in a recent note on bats and wind turbines (Christensen & Hansen 2023).

4.3 Use of the sensitivity map as a dynamic tool

The sensitivity map presented here is based on an expert assessment of available knowledge of bat activity and migration in the Danish offshore area. Standardized monitoring and quantitative modelling and prediction of thresholds for collision risks and species-specific population impacts should be prioritized long-term goals and will serve as useful input for the sensitivity map.

The assessment of high sensitivity within 20 km of the entire Danish coastal zone and in the Belt Sea and Baltic Sea where higher number of bats are recorded offshore warrants caution for the placement of near-coastal OWFs. Existing wind farms are predominantly located within this zone of high sensitivity.

Rather than a finite product, the sensitivity map should be regarded as a dynamic tool and continuously developed and updated with more solid data and knowledge. At present, the map is based on geographical considerations alone. For windfarms in operation or once locations have been planned or established, the temporal occurrence of bats is equally important to consider in the context of sensitivity. To consider variations in sensitivity at a site over time it is important to not only monitor bats during periods of expected migration but also to include monitoring outside of these over a minimum of two or preferably several years. This is in thread with recommendations in guidelines for both offshore and onshore turbines in neighbouring countries (BHS 2013, Klop et al. 2024) and it is of equal relevance to confirm when bats are not present as this knowledge is valuable in the context of mitigation, e.g., to identify 'safe periods' where bat activity does not need to be considered. Input for the map should also include information from targeted studies that aim to evaluate local and overall sensitivity over time, e.g., considering global climate changes or increased density of OWFs and total numbers of offshore wind turbines that would be expected to impact cumulative effects on bats and other species.

4.4 Additional knowledge gaps

The knowledge gaps on bat population sizes and dynamics, bat flyway-populations, bat migration routes and catchment areas of bats for wind turbine projects are substantial. Such gaps hinder realistic modelling of the effects of individual wind turbine areas and the cumulative effects of wind turbines on bat populations. Severe data gaps not only represent a potential conservation threat to bats onshore and offshore (e.g. Fredshavn et al. 2019, Voigt 2012a, 2024a) but are also likely to impede progress for green transition and development of wind energy.

There are very few studies including both pre- and postconstruction monitoring of bats and hence a lack of methods to reliably model and predict bat behaviour in response to new structures and to evaluate the potential mortality risks these may introduce in different habitat types and areas.

In the North Sea off the coast of the Netherlands seasonal movements of bats are related to environmental variables including wind speed, wind direction, and temperature (Lagerveld et al. 2021). These factors can to some extent inform mitigation measures such as curtailment, but without more detailed data, e.g., long-term monitoring over several consecutive seasons and from each of numerous sites, it is not possible to establish whether such information can be used on a finer scale to optimize production while minimizing the risk posed to bats by the rapidly expanding offshore wind industry.

5 Conclusions and perspectives

5.1 Conclusions

Bats forage and migrate over marine areas and there is a significant migration of bats between the Scandinavian Peninsula and Finland and Central and Western Europe across Denmark and Danish waters. We reviewed available information to assess and differentiate the sensitivity level of bats across the Danish offshore area. The resulting sensitivity map is intended to serve as a dynamic tool for the national screening of the potential for offshore wind energy development.

Apart from a few dedicated scientific studies on bat migration, information on marine activity of bats originates almost exclusively from preconstruction surveys in relation to wind turbine projects and other infrastructures. These surveys are based on passive acoustic monitoring and vary widely in intensity, temporal extent and quality. The study design is rarely reported in detail, which further prevents comparisons of the reported results and impact assessments. The data quality and quantity hinder modelling of bat occurrence and impacts by offshore wind turbines on bat populations. Thus, the present sensitivity map is based on expert assessments until systematic and robust data can be added.

A high sensitivity for bat populations to wind turbine development is assessed for the entire Danish coastline less than 20 km from shore and throughout the Baltic Sea and Belt Sea.

The Kattegat and the Skagerrak are assessed as areas of medium sensitivity for bats, but information on bat migration across the Kattegat is very limited and unsystematic. No information on occurrence of bats over the Skagerrak is available.

In the North Sea, the sensitivity of bat populations to offshore wind farms is assessed as low beyond 40 km from the west coast of Jutland. Between 20 and 40 km from the coast the sensitivity is assessed as medium.

5.2 Perspectives

For objective quantitative spatial and temporal modelling of the sensitivity of bats to offshore wind turbines development to become a reliable tool for informed risk assessment, mitigation strategies and management decisions for bats on the overall and species level, more standardized monitoring protocols are a necessity. Where possible, these should include power analysis and multiple replications of the survey effort.

To employ quantitative methods to assess collision risk and impacts of offshore wind farm development on bats, there is an urgent need for thorough pre-construction surveys of minimum two years in the project area and relevant adjacent areas. It is further recommended that pre-construction surveys be complemented by follow-up comparative post-construction monitoring for 5-10 years from stations including several turbines in an OWF, the exact number depending on the size of the OWF.

A long-term bat monitoring programme from existing OWFs in Denmark and adjacent offshore and coastal areas is advised to collect objective and systematic data on temporal and spatial variations in bat activities in marine waters, especially in the Baltic Sea and Belt Sea assessed as high sensitivity areas for bats.

The results of acoustic monitoring in individual OWFs should be considered site-specific and not directly transferable to other locations that have not been monitored. This point is essential if an assessment of the cumulative effects of OWFs on fly-way populations of migrating bats is to be achieved, as is the establishment of a public database with raw data and metadata of appropriate detail. International collaboration involving both authorities and the industry is considered key to realise this goal.

Upscaled supplementary research applying tagging technologies to study the migration routes of individual bats would be able to guide and focus survey and monitoring efforts based on the spatial patterns deduced from the migration vectors.

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SENSITIVITY MAPPING OF RELATIVE RISKS TO BATS FROM DANISH OFFSHORE WIND ENERGY

The data and information available for bats from environmental investigations and independent studies in Danish offshore areas is scarce and data collection has not been systematically planned or repeated on a large scale over time and space. The sensitivity map for bats presented in this report is therefore based on expert evaluations and a cautionary principle as it was not possible based on current knowledge to develop an objective and quantitative spatial model to predict species occurrence, abundance and risk of impact. Until a more robust database is established, bats are predicted to be overall most sensitive within a 20 km distance of the entire Danish coastline and throughout the Baltic Sea and Belt area. From 20 to 40 km offshore the sensitivity is assessed as medium. Further offshore, the sensitivity of bat populations to wind turbines in the North Sea is assessed as low, while the sensitivity in the Skagerrak and the Kattegat is assessed as medium. The report highlights methodological challenges and significant knowledge gaps.

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