North Sea Energy Island

Environmental pre-investigations for bats

Technical report

Energinet Eltransmission A/S

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Contents

1. Summary

This report summarizes the efforts of the environmental pre-investigations for the North Sea Energy Island related to the species group bats. The report describes pre-existing information about bats in the North Sea area and presents the results of the bat field program executed as part of the pre-investigations. The fieldwork and data analysis were conducted by Aarhus University. The report was authored and peer-reviewed by Aarhus University, and quality assured by both Aarhus University (DCE) and NIRAS. NIRAS gave final approval of the report before it was submitted to Energinet. Energinet drafted the introductory passus of the introduction and aim chapter and has commented on a first and second draft of the report.

The purpose of the bat field program was to provide and interpret data and present existing information on bat occurrence and activity in the pre-investigation area. The study design included two surveys in fall 2022 and spring 2023, respectively, each based on 8 passive acoustic monitoring stations installed and deployed on buoys in and around the pre-investigation area.

No bats were detected during the two surveys, indicating little to no bat activity in the pre-investigation area during the monitoring periods and within the space effectively monitored.

As there is no pre-existing baseline information about bats for the pre-investigation area for the North Sea Energy Island and only sporadic baseline information about bats at Danish latitudes of the North Sea in general, follow-up investigations are advisable to document if there are occasional occurrences of bats in the area and whether the absence of bats indicated by the field program here is consistent over time.

Rev. no.	Date	Description	Done by	Verified by	Approved by
2.0	20.08.2024	Field program for bat passive acoustic monitoring in connection with the environmental pre-investigations for the North Sea Energy Island.	Signe Marie Mygind Brinkløv Morten Elmeros (ECOS/AU)	Esben T. Fjederholt (ECOS/AU) Rasmus Bisschop-Larsen (NIRAS)	Jesper Fredshavn (DCE/AU) Annette Lützen Møller (NIRAS)

2. Introduction and aim

With the Climate Agreement for Energy and Industry of the 22nd of June 2020, the majority of the Danish Parliament agreed to establish an energy island in the Danish part of the North Sea as an energy hub with a connection to Jutland as well as interconnectors to neighbouring countries. To establish an environmental baseline for the later environmental permitting processes for the specific projects, a series of environmental pre-investigations have been carried out.

The aim of the environmental pre-investigations is to collect data and compile existing information to be handed over to the future concessionaires as environmental baseline information for the concessionaires' environmental permitting processes.

The specific aim of this technical report concerning the species group bats is to provide a baseline description for bats in the pre-investigation area, based in part on a summary of existing information from available sources about bat species occurrence and migration offshore in the North Sea, in addition to the data outcomes of the bat field program. The field program included two bat surveys, one in fall 2022 and one in spring 2023. Both were based on passive acoustic monitoring using ultrasonic recorders deployed on buoys.

The area definitions used to design the environmental monitoring programs as specified in the original scoping reports are shown in Figure 2.1 and include the North Sea Energy Island *pre-investigation area*, *the phase 1 area of the proposed plan for the program North Sea Energy Island* (hereafter *'the phase 1 area'*) and *the extended survey area*. Most of the bat passive acoustic monitoring was carried out in the trapezoid *pre-investigation area*, as further described in the Methods section. This area is also the geographical scope of the technical baseline reports. *The phase 1 area* is where the first phase of North Sea Energy Island is planned according to the Plan for Programme North Sea Energy Island. *The extended survey area* includes *the Phase 1 area* plus a 15 km buffer zone around it.

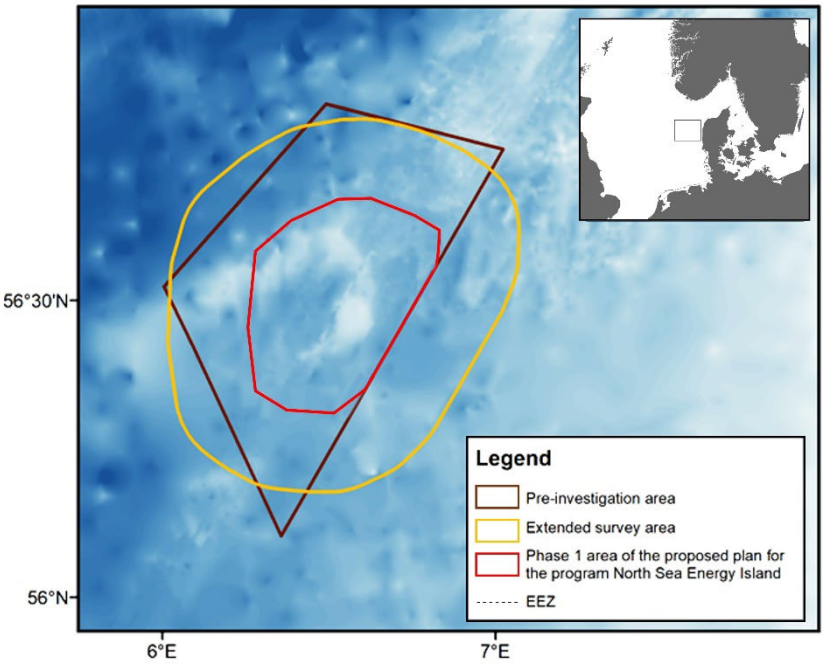

*Figure 2.1. Area definitions used in the design of the monitoring programs for the environmental pre-investigations for the North Sea Energy Island. Trapezoid outlined in brown: **the pre-investigation area**, red outline: **the phase 1 area of the proposed plan for the program North Sea Energy Island** (abbreviated: the phase 1 area), and yellow outline: **the extended survey area**, including the phase 1 area and a 15 km surrounding buffer area.*

3. Existing data and knowledge

This chapter provides a baseline description of existing information about bats in the North Sea area and the bat species considered of potential relevance to the North Sea Energy Island pre-investigation area. No existing baseline data on bat occurrence and activity is available for the North Sea offshore pre-investigation area relevant to this report. A dedicated bat survey based on PAM was therefore undertaken to quantify overall and species-specific abundance and distribution, and document possible migration activity in the area. Such information is crucial as input for assessments of potential impact on bats if offshore construction projects are undertaken and to inform related management initiatives. The methods and results obtained from the bat field survey are also described in this technical report.

3.1 Species conservation status

There are 18 registered bat species in Denmark (Baagøe 2007, Elmeros et al. 2024), including a recent documented record of the grey long-eared bat, *Plecotus austriacus* (arter.dk). All of them are insect-eating and belong to a single family, the vespertilionids. Bats are strictly protected by national and EU legislation under Annex IV of the Habitats Directive (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01992L0043-20130701). As such, disturbances

and incidental killings of bats must be monitored and prevented or limited to ensure that bat populations maintain a favourable conservation status. This requires both baseline knowledge of where bats occur and information about what constitutes potential threats to bats.

Eleven of the 18 species that occur in Denmark have been found to occur at sea at varying distances to the coast (Ahlén et al. 2009, Christensen & Hansen, 2023, Petersen et al. 2014, Seebens-Hoyer et al. 2021). Of these, eight species are considered least concern according to the Danish Red List (Elmeros et al. 2019), although population estimates sizes are not currently known. This includes Nathusius' pipistrelle, a species which exhibits long-distance migration and is predicted the most likely to occur offshore in the North Sea.

The conservation status of most medium and long-distance migratory bats at a European, or cross-border, rather than national, level is, however, generally unfavorable (Table 3.1, see also https://nature-art17.eionet.europa.eu/article17/) or not at present adequately assessed due to a lack of information about population sizes at the national (Fredshavn et al. 2019), international and fly-way level, and a lack of suitable methods to assess conservation status at flyway-population level (Voigt et al. 2012, 2024). The longevity and slow reproductive rates of bats render them sensitive to increased mortality rates. Even small changes in annual mortality rates may have significant impact on bats' conservation status (Elmeros et al. 2024, Frick et al. 2017, Voigt et al. 2012, 2022). Specifically for bat species that migrate at medium or long-range distances, the cumulative effect of threats such as wind turbines may have significant impact on the conservation status of populations, although bat mortality per turbine might seem insignificant (Frick et al. 2017, Freidenberg & Frick 2021).

Table 3.1. Migratory behaviour (see references in text, e.g. Hutterer et al. 2005)) and current conservation status of the bat species observed over the North Sea in the three most relevant biogeographic regions (https://www.eea.europa.eu) from which bats might migrate to and from across the North Sea and the pre-investigation area. 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/).

Species	**Migratory behaviour**	**EU Conservation status**		
		ATL	**CON**	**BOR**
Pipistrellus nathusii	Long	XX	U1	U1
Pipistrellus pipistrellus	Short - Medium	U1	U1	XX
Eptesicus nilsonii	Short - Medium	XX	U1	FV
Eptesicus serotinus	Short - Medium	U1	U1	XX
Nyctalus leisleri	Long	U1	U2	XX
Nyctalus noctula	Long	XX	U1	U1
Vespertilio murinus	Medium - Long	XX	U1	FV

3.2 Records of bat activity and migration in the North Sea

The North Sea in general represents a 'black box' with little to no pre-existing information about bat activity offshore and there are no prior baseline descriptions for the North Sea Energy Island pre-investigation area. Given the area's remote offshore location circa 100 km from the nearest coastline, any bat species encountered in the area are likely medium-to-long distance migrants. Heavy bat activity and migration is not expected for the area, which is not part of the shortest or most direct coast-to-coast travel route between Denmark and any of its neighbouring countries which share a North Sea coastline or between those countries (Norway, Germany, the British Isles).

Most European bat species move between summer and winter habitats, with some species embarking on long-distance migrations of up to 2,200 km, as documented for a ringed Nathusius' pipistrelle (*Pipistrellus nathusii*) (Hutterer et al. 2005, Kruszynski et al. 2020, Alcalde et al. 2021). Other species known to migrate over longer distances include the common noctule (*Nyctalus noctula*), the parti-coloured bat (*Vespertilio murinus*) and Leisler's bat (*Nyctalus leisleri*). Bats can migrate across large areas of open sea (Ahlén et al. 2009; Rodrigues et al. 2015) and bat migration is documented across the southern parts of the North Sea (e.g., Bach et al. 2022, Lagerveld et al. 2017, Seebens-Hoyer et al. 2021) but sparse information exists about bats' presence and activity offshore in the North Sea northwest and west of Denmark.

Records of bat species from the North Sea include: Nathusius' pipistrelle (*Pipistrellus nathusii*), northern bat (*Eptesicus nilsonii*), Leisler's bat (*Nyctalus leisleri*), common noctule (*Nyctalus noctula*), particoloured bat (*Vespertilio murinus*), common pipistrelle (*Pipistrellus pipistrellus*), and the serotine bat (*Eptesicus serotinus*) (Petersen et al. 2014, Lagerveld et al. 2021, Seebens-Hoyer et al. 2021). Records from the northern North Sea are sparse, non-systematic, and most are based on a review of historic findings over a fifty-year period reported from structures (e.g., oil rigs) and vessels (Petersen et al. 2014). As such, they are only useful for documenting species diversity and not for estimating activity, migration routes and patterns offshore.

The occasional registrations reported from vessels may indicate migration between southern Norway, Denmark, and The British Isles (Petersen et al. 2014, J van der Kooij, pers. comm. 31/08/2023), but systematic studies are lacking. Passive acoustic monitoring of bats offshore from wind turbines, buoys or other structures have to our knowledge only been carried out further south in the German, Dutch and Belgian parts of the North Sea but confirm that Nathusius' pipistrelle is the most frequently occurring species, with patterns of occurrence coinciding with spring and autumn migration periods (Brabant et al. 2019, Lagerveld et al. 2017, Seebens-Hoyer et al. 2021).

3.3 Species description of Nathusius' pipistrelle

Nathusius' pipistrelle (*Pipistrellus nathusii*) is common across most of Denmark (Elmeros et al. 2024). It is also a known long-distance migrant and one of the species found in highest numbers killed under wind turbines (Rodrigues et al. 2015, EUROBATS 2017, Voigt & Kingston 2015). The species is relatively small with a forearm length of 32,2-37,1 mm and a body mass of 5-11 g (Dietz et al. 2009, Russ 2022) and feeds on flying insects, particularly dipterans but also moths and beetles during migration periods (Elmeros et al. 2024). The echolocation calls of Nathusius' pipistrelle are either downward frequency modulated sweeps or quasi-constant frequency with most energy around 36-40 kHz. Males also produce a distinct song to attract females during the mating season in late summer and autumn. Nathusius' pipistrelle is often guided by linear landscape features, such as tree rows, parkways, etc. during flight.

During long distance flights, bats presumably fly at low height (Ahlén et al. 2009) but migration of bats at height has been documented (O'Mara et al. 2019, Voigt et al. 2024). There is significant migratory activity of Nathusius' pipistrelle through Denmark and across inner Danish waters (Ahlén 1997, Ahlén et al. 2009, Kruszynski et al. 2020, Rydell et al. 2014). The species has also been recorded foraging at sea in the Baltic (Ahlén et al. 2009). The spring migration of Nathusius' pipistrelle likely takes place during April and May where the bats arrive at breeding sites in Northern Europe and the autumn migration to central- and southwestern Europe happens during August and September (Lagerveld et al. 2021, Pētersons 2004, Voigt et al. 2012, Rydell et al. 2014). Lagerveld et al. 2021 modelled the occurrence of Nathusius' pipistrelle in Autumn based on acoustic data recorded at four locations 15-25 km from shore in the Dutch part of the North Sea and found that activity was strongest in start September, and often coincided with east-northeasterly tailwinds, wind speeds below 8 m/s (measured at 10 m above sea level), and temperatures above 15°C).

4. Methods and surveys

4.1 Passive acoustic monitoring

No standardized method exists to monitor bat occurrence and activity offshore, but the most cost-effective and feasible method uses passive acoustic monitoring (PAM), by which autonomous recorders are programmed and deployed on temporary or permanent structures to record and save audio files for later analysis, including detection and species classification of bat vocalizations, typically echolocation calls. Bat occurrence and activity patterns and levels are then deduced from the acoustic activity recorded.

Most current knowledge of bat activity offshore in Denmark comes from acoustic monitoring but it is important to emphasize that the method does have limits. High-frequency sounds attenuate quickly in air meaning that each detector monitors only a limited volume of acoustic space. The extent of volume covered per detector depends on numerous factors, including properties and directionality of the microphone sensor, the bat species (i.e., directionality, intensity, and frequency of the echolocation calls), the orientation of the bat relative to the recorder, atmospheric conditions, such as rain which may intermittently affect the microphone sensitivity, and ambient noise levels (Adams et al. 2012, Voigt et al. 2021). These limitations are equally real but may not be as obvious in areas with high bat occurrence as in areas of low bat occurrence, as focus tends to be on reporting registrations without considerations of potential bats missed by the monitoring effort. Further, acoustic monitoring cannot by itself map migrations routes of individual bats.

4.2 Survey area

Due to the remote offshore location of the pre-investigation area, the bat field survey relied exclusively on long-term PAM and included a total of eight monitoring stations with bat recorders deployed on anchored buoys. Without any prior information about bat activity in the area, all locations were assumed to have equal chance of detecting passing bats in the area. The buoy locations (figure 3.1) were selected based on the following considerations (also see scope report for bats: https://ens.dk/sites/ens.dk/files/Vindenergi/1213_eins_wp_h_scope_report_ver03_260122_bats.pdf): a) to cover the pre-investigation and phase 1 area, where most bat PAM stations were placed, b) synergy with the marine mammal work package by use of overlapping buoy stations; we selected the bat PAM stations from the planned grid pattern of the buoys deployed to indicate marine mammal monitoring stations, c) to include locations along an East-West transect going through the central part of the phase 1 area, and d) information about trawling activity throughout the area and the associated risk of vessel impact and potential loss of buoys with equipment and data.

The bat field program included 8 passive acoustic monitoring (PAM) stations deployed on buoys: 6 stations were within the pre-investigation area, of these, 5 were within the phase 1 area. Two 2 additional stations were deployed in the extended survey area (see fig. 2.1 for area definitions, fig. 4.1 for buoy locations and table 4.1 for station coordinates). As described in the scoping report for the bat field program, another 2 PAM stations were present on LiDAR buoys in the area. These were not deployed or serviced by Aarhus University and no information has been provided regarding the type and settings of this equipment.

Each monitoring station was defined by a buoy mounted with a bat detector plus the acoustic detection volume covered by the detector.

Table 4.1. Coordinates of bat PAM stations. The NSE-19 bat PAM station (Fall 2022) was replaced by NSE-16 in the Spring 2023) survey.

Station	Latitude (N)	Longitude (E)
NSE-02	56.3823	6.5525
NSE-04	56.4861	6.3511
NSE-05	56.4892	6.4975
NSE-07	56.5206	6.7158
NSE-08	56.5615	6.0784
NSE-09	56.5657	6.3233
NSE-15	56.6857	6.9501
NSE-16	56.5242	6.9099
NSE-19	56.2749	6.5699

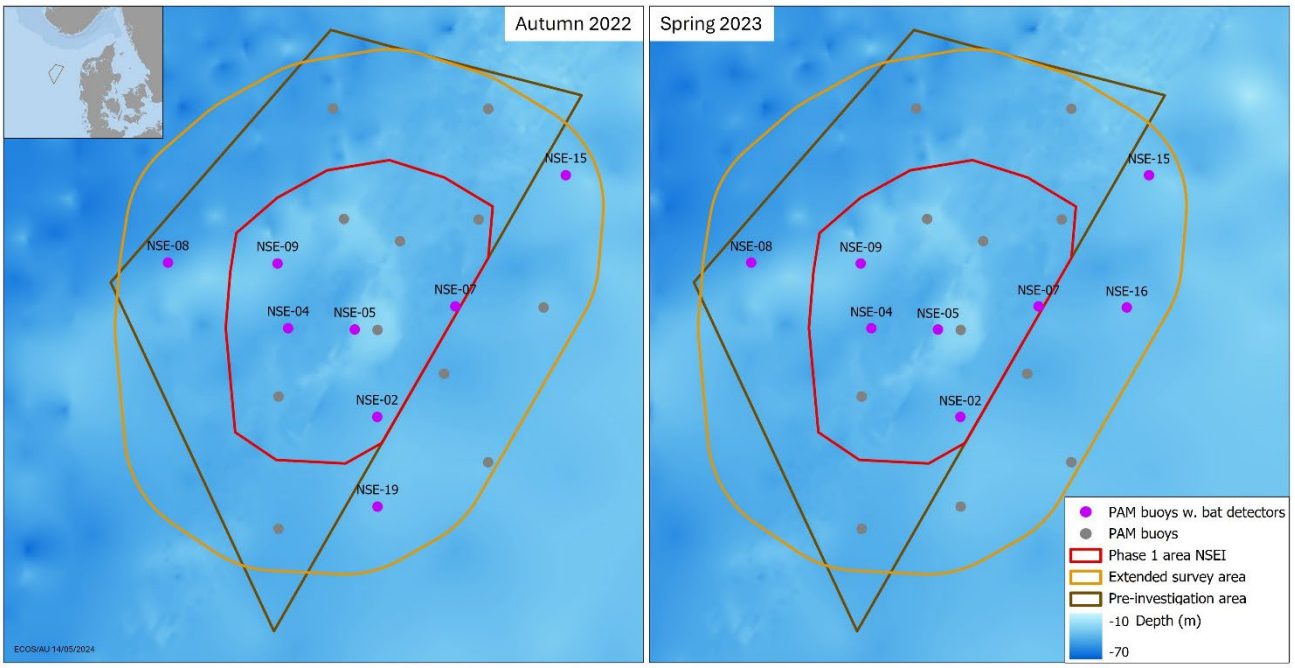

Fig. 4.1. Locations of bat PAM stations for the Fall 2022 and Spring 2023 surveys. The extended survey area (yellow outline) includes the phase 1 area (red outline) of the proposed plan for the program North Sea Energy Island plus a 15 km surrounding buffer zone. Most of the bat PAM stations were located within the trapezoid pre-investigation area (brown outline). The buoy located at NSE-19 drifted away during the Fall 2022 survey and following an evaluation of experienced trawling risk at this specific site, this bat PAM station was re-located to station NSE-16 for the Spring 2023 survey, resulting in eight bat PAM stations per deployment.

4.3 Survey period

The recorders were deployed to include two surveys to cover the expected periods of fall and spring migration activity. The first survey was conducted during fall 2022, where deployments were made on August 24-25th and the

stations recovered again in November. The second survey was conducted during spring 2023, where deployments were made in February, but the recorders were pre-programmed to start on April 1st to prevent draining the battery before the period considered critical for migration. For this Spring 2023 survey, the recorders were recovered again in June. The predicted run-time of the recorders was circa 1.5 months based on preliminary testing. Deployment and recovery were co-scheduled with pre-planned surveys to maintain marine mammal PAM equipment at the same locations.

4.4 Description of recording equipment

We used the commercially available SM4BAT FS from Wildlife Acoustics. This choice was based on the recorder's robustness, the microphone specifications which include documentation of its frequency response (the sensitivity across the range of frequencies of interest) and directional characteristic (https://www.wildlifeacoustics.com/products/song-meter-sm4bat, under ultrasonic microphone plots). The SMM-U2 microphone type we used is labelled by the manufacturer as waterproof and the sensor protected by an ultrasound transparent membrane which essentially means that it can be submerged and still recover to normal sensitivity afterwards. The sensitivity of any ultrasonic microphone can be significantly impacted by water pooling on the microphone membrane causing intermittent periods of decreased sensitivity (Darras et al. 2018). We installed the microphone at an angle to prevent pooling of water on the sensor.

Figure 4.2. Bat Passive acoustic monitoring (PAM) station in the pre-investigation area. The recorder sits inside the metal 'casserole' beneath the light and reflector top piece, with the microphone mounted at the end of the protruding arm. The buoy shown had lost its yellow St. Andrews cross top mark, which was replaced during service.

Each recorder (SM4Bat FS, Wildlife Acoustics) was equipped with 256 GB or 512 GB SD memory cards (two cards per recorder), an internal power supply (4 D-cell batteries, 16,000 mAh capacity), and fixed to the buoy inside a protective case (fig. 3.2).

The recorders were programmed to monitor nightly from sunset +1hr to sunrise –1 hr and actively save recordings of 3-15 seconds duration according to the following user specifications: 12 dB gain, 15 kHz high pass filter on, 384 kHz sample rate, 12 dB trigger level and a 16 kHz minimum trigger frequency. These settings were chosen to optimize monitoring time and recorder storage.

4.5 Data analysis

Data were collected as uncompressed audio files (wav format) and all recordings were inspected visually for bat calls in spectrograms, supplemented by slowed playback using Raven Lite software (K. Lisa Yang Center for Conservation Bioacoustics 2023). Ambient noise sources occasionally trigger recordings but are readily told apart from bat calls using manual evaluation by the call time-frequency structure, which is often also characteristic enough to facilitate species identification.

5. Results of surveys

The PAM data collected during the two seasonal surveys did not include any recordings of bats from any of the eight monitoring stations, although most of the recorders where active nightly for at least one month following their deployment. Figures 5.1 and 5.2 provide an overview of when each recorder was active (ready to record if triggered by potential bat calls) and when it was triggered (prompted to save recordings to memory) during the deployment period. Two recorders (one per seasonal survey) did not yield any data due to physical damage leaving the memory cards beyond recovery (station NSE19 during the autumn survey and NSE8 during the spring survey, see figs. 5.1 and 5.2).

The temporal pattern of trigger events (date and number of triggered recordings) indicated some coincidences between stations for each of the two surveys (fig. 5.1 and 5.2), which were consistent with periods of rough weather, likely leading to more triggered recordings due to increased ambient noise conditions. This was verified by the manual inspection of call spectrograms, where noise is easily distinguished from bat calls.

5.1 Fall 2022 survey

For the Fall 2022 survey, the recorders were deployed on August 24 (stations NSE7, NSE9, NSE15 and NSE19) and August 25 (stations NSE2, NSE4, NSE5 and NSE8). Data were retrieved from stations NSE2, NSE4, NSE5, NSE7, NSE8 and NSE9 on November 13 during a planned service trip. The buoy and bat PAM equipment deployed at NSE15 stranded on October 3rd in Nørre Lyngby and data from this station was retrieved upon its recovery. The buoy and bat PAM equipment deployed at NSE19 came loose during the survey period and was since found in Norway. We did not recover any bat PAM data from this station as the recorder and memory cards had suffered too much damage. The recorder at NSE9 stopped earlier than the rest due to memory card corruption. No bats were recorded on the data files triggered during the active monitoring period in Fall 2022 (Fig. 5.1). The sensitivity of the microphones was within the recommended manufacturer range upon recovery.

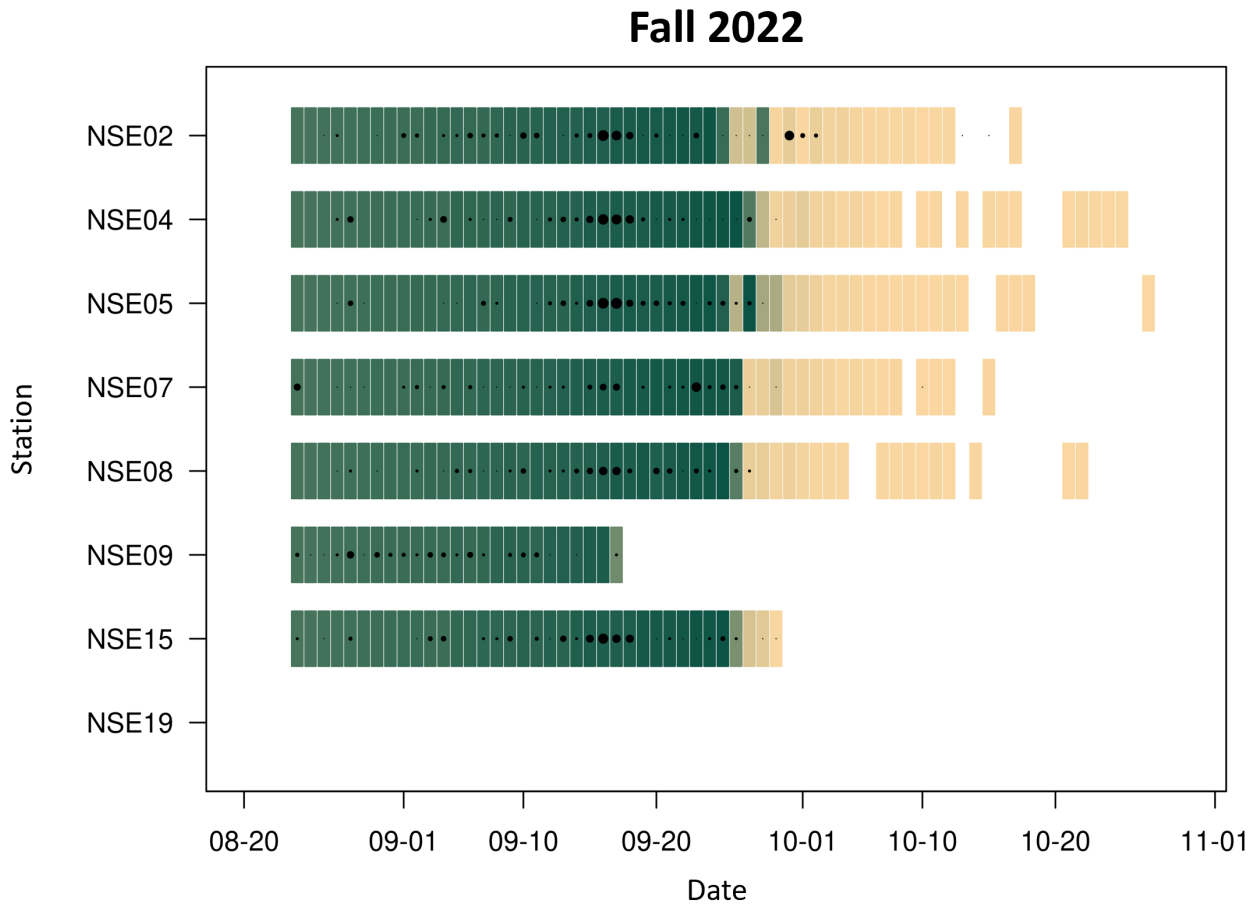

Fig. 5.1. Active monitoring periods during Fall 2022. Dark green indicates nights where the recorder was active and able to trigger recordings from sunset +1 hr to sunrise -1 hr. Lighter green towards beige indicates where the battery level dropped off, gradually limiting the duration that the recorder was enabled. The black dots show when recordings were triggered and saved by the active recorder, with the number of trigger events increasing with the radius of the black dot.

5.2 Spring 2023 survey

The Bat PAM stations for the Spring 2023 survey were deployed on a marine mammal PAM service trip in February. Due to the early timing of this trip and the limited internal power capacity of the recorders, they were programmed to delay start of the monitoring period until 1st of April. Seven of the stations were active nightly for over a month and retained the power capacity to record for up to two months. Station NSE8 had become flooded, and the SD cards corrupted. The bat PAM equipment was recovered during a planned service trip in the beginning of June. The sensitivity of the microphones was within the recommended manufacturer range upon recovery.

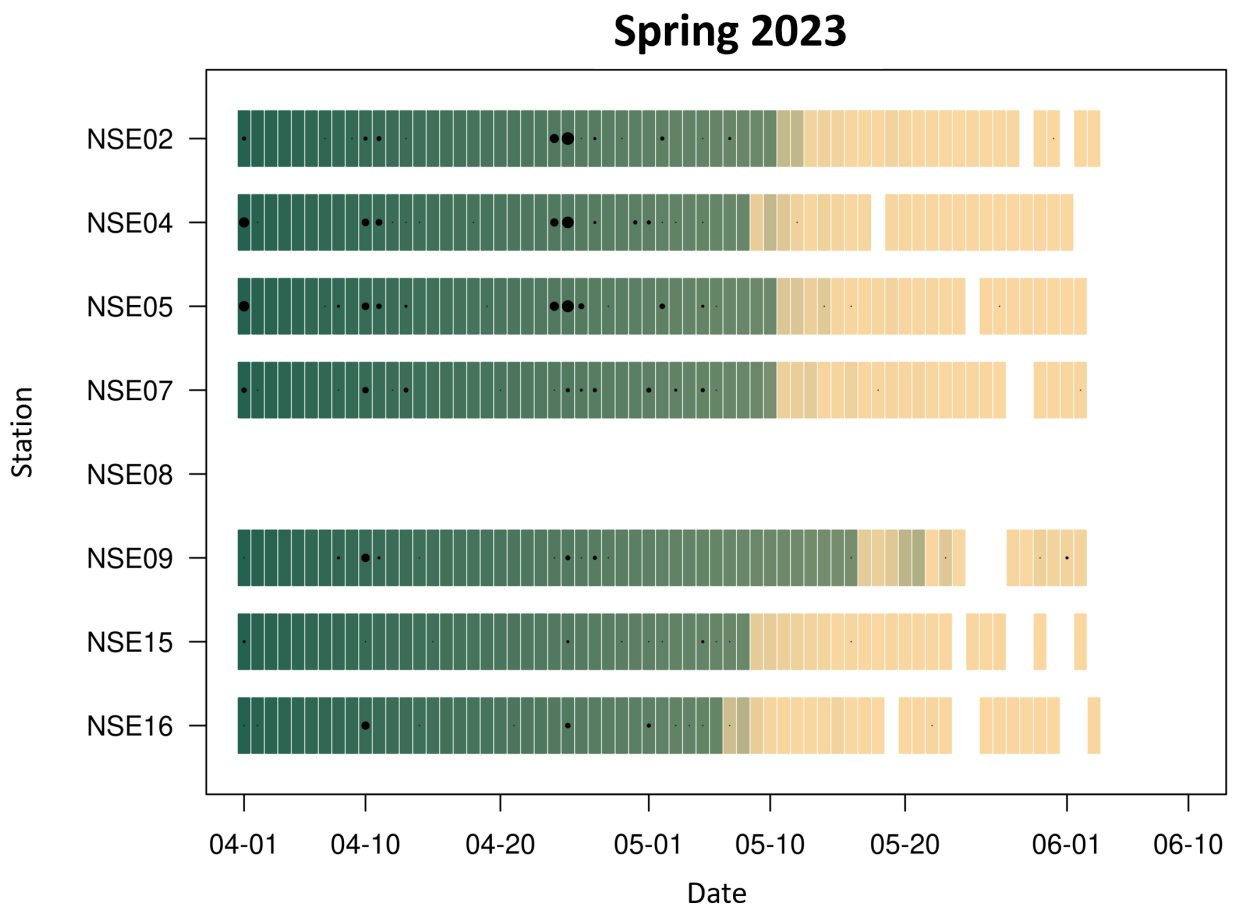

Fig. 5.2. Active monitoring periods during the Spring 2023 survey. Dark green indicates nights where the recorder was active and able to trigger recordings from sunset +1 hr to sunrise -1 hr. Lighter green towards beige indicates where the battery level dropped off, gradually limiting the duration that the recorder was enabled. The black dots show when recordings were triggered and saved by the active recorder, with the number of trigger events increasing with the radius of the black dot.

As described here: https://ens.dk/sites/ens.dk/files/Vindenergi/1213_eins_wp_h_scope_report_ver03_260122_bats.pdf in the North Sea Energy Island scoping report for bats, passive acoustic monitoring data from two LiDAR buoys deployed in the pre-investigation area by Fugro were intended to supplement data from the PAM stations deployed by Aarhus University as part of the field program and add to the robustness of the baseline data. Aarhus University was informed by Energinet that an independent consultant has validated a subset of recordings from the LiDAR buoy detectors and concluded that no bats were recorded on these. Aarhus University has not seen or been involved in analysis of the raw data from these LiDAR buoys. Consequently, the results from the LiDAR buoy detectors are not included in the assessment of bat occurrence in the survey area contained in this report.

6. Discussion

No bats were recorded during the surveys in fall 2022 and spring 2023 during the active monitoring periods when recorders were armed and ready to be triggered by sound to save recordings to memory. Relatively few recordings were triggered and saved on the recorders. These were manually inspected for bat calls but contained only ambient

noise, meaning that they were indeed triggered, but by noise sources and not by bats. The calibration included upon recovery of the equipment suggested no deviations from the range of normal microphone sensitivity suggested by the commercial manufacturer of the equipment, indicating that the deployed stations recovered in place had maintained functionality and suggesting that no bats passed within the detection range of the recorders during the monitoring period.

Most of the bat PAM stations were active for at least one and up to two months during the assumed main migration periods for bats where most activity would be expected. Although the absence of triggered recordings with bats aligns with expectations given the location of the pre-investigation area and the distance of the pre-investigation and extended survey area from shore, bats have occasionally been documented far offshore in the North Sea (Petersen et al., 2014, J van der Kooij, pers. comm. 31/08/2023, S Brinkløv, unpublished data) it should be cautioned that the surveys were exclusively based on PAM, included a single spring, and a single fall monitoring period, and that the timing of peak bat activity can differ significantly between years. Passive acoustic monitoring is currently the most economic, time-efficient and most widespread method to document bats offshore. Nevertheless, it is important to realize its limitations as described in the methods. Bats vocalize at ultrasonic frequencies that attenuate quickly in air and the size of the effectively monitored area with a detection range of up to a few hundred meters per detector, depending on the bat species and echolocation call characteristics, is minute relative to the overall size of the pre-investigation area.

7. Conclusion

This is the first baseline study of bat activity carried out in the area and the two seasonal surveys conducted indicate little to no bat activity in the area. Given the absent baseline information for the area prior to these investigations and the general limitations of the PAM method for bats, the results should, however, not be used to definitively exclude the occurrence of bats in the area without further monitoring efforts to support the results of the present survey.

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