Harbour Porpoise surface behaviour in response to vessel traffic within the Eastern Scheldt

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Contents

Introduction

Since the early 1990's ship density has increased by fourfold globally and between two and threefold in the Northern Atlantic and Pacific (Tournadre, 2014). Vessels cause multiple anthropogenic disturbances to cetaceans. This includes ship strikes, chemical pollution (i.e., accidents and spills), bycatch, entanglement with fishing nets and noise disturbance (Prideaux, 2003). Cetaceans use sound in the form of songs, whistles and echolocation for foraging, communication, and navigation (Au, 2004; Deecke et al., 2005; Filatova et al., 2013; Quick & Janik, 2008).

Multiple studies show different reactions of cetaceans when vessels are present. However, the long-term effect of anthropogenic noise on cetaceans is still unclear (Perry, 1998). Examples of observed short term responses are increased or decreased swimming speed, a decrease in resting and foraging, changes in swimming directions and vocal behaviour, sudden dives and longer dive times (Perry, 1998; Senigaglia et al., 2016). Changes in behaviour is the most seen reaction (Senigaglia et al., 2016). These responses could affect the food intake, survival rate of offspring and breeding success. Another result of anthropogenic noise is damage to the auditory system or masking and lastly continuous anthropogenic noise could possibly result in stress (Perry, 1998).

The harbour porpoise (*Phocoena phocoena*) is the most common cetacean in the North Sea, with an estimated abundance of approximately 350.000 (Hammond et al., 2017). Additionally, in the Eastern Scheldt, the Netherlands a population of approximately 50-60 harbour porpoises were identified by a photo identification project of the Rugvin Foundation (Stichting Rugvin, n.d.-a). The Eastern Scheldt is in connection with the North Sea and an area for birds, seals, shellfish, and porpoises (National Park Oosterschelde, n.d.). It can be closed off by the Eastern Scheldt Barrier to prevent flooding (Rijkswaterstaat, n.d.). The Eastern Scheldt Barrier was built in 1986, the number of harbour porpoise during this time was likely zero. In the early 2000's harbour porpoises were spotted year-round in the Eastern Scheldt. Because harbour porpoises are sensitive to sound, it is expected that harbour porpoises do not swim through the storm surge barrier and are therefore seen year-round (Stichting Rugvin, n.d.-a).

The Netherlands is a part of the intergovernmental treaty ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas) for achieving and maintaining a favourable conservation status in the ASCOBANS area (Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas, n.d.) The Dutch Ministry of Agriculture, Nature and Food Quality has established a conservation plan for the harbour porpoise (Ministry of Agriculture, Nature and Food Quality, 2020). This plan contains research, policy, legal developments, concerns, and actions to maintain the conservation status. The conservation of status, range, population, and habitat of the harbour porpoise in the Netherlands is "favourable" since 2019, future prospect is however described as "unknown". The harbour porpoise is protected by the Habitats Directive and in four Natura 2000 sites, one of which is the Eastern Scheldt. Recently the harbour porpoise has been included in the Standard Data form (SDF). This is a form used to notify the European commission about the status, management plans etc. of the Natura 2000 sites and is mandatory for all EU members. Since the harbour porpoise has been included in the Standard Data form it also needs to be taken up in the management plans of theses protected areas. Additionally, four Natura 2000 sites in the Dutch part of the North Sea are described as an area of conservation (Ministry of Agriculture, Nature and Food Quality, 2020). The conservation plan does however not contain guidelines for watercrafts and whale watching. However, whale watch guidelines do exist in other countries like Norway, England, France and many more. There are guidelines for speed, distance, approaching and number of vessels to minimise disturbance to cetaceans (International Whaling Commission, n.d.).

Oakley et al. (2017) studied the reaction of harbour porpoises to vessels in the United Kingdom. No positive behaviour was seen, e.g., moving towards vessel. Neutral behaviour was seen the most, which means no change in behaviour. Negative behaviour was also seen, this indicates moving away from vessel or prolonged dives. The vessel distance ranged from 10 metres to 1 kilometre and 95% of the vessels had an engine. Negative behaviour, e.g., swimming away from vessels or prolonged dives were mostly seen with cargo/ recreational fishing and speedboats. Furthermore, during the surveys they observed a porpoise with a propeller injury. During surveys in Southwest England harbour porpoises had a reduced presence and foraging rate when vessels were present (Roberts et al., 2019). A study that used tagging found that harbour porpoises cease echolocation or produced fewer buzzes and recontinued after the vessels passed (Wisniewska et al., 2018).

This study is a pilot study and was conducted to determine what the harbour porpoises behaviour is during and without vessel presence in the Eastern Scheldt. Thereby exploring if there's a difference in behaviour between vessel presence. These will be answered by the following research questions: "How does vessel traffic effect the behaviour of the harbour porpoise (*Phocoena phocoena*) in the Eastern Scheldt?", "Does the harbour porpoise show different behaviour to various types of vessels in the Eastern Scheldt?" and "Do vessels in the Eastern Scheldt follow the guidelines regarding cetaceans and harbour porpoises?".

Methodology

Location
Data collection was performed at Studio Porpoise in the Eastern Scheldt in the Netherlands.

Figure 1
Study area location in the Eastern Scheldt.

Note. Retrieved from Rugvin n.d.-c.

Data collection
To answer the research questions land-based observations were performed. Previous cetacean behavioural studies used a combination of *ad libitum*, scan, and continuous recording as the sampling rule (Oakley et al., 2016; Oakley et al., 2017). In this study *ad libitum* and continuous recording was used. *Ad libitum* recorded all behaviour, and continuous recording documented the duration and frequency of the behaviour. Continuous behaviour was described as useful for behaviours at the water surface, however it was advised to observe a maximum of two individuals simultaneously (Mann, 1999). Individual-follow and survey were used for the recording rule. Mann (1999) described the group-follow as an observation method for groups with a duration of at least 30 minutes. There will be a maximum of two individuals in a group and were only considered a group when they were swimming in close proximity, when this was not the case an individual follow was used. An individual follow was also used when one individual or more than two individuals were present. In case of multiple individuals, one was selected as subject that was easily identifiable, e.g., closer in distance, further away from the other individuals etc. (Mann, 1999).

A combination of previous cetacean behavioural studies was used to establish this method. In 2023 observations were held (Bas et al., 2017) from June until October, in daylight hours (Oakley et al., 2017; Williams et al., 2009). Locating harbour porpoises at a high sea state was difficult, therefore observation was mostly made at 0-2 Beaufort, 0-4 Beaufort was also acceptable (Oakley et al., 2017; Zanderink & Osinga, 2020). With a wave height lower than 0,5 metres. A sighting began when a harbour porpoise was spotted. During the sightings the harbour porpoise behaviour and presence were recorded, regardless of whether a vessel was present. Behaviour before, during and after vessel encounters was recorded to establish the possible effect of vessel disturbance (Oakley et al., 2017; Scheidat et al., 2004). The survey began when a harbour porpoise was spotted. Vessels in the observation area was recorded on a different data sheet. After a vessel encounter the survey would continue for 15 minutes, whether a harbour porpoise was present or not (Bejder et al., 2006). When the harbour porpoise stayed in the observation area, the survey continued. If no vessels were present the sighting ended when the harbour porpoise was no longer in sight for more than five minutes (Ribeiro et al., 2005), since harbour porpoises dives for short period of times, averaging 26 to 103 seconds, with longer dives for approximately four to five minutes (Otani et al., 1998; Otani et al., 2000; Westgate et al., 1995), and was therefore considered as 'leaving the study area'. When a harbour porpoise was spotted again, a new sighting began. It was considered as a new individual and sighting, since identifying a harbour porpoise from a distance can be difficult.

Behaviour was observed by eye or with binoculars (Ribeiro et al., 2005), the used binoculars had a distance range of 10 x 42. All surface behaviour and duration were recorded in a data sheet (Appendix B). When the harbour porpoise was underwater, it was described as underwater behaviour since the exact behaviour could not be determined. For foraging and feeding, as well as normal swim the time of surfacing was recorded, the following surface was the next recorded time. The duration of these two behaviours is therefore surfacing and submerging times combined. At some instances the exhale of the harbour porpoise was audible, this was recorded as "whale blow" (see Appendix A for the full ethogram). For every behaviour the behavioural code and duration, timed with a stopwatch were documented. Additionally present vessels and the environmental conditions at the beginning, during and at the end of every observation were described (see Appendix B for the protocol form). The recorded environmental conditions were tide, tide and wave height, weather conditions and Beaufort (Williams et al., 2009). The environmental conditions were obtained from windfinder.com.

Vessel traffic was recorded separately (see Appendix C for vessel traffic form) (Williams et al., 2009). The vessel type, use of engine, estimated speed, estimated distance to the observed harbour porpoise, sailing direction, sailing towards or away from the observed harbour porpoise, number of present harbour porpoises and changes in environmental conditions were recorded. The followed guidelines were recorded when possible. The estimated distance between the vessel and harbour porpoise was manually calculated using the distance to the buoys, shore, and Zeeland bridge (Bristow & Rees, 2001). An area of 0-1 kilometre was used for recorded vessel traffic, in Oakley et al. (2017) the vessel distance ranged till 1 kilometre. The distances until 300 metres were the most important, since odontocetes have reacted to vessels within 50 – 300 metres (Koschinski, 2008). Speed was categorized as stationary, normal (<6 knots) and fast (>7 knots). The speed could be verified with marinetraffic.com. The described vessel types were first categorized as use of engine and no use of engine. The use of engine vessels was inland cargo vessel, passenger vessel (e.g., ferry), motor tanker, tug / special craft (e.g., law enforced), service vessel (e.g., police patrol), commercial fishing vessel (e.g., trawler), sailboat, pleasure craft or other. The no use of engine vessels was sailboat and other. The category 'other' was used when the observed vessel did not fit in any of the categories. Furthermore, a description of the vessel was provided. The vessel categories were described using categories from marinetraffic.com. Afterwards, the recorded behaviour and vessel traffic were combined in the analyses (Williams et al., 2009).

Excel was used for the overview of all data and to create the histograms, graphs, and tables. In the analysis the duration, frequency and average time of each behaviour was calculated. The duration is calculated as the total sum of durations for each behaviour. The frequency is the number of occurrences of each behaviour. For foraging and feeding, as well as normal swim it counted as one occurrence until the porpoise was submerged for a longer time (longer than one minute), irrespective of the number of resurfaces. However, every resurface was recorded. The average time was calculated by dividing the total sum of duration with every recording for each behaviour. Additional statistic tests were conducted in R.

Results

Between June and September, a combined observation effort of 12 hours and 2 minutes. A total of 16 observation days were conducted. Harbour porpoises were sighted on 10 of those days, with a total of 17 observations. The number of observations per day varied between 1 and 3. The longest observation lasted 1 hour 38 minutes and the shortest was 7 minutes, during the shortest observation a harbour porpoise was seen surfacing once and no vessels were seen. The average observation duration was 44 minutes. Out of a total of 17 observations, vessels were observed in 15 of them, while the remaining two recorded no vessel sightings.

Weather conditions

The majority of the observations were conducted during two or three Beaufort, with both 6 observations during these conditions. During one observation the conditions changed from two to three Beaufort. Four observations were conducted under the conditions of one Beaufort and twice under four Beaufort. The average wave height was 0,2 metre and the average tide height was 1,3 metres. Eleven observations were performed at rising tide, three at falling tide, two at high tide and one at low tide.

Vessel types

During the observations multiple types of vessels were observed. The most observed vessel types were sailboats, where sailboats with no use of engine and using their sail were the most abundant. Other vessel types were pleasure craft e.g., yachts, passenger vessels like ferries and fishing vessels. A police patrol vessel was seen once and categorized as service vessels. Three vessels did not fit in the categories, these were speedboats and ribs.

Table 1

Observed number of vessels per category

Number of vessels for every vessel category	
Sailboat without engine*	138
Sailboat with engine	36
Pleasure craft	14
Fishing vessel	7
Motor tanker	1
Passenger vessel	3
Service vessel	1
Other	3

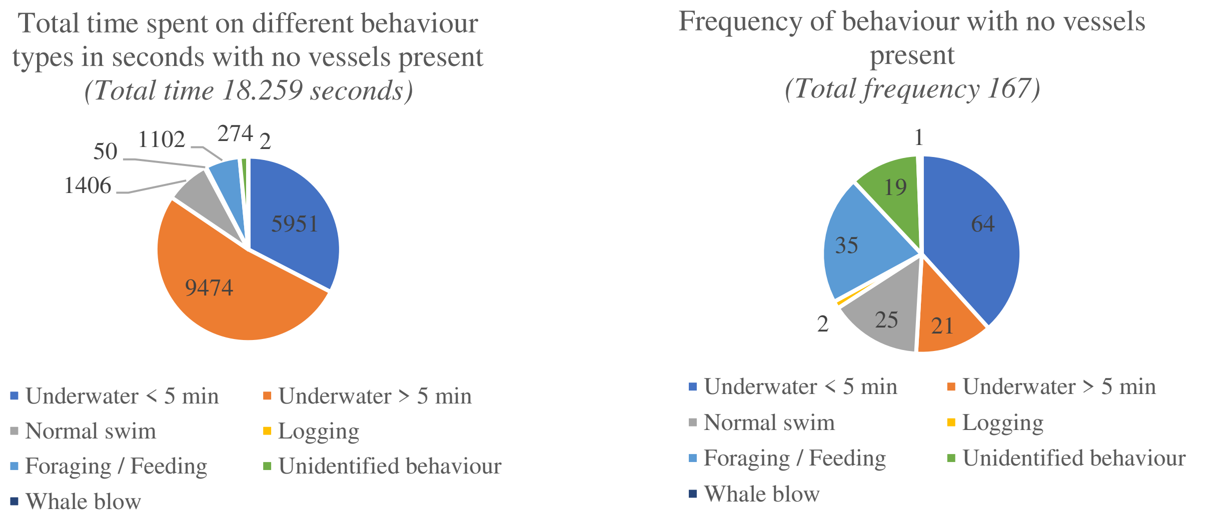
*Sailboats without apparent use of engine, relying on their sail to travel.

Behaviour during vessel absence

The total time of no vessels present was 18259 seconds. The behaviour that is most seen when no vessel were present was underwater > 5 minutes with a total duration of 9474 seconds and underwater < 5 minutes with a total of 5951 seconds. Though, underwater < 5 minutes exhibited a higher frequency of 64. Normal swim accounted for 1406 seconds and 25 occurrences. And foraging and feeding totalled 1102 seconds with 35 occurrences. Logging is seen for a short amount of time of 50 seconds with a frequency of 2.

Figure 2

Total time spent on different behaviour in seconds (left) and frequency of these behaviours (right) when no vessels were encountered.



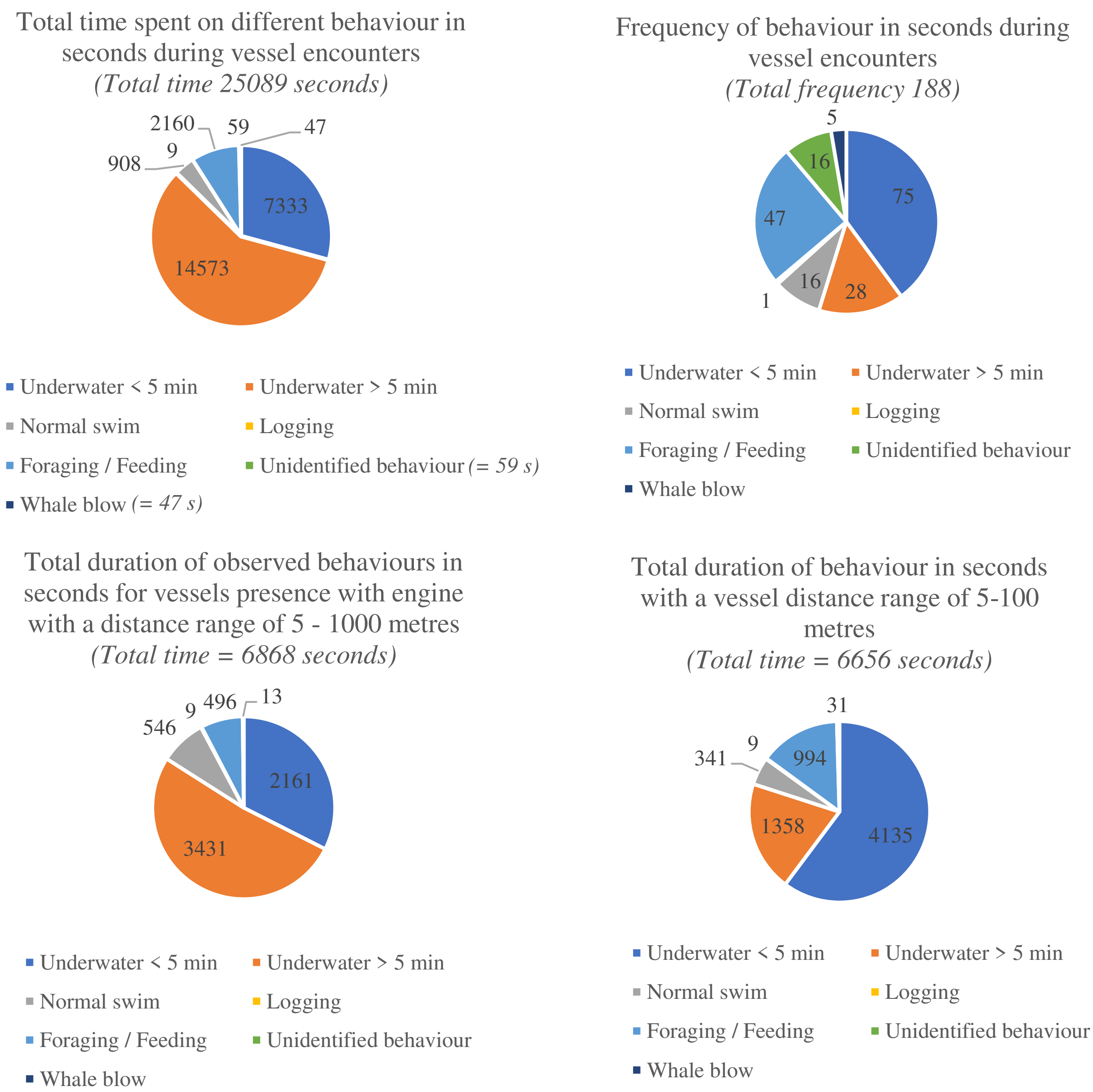
Behaviour during vessel presence

The total time of vessel presence was 25089 seconds. The longest total durations were observed in the two underwater categories: underwater < 5 minutes and underwater > 5 minutes (Figure 3). Notably, underwater < 5 minutes exhibited the highest frequency with 75 occurrences, while underwater > 5 minutes has a frequency of 16 and a total duration of 14573 seconds. What is noticeable is that underwater > 5 minutes is seen approximately half of the time during vessel encounters with engine with 3431 seconds out of a total of 6868 seconds. During a vessel distance range of 5 – 100 metres underwater < 5 minutes is seen the most with 4135 seconds out of a total of 6656 seconds (Figure 3).

Foraging and feeding accounted for a total frequency of 47 and a total duration of 2160 seconds. Foraging and feeding is seen 994 seconds with vessel distance of 5-100 metres. Both normal swim and unidentified behaviour was seen with a frequency of 16, however normal swim had a longer total duration of 908 seconds.

Figure 3

Total time spent on different behaviour in seconds (top left) and frequency (top right) of these behaviours during vessel encounters. Total time spent on different behaviour in seconds with a vessel distance range of 5-100 metres (bottom left). Total time spent on different behaviour in seconds with vessels using their engine (bottom right).



Difference in behaviour between no vessels and vessels present

The highest percentage of total duration was observed in underwater > 5 minutes when vessels were present, with a total duration of 59,37%, a frequency of 14,89% (Figure 4). In contrast, underwater > 5 minutes without vessels exhibited a total duration of 51,89%, a frequency of 12,57% (Figure 3). The behaviours whale blow and logging had the lowest percentages in both total duration and frequency. Whale blow accounted for 0,18% of the total duration and 2,66% of the frequency when vessels were present, and 0,01% for total duration and 0,60% for frequency when vessels were absent. Logging had a total duration of 0,03% and a frequency of 0,53% in the presence of vessels and 0,27% for total duration and 1,20% for frequency in their absence. The total time spent on both underwater categories, logging, and whale blow (comparing figure 2 and 3) did not differ significantly between vessels present and no vessels present (p= >0,05).

Normal swim represented 7,70% of the total duration and 14,97% of the frequency when vessels were not present, while it had a total duration of 3,51% and a frequency of 8,51% in the presence of vessels. Normal swim showed a normal distribution after log transformation. The difference between vessel presence and vessel absence was found to be significant with a paired t-test conducted in R (p= 0,03).

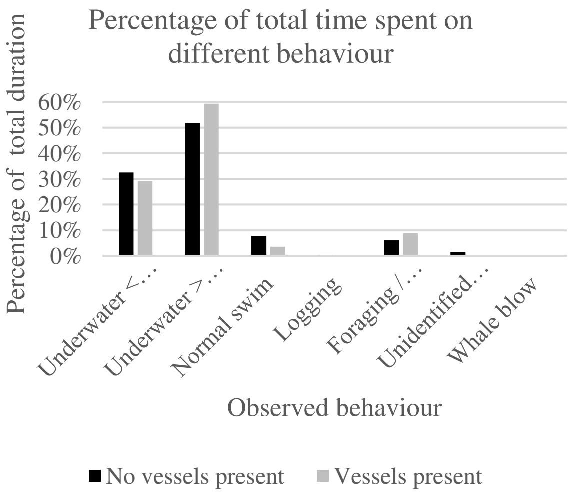
Foraging and feeding showed a total duration of 8,76% and a frequency of 25% when vessels were present, whereas in the absence of vessels, it exhibited a total duration of 6,04% and a frequency of 20,96%. Foraging and feeding showed a non-normal distribution. The difference between vessel presence and vessel absence was found to be significant with the Wilcoxon rank sum test conducted in R (p= 0,03).

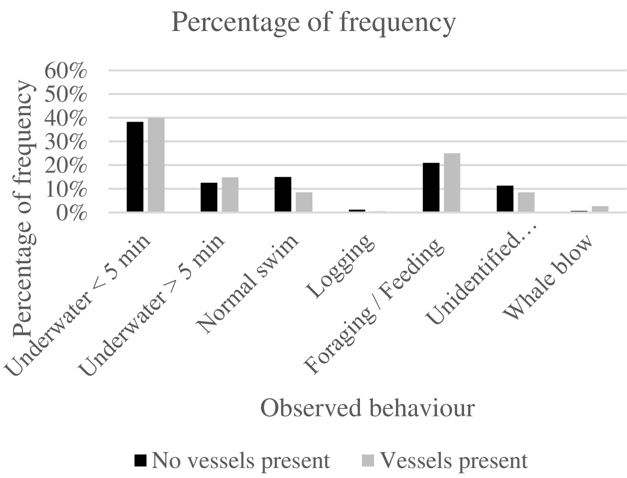
The t-test conducted in Excel showed the average times of all behaviours when vessels were present and absent. This was calculated by the total duration divided by every recording of each behaviour. The average time spent underwater > 5 minutes with vessel presence was 828,8 seconds. When no vessels were present the average time was 631,9 seconds. Underwater < 5 minutes showed an average time of 105,8 when vessels were present and 94 seconds when vessels were absent. The average time for normal swim with vessel presence is 20,3 seconds, whereas the average time when vessels were absent was 38 seconds. Foraging and feeding showed an average time of 23,9 seconds when vessels were present and 17,2 seconds when vessels were absent.

Appendix E shows histograms of underwater < 5 minutes, underwater > 5 minutes, normal swim, and foraging/ feeding. It showed a higher frequency between 0-50 seconds of the behaviour underwater < 5 minutes when vessels were absent. The histogram of underwater > 5 minutes indicates that there is a higher frequency by longer total durations when vessels are present. Foraging and feeding has a higher frequency for 10-15 seconds and 25-30 seconds. Normal swim shows a higher frequency between 0-5 seconds and 45-55 seconds when vessels were present.

Figure 4

The percentage of total time spent (left) and frequency (right) for each behaviour in the presence and absence of vessels.





Note. The duration and frequency in the presence of vessels are represented in grey, totalling 100%. The duration and frequency in the absence of vessels are represented in black, also totalling 100%.

Vessel distance and speed

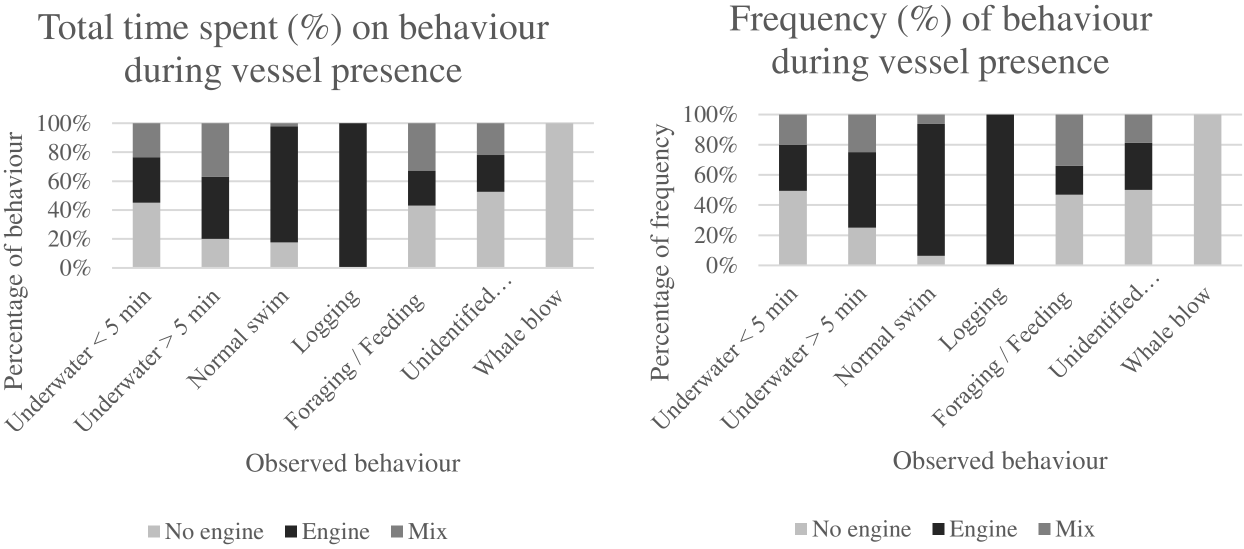
The closest point of approach of a vessel with engine was approximately 5 metres, the speed of the vessel was under 6 knots. At this vessel distance the behaviours normal swim and underwater (<5 minutes) were seen. The closest point of approach for foraging and feeding was seen by a vessel with engine at a distance of 10 metres, this vessel reduced their speed when approaching the harbour porpoise and was eventually stationary at the closest point of approach. At 20 metres foraging and feeding was also observed, this is regarding a 'mix', which indicates multiple types of vessels. During this 'mix' a sailboat without engine was present at 20 metres, a pleasure craft and sailboat with engine at 50 metres and 4 sailboats without engine at 500-1000 metres, all vessels travelled under 6 knots. The highest foraging and feeding duration are seen at 300 metres, divided by vessels with engine and without engine. Normal swim is mostly seen when vessels with engine were present. Whale blow was only observed at a distance of 300 metres and 300-500 metres and no use of engine. Logging was observed once during vessel encounters at 300-500 metres with a vessel with use of engine. On a few occasions vessels travelled at a speed higher than 7 knots. During this speed normal swim and underwater < 5 minutes and underwater > 5 minutes were seen with a distance of 200 metres. Foraging and feeding was observed with a distance of 300 metres. Since the dataset was too small no statistic tests were performed on vessel distance and speed.

Use of engines

The behaviours underwater (< 5 minutes), foraging & feeding and whale blow are mostly seen during vessel encounters with no use of engine, this applies for duration and frequency (Figure 1). Normal swim and logging were the most observed when vessel with use of engine were present, for duration as well as frequency. Where use of engine accounted for 100% of duration and frequency for logging. And no use of engine accounted for 100% for whale blow. Underwater (> 5 minutes) has a longer duration of 37,04% and a lower frequency of 25% for mix. Since the dataset was too small no statistic tests were performed on types of vessels.

Figure 5

Comparing the total time spent (left) and frequency (right) of each behaviour (as a percentage) with and without engine use, as well as a mix of use and no use of engine. These categories combined gives the total duration and frequency of each behaviour.



Guidelines

If whale watching guidelines from the IWC of various countries were followed was also documented. The guidelines contained the same information across the different countries (Table 2). A lower distance than 50 metres was seen 13 times. A lower distance of 200 metres when a calf or other vessels were present was seen 15 times. Three out these 15 times a possible calf was present, these three times occurred during the same observation. A speed higher than 7 knots was seen 11 times. Cutting the path and not sailing parallel to the animal was seen 2 times. Approaching when the animal was staying in the same spot happened once and approaching from the front or behind happened twice. The other guidelines were followed. This is a total of 44 disturbances. Since the dataset was too small no statistic tests were performed on the guidelines.

Table 2

Whale watching guidelines retrieved from the IWC.

Guidelines
A distance of 50-100 metres
A distance of 200 metres when a calf or other vessels are present
Animals are able to leave the vicinity of the vessel
A speed of less than 5 or 6 knots when in close proximity (<300m) with the animal
Sailing parallel to the animal and not cutting the path
Not approaching when it is staying in the same spot
Not approaching from the front or behind
If the animal shows avoidance behaviour, gradually reducing speed and sailing away from the animal
No food or rubbish are thrown overboard

Discussion

A combined observation effort of 12 hours and 29 minutes is conducted over 16 days, observing a total of 201 vessels and nine vessel types. The most abundant vessel type was sailboats with no use of engine, thus relying on their sail. Both underwater categories are the most observed. Underwater shorter than 5 minutes shows a slightly higher total duration, however a lower frequency by vessel absence. This is also seen in the average time where the average underwater time for vessel presence is 105,8 seconds, while the average underwater time for vessel absence is 94 seconds. Underwater longer than 5 minutes has a higher total duration, frequency, and average time when vessels were present (p= >0,05). Which shows that during the observations in this study harbour porpoises were longer underwater when vessels are present. Whale blow and logging had the lowest percentages in both total duration and frequency during vessel present and vessel absence. These observations are however visual differences and do not significantly differ (p = >0,05). The closest point of approach for a vessel with engine is approximately 5 meters, where behaviours such as normal swim and underwater (<5 minutes) are observed, this is regarding a vessel with engine that was stationary at closest point of approach.

Because the dataset was too small the distance, speed and type of vessel were not statistically tested. Even though, the dataset was small there are two behaviours that do show a significant difference between vessel presence and absence (p= <0,05). These behaviours are normal swim and foraging and feeding. What is noticeable is that foraging and feeding has a higher total duration, frequency, and average time when vessels are present. The average time indicates that when vessels are present resurfacing takes longer than when vessels are absent. While foraging and feeding did happen at closer distances like 10, 20, 50 and 100 metres, the highest durations of foraging and feeding occurred with a vessel distance of 300 metres. The higher rate of foraging and feeding can also indicate an irregular swimming behaviour identified as foraging and feeding but could be a form of disturbance.

Normal swim shows the opposite with a lower total duration, frequency, and average time when vessels are present. The total duration between vessel presence and absence showed a significant difference (p= <0,05). The average time indicates that the resurfacing time is faster when vessels are present. The highest duration of normal swim is seen at vessel distance of 200 and 300-500 metres. Indicating that during this study normal swim and foraging and feeding by harbour porpoises is seen during vessel presence, however with a higher duration when vessels are further away. Distance, average time, and frequency was however not significantly tested.

A total of 44 disturbances were seen regarding the guidelines and a total observation duration of 722,47 minutes. This suggest that every 16,4 minutes a disturbance occurs (722,47 / 44). Vessels were present for a total of 418,15 minutes. With only considering the vessel presence time, a disturbance occurs every 9,5 minutes (=418,15 / 44). This study was no disturbance factor since the observations were land-based.

Oakley et al. (2017) studied the reaction of harbour porpoises to vessels in the United Kingdom. Moving towards vessels is not seen in the study of Oakley et al. (2017). In the study in Zierikzee this was also not observed. No change in behaviour is seen 74% of the time with a mean distance of 250 metres in the United Kingdom. This is seen multiple times during the study in Zierikzee. The most noticeable is when a vessel was approximately 5 metres from the harbour porpoise and the porpoise kept foraging and feeding. This vessel was stationary at closest point of approach. Prolonged diving of 8 – 20 minutes and moving away from vessels is seen 26% of the time in the study from the United Kingdom. In Zierikzee underwater longer than 5 minutes was seen but did not differ significantly and was also observed when vessels were not absent. What stands out is that during the study in the United Kingdom the mean distance of this behaviour is 25 metres, while underwater longer than 5 minutes was mostly seen with a vessel distance of 200-500 metres in Zierikzee. Vessel distance ranged from 10 metres to 1 kilometre and vessels with engine is the most seen in the study of Oakley et al. (2017). In Zierikzee it ranged from 5 metres to 1 kilometre and the most observed vessel is no use of engine.

In Roberts et al. (2019) harbour porpoises showed a reduced foraging rate when vessels were present, which is not shown in this study. However, the most observed vessel in the study of Roberts et al. (2019) is marine vessels and thus using engines. Which differs from this study as more sailboats is observed here and less use of engine.

This study was conducted between June and September of 2023. Throughout these months, there were only a few days when the weather conditions were favourable. As a result, there are too few observation hours to make a correct conclusion about the effect of vessels on harbour porpoises. Therefore, further research is needed.

Conclusion

This study aims to answer the following questions: "How does vessel traffic effect the behaviour of the harbour porpoise (*Phocoena phocoena*) in the Eastern Scheldt?", "Does the harbour porpoise (*Phocoena phocoena*) show different behaviour to various types of vessels in the Eastern Scheldt?" and "Do vessels in the Eastern Scheldt follow the guidelines regarding cetaceans and harbour porpoises (*Phocoena phocoena*)?".

The visual data indicates that the average time porpoises spent underwater was longer when vessels were present, suggesting that they may spend more time submerged in the presence of vessels. The distance of vessels could also affect the behaviour, as behaviours were observed at different distances. Such as normal swim, which showed variations depending on the distance from vessels, suggesting that the type of vessel and its proximity may affect this behaviour. This was however not statistically tested. Lastly, when vessels were present, the total duration of certain behaviours, such as foraging and feeding was higher compared to when vessels were absent, which was found to be significantly different ($p= < 0,05$). This differs from found literature where foraging rates were lower when vessels were present. These findings answer the research question "How does vessel traffic effect the behaviour of the harbour porpoise (*Phocoena phocoena*) in the Eastern Scheldt?" indicating that vessel traffic does have an impact on the behaviour of harbour porpoises in the Eastern Scheldt based on the observations. However, more research is needed for a more definitive conclusion of the effect on harbour porpoise behaviour. Such as, what the reasons are for higher foraging rate e.g., distance, vessel type or speed, which cannot be answered with the limited data obtained during this study. Or if the foraging and feeding rate changes when there is more data to analyse.

The research question "Does the harbour porpoise (*Phocoena phocoena*) show different behaviour to various types of vessels in the Eastern Scheldt?" cannot be answered. The dataset was limited for a definite conclusion and statistic tests. However, the visual data without significant difference shows that the presence of vessels without engine is associated with longer durations and higher frequencies of the behaviours underwater, foraging and feeding and whale blow. While normal swim and logging shows a higher total duration and frequency during vessel encounters with engines. However, further research is needed to determine if this is significantly different.

The data regarding the guidelines indicates that on occasions the whale-watching guidelines where not followed in the Eastern Scheldt. Guidelines regarding a close distance and speed were the guidelines that were mostly disregarded. Answering the research question "Do vessels in the Eastern Scheldt follow the guidelines regarding cetaceans and harbour porpoises (*Phocoena phocoena*)?". The guidelines do not specifically apply to the Eastern Scheldt, but this section was included to assess vessel interactions with harbour porpoises and identifying areas for potential improvement. The data of guidelines were limited, as a result no statistic test was conducted on this data.

Even though the data was limited some significant differences were found. Further research is therefore needed. This report demonstrates a method for assessing the effect of vessels on harbour porpoises and providing initial findings, offering the potential for future continuation in upcoming years.

Recommendations

The following is recommended for further studies. This study was conducted with one observer, limiting the amount of data that could be recorded. Therefore, for future research it is recommended that two observers conduct this study. As a result, more specific data can be recorded. Such as, the exact time of closest point of approach and the exact speed of the vessels. With two observers one observer can record the behaviour, while the other records the vessel information. To make the data collection more efficient it is recommended to use an app like PADOC, to reduce the time required for data entry. When more data is obtained, the effect of specific vessel types, vessel distance and speed can be concluded.

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Appendix A
Ethogram for Harbour Porpoises

Behaviours exhibited by the Harbour Porpoises, included with the behaviour description, name and code. Categorized by surface behaviour, social behaviour, behaviour around vessels and other.

	Code	Name	Description
Surface behaviour	BR	Breach	Body exits halfway and falls back creating white water.
	FF	Foraging/ Feeding	Surfacing once, followed by an irregular swimming pattern underwater and surfacing again. Or repeated and unsynchronised diving in different directions but staying in the same area (Oakley et al., 2017).
	FD	Foraging/ Feeding at deeper depths	Surfacing around three times, followed by a dive where the tail is seen.
	FS	Fast Swim	Surfacing quickly, possibly with white water.
	LG	Logging	Lying motionless at the surface and appears to be in a resting state (MacLaren et al., 2012; Zanderink & Osinga, 2020)
	LP	Leaping	Full body exiting out of the water and re-entering the water.
	NS	Normal Swim	Surfacing with no splash. The blowhole is seen first, followed by the anterior part of the back, the dorsal fin and lastly the posterior part. The tail remains under water and is not seen. Usually in a sequence of three. Between the surfacing the porpoise is under water for a couple seconds (Zanderink & Osinga, 2020).
	PP	Porpoising	Surfacing at a fast pace and repeated leaping (Baker et al., 2017).
	TS	Tail slap	Slapping the ventral surface of the tail on the water surface (MacLaren et al., 2012).
	WB	Whale Blow	Exhale through blowhole, this is heard and not seen.
Social behaviour	GR	Group	Two or more Harbour Porpoises are seen closely swimming together in the same direction.
	EG	Exiting Group	One or more Harbour Porpoises exiting a group.
	JG	Joining Group	One or more Harbour Porpoises joining a group.
Other	OS	Out of Sight	Harbour porpoise is out of sight for more than 5 minutes.
	UW	Under water / Diving	Harbour porpoise is under the water surface and cannot be seen.
	UB	Unidentified behaviour	An observed behaviour does not fit in any of the categories.

Note. Behaviour at the water surface is included, underwater behaviour is not included in this study and therefore not described. Ethograms of bottlenose dolphins (Baker et al., 2017), Yangtze finless porpoise (Yi-Jie et al., 2010) and other cetaceans (MacLaren et al., 2012) were used in combination with behavioural literature of the Harbour Porpoise (Amundin, 1974; Dyndo et al., 2015; Zanderink & Osinga, 2020) to establish this ethogram.

Appendix B

Protocol

Form used during observation. Environmental conditions at the start, during and at the end of the observation, the time of the behaviour and the behavioural code are described.

Start time (hh:mm): : Date (dd/mm/yy): / / Observer:

Environmental conditions start of the observation

Weather: Sunny / Partly Cloudy / Cloudy / Overcast / Raining / Fog
Beaufort: 0 / 1 / 2 / 3 / 4
Tide type: High / Falling / Low / Rising Tide Height:
Wave Height:

Environmental conditions (changes) during the observation

Weather: Sunny / Partly Cloudy / Cloudy / Overcast / Raining / Fog
Beaufort: 0 / 1 / 2 / 3 / 4
Tide type: High / Falling / Low / Rising Tide Height:
Wave Height:

Environmental conditions at the end of the observation

Weather: Sunny / Partly Cloudy / Cloudy / Overcast / Raining / Fog
Beaufort: 0 / 1 / 2 / 3 / 4
Tide type: High / Falling / Low / Rising Tide Height:
Wave Height:

End time (hh:mm): :

Time (mm:ss):	**Observed behaviour (Behavioural code)**	**Swimming direction (Number of degrees and direction)**	**Swimming distance in metres**	**Vessel in observation area:**
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No

General Remarks:

Appendix C
Vessel information

Vessel information during the observation period. The time and date of the observed vessel is recorded. In addition, the vessel type, speed, distance of the harbour porpoise and if the guidelines are followed is included.

Time of entering observation area (hh:mm): : **Time of leaving observation area (hh:mm): :**	**Date (dd/mm/yy): / /**	**Observer:**
Change of environmental conditions:	Yes, … No	

Vessel type:

Engine:

- o Inland cargo vessel
- o Passenger vessel, e.g. Ferry
- o Motor Tanker
- o Tug / special craft, e.g. Law enforced
- o Service Vessel, e.g. Police patrol
- o Commercial fishing vessel, e.g. Trawler
- o Sail boat
- o Pleasure craft
- o Other:

No engine:

- o Sail boat
- o Other:

Number of harbour porpoises present in observation area before vessel was present:

Number of harbour porpoises present in observation area after vessel was present:

Closest point of approach to the focal-animal:

Estimated speed:

Sailing direction: North / Northeast / East / Southeast / South / Southwest / West / Northwest

Sailing in the direction of the Harbour Porpoise: Yes / No

Guidelines followed:

Yes	No	Does not apply	
			Distance:
○	○	○	- A distance of 50 - 100 metres.
○	○	○	- A distance of 200 metres when a calf or other vessels are present and when the animal is foraging.
○	○	○	- Animals are able to leave the vicinity of the vessel.
			Speed:
○	○	○	- A speed of less than 5 or 6 knots when in close proximity (< 300 m) with the animal.
			Approaching:
○	○	○	- Sailing parallel to the animal and not cutting the path of the animal.
○	○	○	- Not approaching the animal from the front or behind.
○	○	○	- Not approaching the animal when it is staying in the same spot.
○	○	○	- If the animal shows avoidance behaviour, gradually reducing speed and sailing away from the animal.
			Other:
○	○	○	- No food or rubbish are thrown overboard.

Note. Literature used for the guidelines (Berglund et al., 2017; Greenland Tourism, n.d.; Scottish Natural Heritage, n.d.; Stichting Rugvin, n.d.-b).

Appendix C (continuation)
Vessel information (multiple vessels present)

Vessel information for multiple vessels present during the observation period. The time and date of the observed vessel is recorded. In addition, the vessel type, speed, distance of the harbour porpoise

Change in environmental conditions:
Yes,..
No

Time of entering observation area (hh:mm)	**Estimated speed:**
Time of leaving observation area (hh:mm)	**Sailing direction:**
Vessel type with engine	**Sailing in direction of harbour porpoise:**
Vessel type without engine	**Closest point of approach (in m)**

Genaral remarks:

Time of entering observation area (hh:mm)	**Estimated speed:**
Time of leaving observation area (hh:mm)	**Sailing direction:**
Vessel type with engine	**Sailing in direction of harbour porpoise:**
Vessel type without engine	**Closest point of approach (in m)**

Genaral remarks:

Time of entering observation area (hh:mm)	**Estimated speed:**
Time of leaving observation area (hh:mm)	**Sailing direction:**
Vessel type with engine	**Sailing in direction of harbour porpoise:**
Vessel type without engine	**Closest point of approach (in m)**

Genaral remarks:

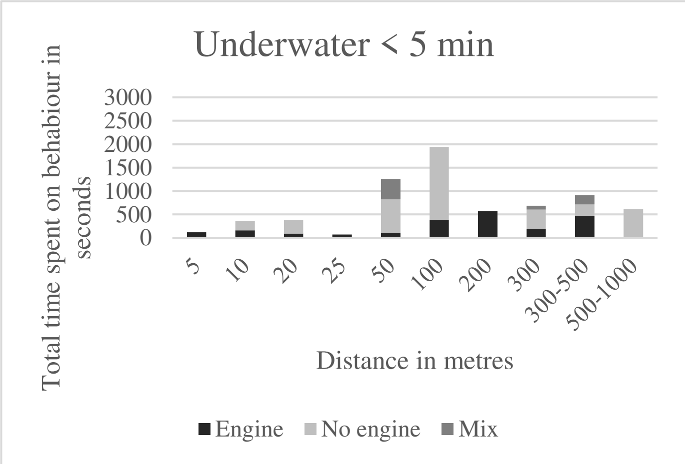
Time of entering observation area (hh:mm)	**Estimated speed:**
Time of leaving observation area (hh:mm)	**Sailing direction:**
Vessel type with engine	**Sailing in direction of harbour porpoise:**
Vessel type without engine	**Closest point of approach (in m)**

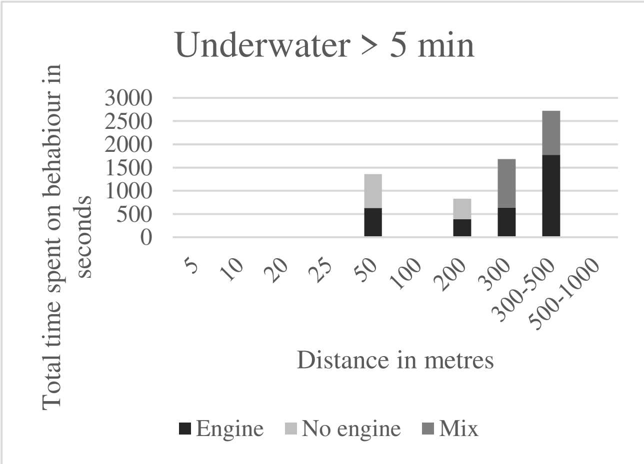
Genaral remarks:

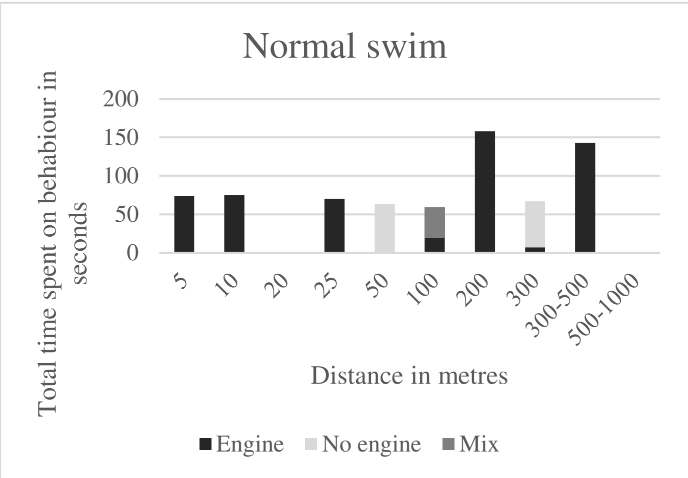
Appendix D

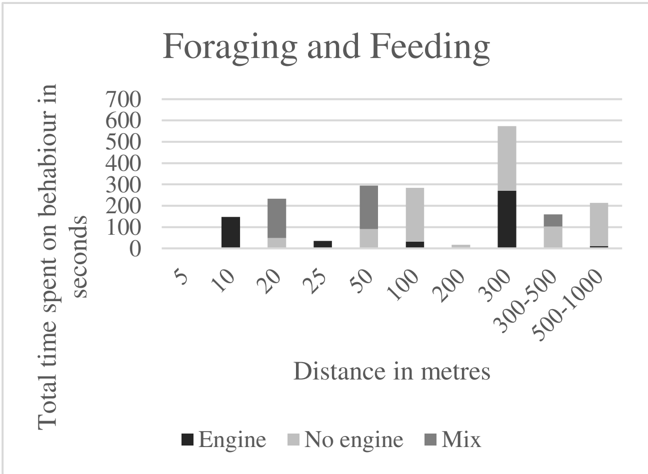
Vessel distance per behaviour

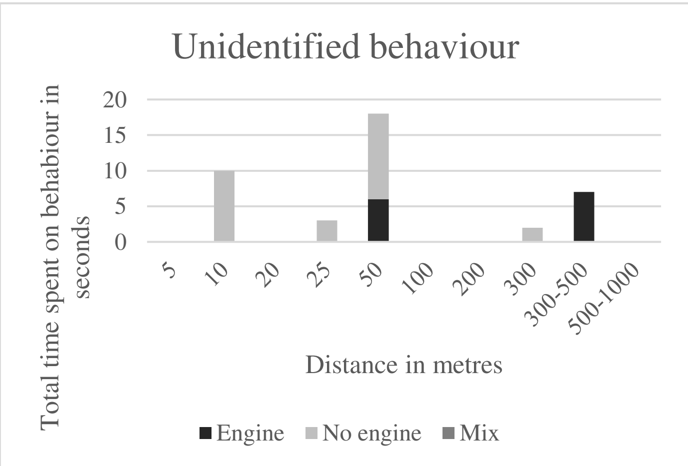
Vessel distance per behaviour categorized between engine, no engine and mix vessels.

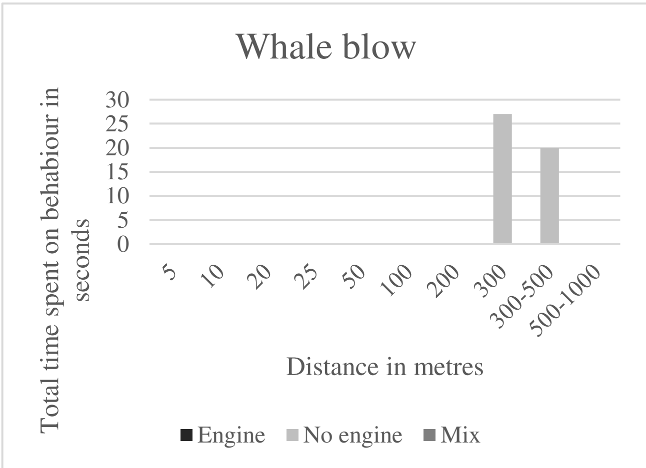


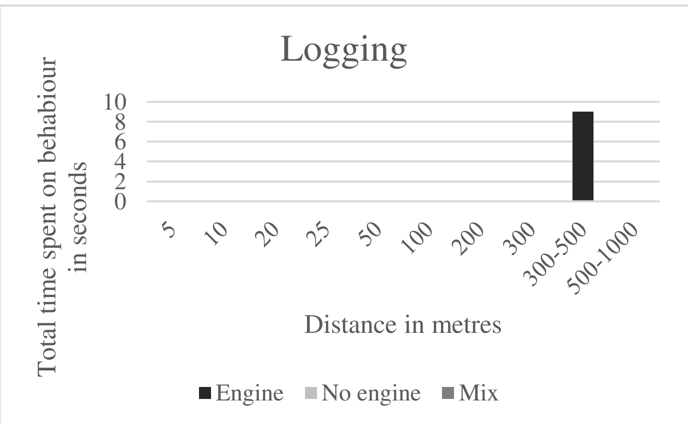












Appendix E

Histograms of the behaviours, underwater < 5 minutes, underwater > 5 minutes, normal swim and foraging and feeding. Showing duration blocks and the frequency that this duration occurred.