Bachelors Thesis

An assessment of boating activities and the interactions with harbour porpoise (*Phocena phocena*) in Ramsey sound:

Towards an improved management strategy

Carla M. Lange

Advisors: Cliff Benson- Sea Trust

Peter Hofman

Linde van Bets

University of Applied Science Van Hall Larenstein

Part of Wageningen University

Coastal zone management

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Abstract

In Pembrokeshire/ Wales harbor porpoise (*Phocena phocena*) make daily use of Ramsey sound, a narrow ocean channel characterized by strong tidal currents. The sound is an important socializing and feeding area for porpoise and was designated marine special area of conservation (MSAC) in 2004. The region is popular for leisure boating and vessel based wildlife watching. A voluntary code of conduct was put in place to protect the animals from disturbance through vessels but proved ineffective, leaving the animals with little protection. A dedicated land based survey was carried out between April- July 2012 in order to assess boating activity in the sound and potentially associated signs of disturbance in porpoise. It was found that 58% of the total number of vessels observed in the sound are wildlife watching boats. They followed the code requirements to a certain degree, however especially in the narrow centre of the sound high speeds up to 42 knots were observed and frequent porpoise encounters suggest high vulnerability of the animals. The majority of porpoise sightings (56%) were made in the southern area of the sound where foraging activity was found on a daily basis. Porpoise showed signs of disturbance on some occasions but seemed to ignore vessels on others. No direct responses of foraging porpoise to vessels were observed. They continued their activity with vessels in close proximity. Based on the precautionary principle, a need for protective measures was indicated. Recommendations for improved management including dynamic no take zones, communication with land based observers and statutory measures if porpoise can proved to be resident in Ramsey sound, as well as future research goals were developed. The results of this study will help to increase the chance for long-term sustainable use of the region by both humans and animals.

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1. Introduction

Living in coastal and shelf areas, harbor porpoise (*Phocena phocena*) increasingly suffer under pressure from anthropogenic activities like marine boat traffic. A number of short term effects of boat traffic on cetaceans and in particular of cetacean focused tourism have been recognized in the past (Koschinski, 2008; Allen & Read, 2000). These effects include direct and indirect effects like decreases in resting and feeding periods, longer dives, escape, avoidance and abandonment of formerly preferred areas, decrease of reproductive rates injury and potentially death (Koschinski, 2008; Allen and Read, 2000, Wells & Scott,1997).

Little is known about the impacts of these short term changes in behavior on long term development of individuals and populations (IWC 1991 in Koschinski 2011; Warburton, 1999; Richardson & Würsig, 1997). Effects of marine traffic however are likely to have an accumulative effect in combination with other anthropogenic pressures including bycatch, depletion of fish stocks, pollution, and habitat destruction (Koschinski, 2008).

The coast of Pembrokeshire in south west Wales is considered a "hot spot" for harbour porpoise in Europe and was classified as category one area for cetacean MPAs (Evans & Wang, 2009) which shows that it is favourable habitat for whales and dolphins. On a daily basis harbour porpoise travel through Ramsey sound, a narrow channel between Ramsey island and the mainland, to forage in the strong tidal currents.

Ramsey's popularity for outdoor activities and wildlife watching attracts high amounts of boat traffic in the sound. Concerns exist that these and in particular the small wildlife watching boats, producing high frequency sounds and performing unpredictable movements boats disturb the animals.

Whether or not boat traffic affects mammals in the sound and to which extend is not clear. Baradell (unpublished) states that the "frequency, abundance and speed of boats at certain times are a cause of short term disturbance to porpoise movements within the Sound."

A voluntary code of conduct, the Pembrokeshire Marine Code (PMC) was introduced in the region in 2003 to protect wildlife from disturbance and injury through vessels. However it has not proven to be effective around Ramsey sound. Several parties have left the marine code group. As a result and also due to minimal available funding, efforts to manage commercial wildlife watching activities have been resigned and focus is now on raising awareness in the general public. That leaves harbor porpoise without effective protection from disturbance by boats. Due to a lack of financial means no effective monitoring or studies exist on current wildlife watching practices in Ramsey sound other than opportunistic observations.

There is a conservation need to assess activities of boats in Ramsey sound with a focus on its interactions with and potential impacts on harbor porpoise to be able to clarify whether a more dedicated management approach is needed and also in order to predict effects of other potentially disturbing factors like a planned tidal turbine. This study aims to do so in order to improve the situation as far as necessary and increase the chances for a longtime sustainable utilization of the region with all its features.

2. Research questions and goals

2.1. Goals and objectives

There is need for a framework that addresses the protection of harbour porpoise from disturbance through boat traffic but allows low impact utilization of Ramsey sound. However in order to be able to develop an effective management plan it was necessary to assess current boat and porpoise activities including: times and places of boat and porpoise activities, times and locations of overlap (porpoise- vessels), boaters compliance with the PMC and potential effects of motorized traffic on porpoise. The observed behavior of vessels was compared to the requested behavior stated in the PMC. Furthermore efforts were made to observe reactions of harbor porpoise to wildlife watching vessels and find out whether disturbance was taking place. Recommendation for a well-reasoned and integrated management strategy as well as future research were made.

The following objectives have been identified:

1. Assess *numbers and types* of boats active in Ramsey sound.
2. Identify *travel routes of animals and boats* and find places of *crossing and overlap*.
3. Find *times of overlap between boats and porpoises* in sound use.
4. Assess whether the *presence of vessels influence the presence of animals or the numbers of animals present.*
5. Identify *reactions of the animals to vessels.*
6. Establish a list of *management measures* to improve the situation.
7. Establish a list of *future research goals*.

2.2. Research question

What is the traffic situation in Ramsey sound, does it affect harbor porpoise and what management measures can improve the situation?

The following questions were answered in order to reach the stated goals:

1. Which *types of boats* visit the sound?
2. At *what time* of the day and day of the week are *most* boats present in the sound (peaks)?
3. *Where* in the sound does the highest density of boat traffic occur and when?
4. At what *speeds* do boats travel in different areas of the sound?
5. How do boats *change their speed* in close proximity to harbor porpoise?
6. How do boats *change their course* in close proximity to porpoise?
7. *Where* do most harbor porpoise occur in the sound and when?

8. Do harbor porpoise *behave differently* if boats are present/ in close proximity and how?
    8.1. travel direction
    8.2. group behavior
    8.3. surfacing pattern
    8.4. stop what they are doing

3. Theoretical overview

3.1. Porpoise biology and distribution

Harbour porpoise are the smallest and most common cetaceans in European waters. The robust odontocetes (toothed whale) are rarely more than 2 m long, males being slightly smaller than females. Their average weight ranges between 40 and 60 kg. Harbour porpoise are characterized by a small triangular fin and a round head lacking a distinctive beak. They reach an age of 8-10 years on average with maximums of 23 year having been recorded. (Perrin et al. 2008)

The small whales are endothermic and cannot store energy for extended periods of time. Therefore they need to feed frequently and try to stay close to or follow their prey (Fontaine et al. 2007). The diet of harbour porpoise is highly varied containing of several species of small schooling fish and crustaceans (Pierpoint 2008). Porpoise are presumed to be opportunistic predators choosing prey that is available or most abundant (Santos et al. 2004). In UK waters their main prey species are whiting *(Merlangius merlangus*) and sandeels (Ammodytidae) (Pierce et al. 2007).

The species frequently uses tidal high energy sites for foraging (see e.g., Evans (1997); Pierpoint (2008); Marubini *et al*. (2009)).

Porpoise use ultra sound to locate prey, orientate and to communicate producing high frequency echolocation clicks between 100 and 150 kHz(Evans & Hammond, 2003, Roussel, 2002, Lusseau, 2008, Novacek et al. 2007, Read et al. 1997 in Baradell (unpublished))

Females give birth after a gestation period of about 10- 11 months. After about 4-8 months of lactating, the calves mature between age 3 and 4 years. Females reproduce about every 1 to 2 years. Mating takes place about 1 1/2 month after the calves are born which happens at different times of the year depending on the region. (Perrin et al. 2008)

Harbour porpoise behaviour is characterized by short rapid surfacing followed by extended dives of several minutes. They can reach depths of at least 226 m. They rarely show aerial activity and active social behavior known in other small odontocetes which makes them a challenging species to study. (Otani et al, 1998, Westgate et al. 1995).

Porpoise often live in groups of 2 or 3 animals usually consisting of a female, calf and a juvenile (yearling).

However groups of 6-8 animals are not uncommon and occasionally they can be observed in even larger groups (Perrin et. al 2008). Relatively little is known about their social interactions (Westgate et al. 1995).

Harbour porpoise distribution reaches from coastal and circumpolar regions, to temperate but also subarctic shelf waters of the northern hemisphere. They are sometimes recorded in offshore waters however rarely in waters deeper than 200 meters. Their preferred water temperature ranges from 11- 14°C. (Evans et al. 2003) Several studies have made estimates of the population sizes in Welsh waters. The most wide ranging one was SCANS in 1994 and 2005. In 2005 it resulted in an estimated 15 200 porpoise in the Irish Sea. (Hammond & Macleod (2006))
They are present off the Welsh coast year round, although probably under-recorded in winter due to adverse conditions for observations.

3.2. Status of conservation

The species is and has always been exposed to human influences. Having been hunted in the Baltic and off the coast of the Faroe islands and Holland, they are now protected against killing and purposeful harming internationally. This is amongst others regulated by the Agreement for the Protection of Small Cetaceans in the Baltic and North Sea *(ASCOBANS, 1994),* the Convention for the Protection of the Marine Environment of the North-East Atlantic *(OSPAR 1992),* Article 4 of the *EU habitat and species directive* Annexes I & II (1992) and the *IUCN Red List* of Threatened Species. On a national level porpoise are a priority species of the Pembrokeshire Bio-diversity Action Plan of 1994 *(BAP)*, the UKs response to the Convention on Biological Diversity (CBD) and are protected by the Wildlife and Countryside Act (*WCA 1981* as amended), and the Countryside and Rights of Way Act (*CROW 2000).*

Their local habitat (Pembrokeshire coastal region) is protected as Pembrokeshire Coast National Park and as Pembrokeshire Marine Spatial Area of Conservation (PMSAC) under the EU habitat directives (Natura 2000 network)

Locally cetaceans are protected by statutory or voluntary best practices and codes of conduct like the Pembrokeshire Marine Code (described below).

3.3. Previous research

Several studies have been conducted to estimate harbor porpoise activities and abundance in and around Ramsey sound. (See Baradell (not published), Berg & Schrijver (2010), Pierpoint, 2008). Porpoise have been proven to be present in Ramsey Sound all year round, with on average 12 individuals observed per day in 2008 and 2009 (Baradell, unpublished).
Seasonal fluctuations have been recorded. Baradell (unpublished)and Pierpoint (2008) found that porpoise travel through the sound in relation to the tidal movement. They detected that porpoise move southwards "at the end of the flood tide and at the beginning of the ebb tide phase" and northwards "at the end of the ebb tide phase and the beginning of the flood tide phase". Baradell states that porpoise were observed largely (5-6 h) in an area at the South end of the sound during low tide and likely foraging as suggested by their behavior (rapid diving, tail slabs and leaps, associated gannets). Foraging behavior has been observed in other parts of the sound but to a much lesser extent. Pierpoint (2008) observed behaviour suggesting activities other than foraging (Slow milling and intermingling of school members), indicating that the sound is an important habitat not only for foraging but also for socializing. Disturbance of harbor porpoise by boat traffic has been recognized as a probable threat, but "no systematic studies of harbor porpoise behavior relative to personal water craft (PWC) exist" and the actual effects are still poorly understood. (Evans 1992; Evans 1994; Evans 1996; Polacheck and Thorpe 1990; Kinze, 1986 in Koschinski, 2008).

In 2010, Strong and Morris studied the effects of tourism on grey seals(*Halichoerus grypus*) on Ramsey island and found a number of boat based activities disturbing seals. They observed peak numbers of 80 commercial boat tours per day and suggest that "commercial ecotour boats cause the majority of total and severe level disturbance (on grey seals)". They found non compliance with the code of conduct in 13% of all disturbance cases. However their study focused on the Code practices requested for seal encounters.
Several studies on the effects of boat traffic on bottlenose dolphins have been conducted (Nowaceck & Wells, 2001, Allen & Read, 2000 in Koschinski, 2008; Mattson et al. 2005 in Koschinski 2008, Lemon et al., 2006). They found amongst others reactions, decreasing interanimal distance, longer dive times and increased swimming speed when approached by a boat. Ng & Leung (2003) found "disruption of behavior and social life" in humpback dolphins as a response to the approach of fast moving vessels. David (2002) noted that harbor porpoise studies by Evans (1994) reacted particularly negative to speed boats rather than yachts although they showed negative responses to all boat types.

Harbour porpoise seem to show reactions at greater distances to boats than bottelnose dolphins (*Tursiops truncatus)* (Kinze 1986;Evans et al. 1994 in Koschinski 2008) which suggests that they are more sensitive. Evans et al. (1994) showed that harbor porpoise show more evident responses to fast moving vessels than to slower ones. This is likely due to the better predictability and lower noise intensity of a slow moving vessel.

3.4. Threats through marine traffic

Being killed as by catch is considered the major threat for harbor porpoise in UK waters (Northridge & Hammond 1999 in Baradell (unpublished)). However it will be less likely for the species to deal with that problem or recover from it if additional pressure is put on the population by boat traffic. Effects of boat traffic on harbor porpoise can be divided into long- and short-term effects, ranging from subtle changes in behavior through brief interruptions to long term displacements. Long-term effects are often times associated with accumulative effects of short term effects combined with other pressures such as pollution or lack of food due to a decline of fish stocks (Wells & Scott (1997)), Allen & Read (2000) in Koschinski 2008). Disturbance by boat traffic is thought to come in two ways. One being visual (e. g. erratic movements of small boats), the other and likely more sever one is acoustically as porpoise heavily rely on sound for hunting, socializing and navigating. Anthropogenic noise can lead to temporary or permanent hearing impairment and/ or have a masking effect of biologically important signals. Masking happens if the masking noise and the porpoises signal have similar frequencies and occur very close together in time (e.g. overlap) (National Research Council (2003), Au 1993 in Koschinski 2008). In the long term such disturbance can lead to reduced reproductive rates and higher mortality. Also injury and death through collision are a hazard. Andersen (1970 in Koschinski 2008) for example assumed that young harbor porpoises might not be able to gain enough weight to survive their first winter if "heavily disturbed in the nursing areas e.g., by speedboats".

It is suspected that apart from frequency and intensity of sound, "physical features" of a boat including size and propulsion but also its behavior (speed, way of approach and distance to animals) determine the boats impact potential (Amundin & Amundin 1974; Evans 1994, Kinze 1990 in Koschinski, 2008; Roussel, 2002). According to Koschinski (2008) harbor porpoises do not respond in the same way to various types of boats and ships. They for example flee from approaching jet skis at considerable distances (Koschinski, 2008) but seem to show no reaction to familiar vessels that move at a constant speed and direction (pers. observation).

Papale et al.(2011) found that bottlenose dolphins always responded neutral to sailing boats while fast boats caused interruption of activities and negative responses. Also the number of boats around an animal is "an important factor" determining the disturbing potential (David, 2002).

3.5. Pembrokeshire Marine Code

The Pembrokeshire Marine Code (PMC) is a voluntary code of conduct for best practice in wildlife watching in the Pembrokeshire coastal region. It was developed by the Marine Code Group, a voluntary association of key stakeholders formed in 2003. It is coordinated by a project officer and members are wildlife tour boat operators, sea kayakers and jet skiers, as well as conservationists.

The code includes rules and best practices for several marine sites and for each, seals, sea birds and cetaceans, one of which is Ramsey sound/ island. Porpoise sensitive areas and extremely sensitive areas have been identified in Ramsey sound (Fig. 1). Times of high likeliness to encounter cetaceans (1hr before and after slack water) are pointed out.

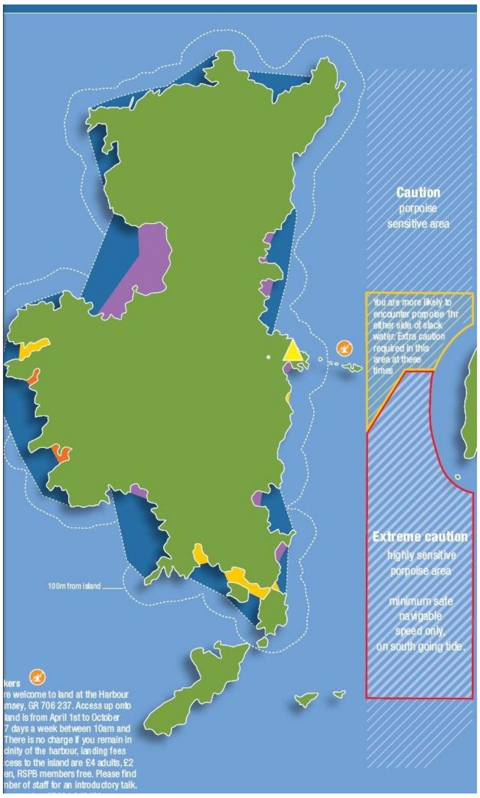


Fig 1: Agreed access restrictions in Ramsey sound (Pembrokeshire Marine Code)

The code recommends to slow down to less than 5 knots when encountering cetaceans as well as avoiding erratic movements. Animals with calves are asked to be left alone and groups should not be split by vessels. (Box 1)

Box 1: Requirements of the Pembrokeshire marine code:

1. On sighting cetaceans fast vessels should slow down to a speed less than 5 knots and continue on a steady course presenting predictable movements. Avoid erratic movements or speed changes.

2. Allow groups of cetaceans to remain together and avoid deliberately driving through them.

3. Leave cetaceans with young alone and avoid coming between a mother and calf.

4. Always allow cetaceans an escape route and avoid boxing them in, do not chase cetaceans.

5. Leave if you notice any signs of disturbance; such as erratic changes in speed and direction, or lengthy periods underwater. (Pembrokeshire Marine Code, Outdoor Charter Group)

No legal enforcement measures are in place. However a self policing system has been adopted where operators and conservationists as well as visitors can report violations of the code to the marine code officer or the police marine unit.

Code group meetings were terminated after discussions about code violations in Ramsey sound became the overruling topic. Now emphasis is on providing information to the general public about the code. (MCG, 2012)

4. Research methods

Prior to data collection in the field a comprehensive literature review was carried out in order to bring the study in context with current knowledge and existing studies.

4.1. The research area

The study was conducted in Ramsey sound in Pembrokeshire, Wales (UK) (Fig. 2, Appendix III)). It is a narrow channel of 1 km width between the mainland of Pembrokeshire (St Davis, St Justinians) and Ramsey island (position: 51°52'16"N 5°19'21"W).

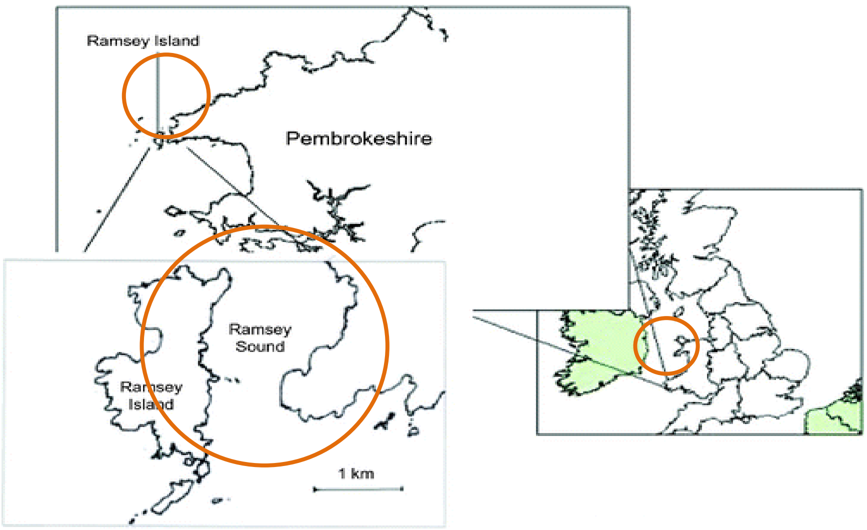


Fig 2 Ramsey sound, West Wales, UK (Strong & Morris, 2010)

Ramsey sound is a tidal high energy site. Tidal currents vary between 3 knots (neap tide) and 6-8 knots (spring tide) (United Kingdom Hydrographic Office in Baradell (unpublished)). The area was chosen for the study because it is an important habitat for harbor porpoise.

The tidal currents of up to 8 knots make it an ideal feeding ground for them as they utilize such high energy areas to forage (Pierpoint, 2008). It is a popular recreational site and is frequently visited by different kinds of vessels including sailing boats, kayaks and rigid inflatable boats (RIBs) for wildlife watching. The summer months are particularly busy.

Being on average 1 km wide the entire sound can be overlooked by a land based person. Distinctive landmarks allow reliable distance estimations without complex measuring techniques.

The vantage point (Fig. 3) used was **Penmaenmelyn (PMM)** which overlooks the waters between the mainland and Ramsey Island, North and South of the Bitches reef, the Ramsey Island landing point and Porth St Justinian (App.III). It is located on the mainland on a small "peninsula" called Pen dal-Aderyn headland. It has been successfully used as vantage point for porpoise observations before (Baradell, 2009, Pierpoint 2008).

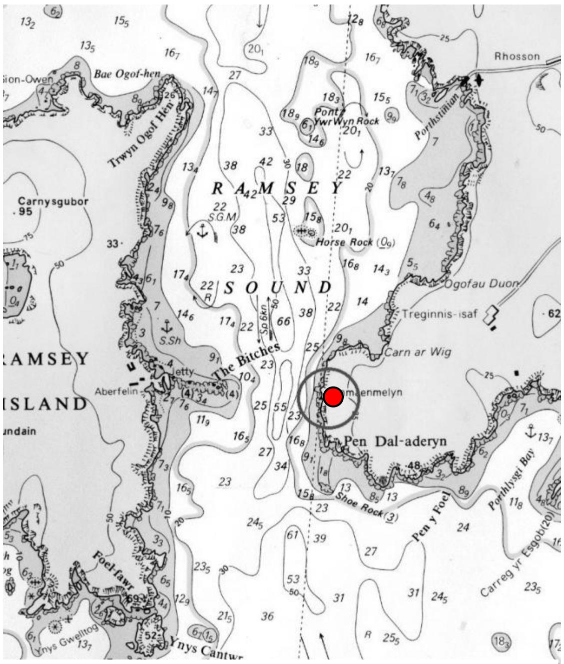


Fig. 3: Vantage point Penmaenmelyn (PMM) (UK hydrographic Office)

4.2. Data collection & collection effort

A shore based survey was conducted using scan sampling. Fieldwork was carried out between April 7th and June 9th 2012.

The shore based observation method was chosen in order to avoid disturbing or influencing the activities in the sound. In addition it is relatively cheap and observations can be started and ended at any time of the day. The elevated cliffs (between 20 and 40 m) of the Pembrokeshire coastline provide ideal conditions for land based observations.

The 12 hour tidal period was divided into four **observational periods** (table 1) (referring to Gregory & Rowden, 2001). This division allows to display porpoise movement patterns throughout the tidal cycle. Depending on the available daylight hours and weather conditions 1-2 of the observation periods were covered per day. The time of the day when observation started varied due to variations of the tidal cycle and weather conditions. All tidal references are based on the tidal predictions for Milford haven as published by Proudman Oceanographic Laboratory.

I High water to slack water 0-3 h after HW	II Slack water to low water 4-6 h after HW	III Low water to slack water 5-9h after HW	IV Slack water to high water 10-12 after HW

Table 1: The 4 observational periods of the (12h) tidal cycle used to categorize the scan sessions.

Based on personal commends by M. Baradell, Baradell (unpublished) and Pierpoint (2008), porpoise were most likely to be present in the sound around 3 and 9 hours after high tide to forage. Observation efforts were focused on these times in order to collect sufficient data on porpoise-vessel interactions. However some time was spent observing throughout all hours of the tidal cycle in order to reassure those statements.

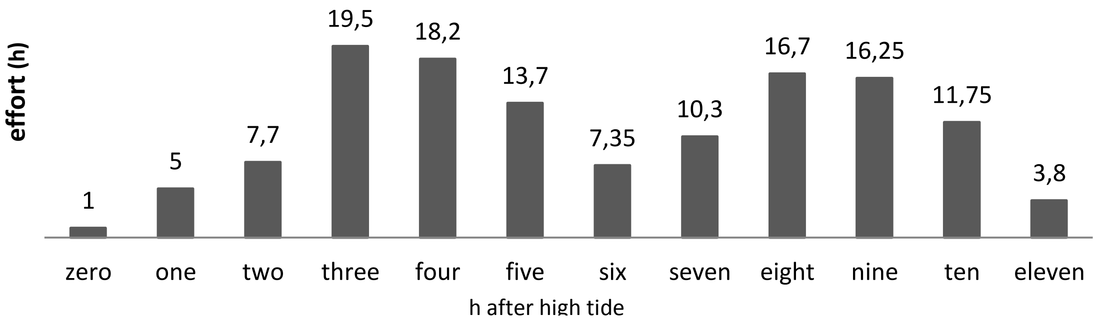


Fig 4 Observation effort/ h after high tide during the field period 7.4.-9.6.2012 (n=139 h)

In total 139 hours of observation were carried out spread over 41 days. Observation efforts were distributed equally between phases of high and low water: 54% of observation conducted in the first six hours after high-water, and 46% during seven to twelve (zero) hours after high-water (Fig. 4).

In order to systematically collect data on boat and animal movements, point or instantaneous samples were collected. Within each scan, location or behavior of an object of interest at that particular moment are noted and then the scan continues. The entire research area was scanned with the naked eye and binoculars (Nikon Action EX, 8x40 8,2°) at regular intervals of 5 minutes. 10 scans were conducted per hour and 10 minutes were free for taking notes or resting. Scans started at the southern end of the sound moving north. That way, the entire study area was observed with each 5 min scan.

Data was recorded using a dictaphone (Olympus digital voice recorder VN-700) and by taking notes in a field log by a second observer who was present during the second half of the fieldwork period (02.05.- 08.06.). A hand-held compass (Plastimo Iris 50) was used to measure bearings to landmarks in 10 degree steps. These estimations were used to determine the position of the observed object. Distance was estimated by eye, taking known distances like the width of the sound as a reference.

The distances between landmarks were measured with Google Distance Measurement Tool. Estimated distances were compared between two independent observers and similar results were acquired.

At the beginning of each scan session, *time and date, state of the tide, state of the sea (Bft) and visibility* were recorded (and adapted if changing). All boats were recorded once they entered the sound (North or South) or crossed the sound (West-East (Ramsey island - Mainland) or East- West)). That way the number of vessels crossing the sound (traffic density) were determined. Also vessels visiting or crossing the harbor porpoise sensitive area (PSA) where porpoise spend up to 12 h per day foraging (Pembrokeshire Marine Code) were noted. In addition information on *vessel type, being motorized or non motorized and travel speed* were recorded.

Vessel speed was defined with categories adopted from Gorzelany (2004) as originally adapted from the Florida Administrative Code 62N-22 namely *idling speed (IS), slow speed (SS), plowing speed (PS), and planing speed (PLS)* (Appendix II)(Table 2). All speeds are presented in knots (1kn= 1,85 km/h).

Idling speed (IS)	1 -3 kn/ 1.8 - 5,5 km/h
Slow speed (SS)	5-7 kn/ 9,2 - 13 km/h
Plowing speed (PS)	10-15 kn/ 18 - 27 km/h
Planing speed (PLS)	>15 kn/ 27 km/h

Table 2: Speed categories as adopted from Gorzelany (2004)

On an opportunistic basis time measurements were conducted for vessels travelling from one distinctive landmark to another using a stopwatch.

Vessel types were identified by both design and function and were designated as: *wildlife watching vessel, fishing vessel, sailing vessel, ferry, kayak or other.*

All porpoise sightings were recorded including *time, bearing, distance* of sighting and the *presence of vessels nearby (<200 m).* The distance of 200 m was chosen in accordance with previous studies who reported that small odontocetes including harbor porpoises react to fast-moving motor boats at a distance between 150–300 m (Kinze, 1986 & Evans et al., 1994) in Koschinski, 2008, Liret, 2001). Effort was made to furthermore record the *group size (1; >1).***,** the *presence of calves, travel direction (N, E, S, W) and activity (foraging, travelling)*. Foraging was noted when repeated and often rapid surfacing in one spot with differing orientations was observed, sometimes associated with leaps and tail slabs (Baradell, unpublished). Mostly circling and diving gannets were associated. Travelling was noted if porpoise surfaced repetitively in one direction. The porpoise were tracked for at least 2 surfacing events if possible in order to determine travel direction and number of individuals

General observations were recorded including everything noticed by the observer that might be of significance for the study.

The number of porpoise sightings only reflects the activity of porpoise in the sound because it was not possible to identify individuals. Every sighting of an animal per scan was recorded regardless whether the individual had been recorded before.

The length of scan sessions usually did not exceed 4h in order to avoid misidentification and missed animals due to fatigue. Scan session refers to the total duration of scans made during one day.

Because harbor porpoise are small, relatively inconspicuous and often solitary and are more likely to be observed in calm conditions (Evans & Hammond, 2003), observations were terminated if visibility was < 1 km due to rain or fog or state was above 3 Bft in other words as soon as white caps appeared on waves or visibility deteriorated. These limits are based on boundaries set in several recent studies (Baradell, 2009; Papale, 2011; Culik et al., 2001, Goodwin & Speedi, 2008). Days for observation were chosen based on the weather/ wind conditions. Because Ramsey island somewhat protects the sound from swell and weather influences, observations were possible in wind conditions of more than 3 Bft. The seastate was the decisive factor. However due to strong tidal currents, seastate in the sound was not homogeneous. Parts could be mirror like while others were at seastate 5. It was up to the judgment of the observer in these conditions to decide whether observations were possible.

4.3. Control

Times when boat traffic was absent, for example in unfavorable weather conditions or times of the day when no nature tours were taking place were used as control times for porpoise behavior with no vessels present. Times when no harbor porpoise were present, which is around high tide and three hours after were used as control periods for boat traffic with no porpoise presence.

4.4. Data analysis

Vessel numbers, types, speed and travel direction were analyzed by dividing the database into the required variables and comparing them using Microsoft Office Excel. Results were displayed in maps and diagrams.

Because observation effort was not divided equally across the entire tidal cycle but was focused on times of (expected) higher porpoise density the numbers of porpoise sightings per scan session were divided by observation effort in order to obtain the true results.

Speed measurements were diverted into knots. The distance between the two points (leaving and arriving) were measured using Google distance measuring tool. Then the simple formula s=d/t was used to calculate the speed, where s= speed, d= distance, t= time.

In order to analyze porpoise movements throughout the tidal cycle (which influences their position within the sound (Baradell unpublished, Pierpoint 2009)) data was divided into four tidal stages according to the 4 observational periods. Porpoise positions and travel directions throughout the tidal cycle were organized in an Excel sheet and visualized in position+ density tables.
Maps displaying vessel and porpoise density and movement patterns were compared in order to find times and places of overlap in the sound.
Vessel speed and behavior when encountering porpoise was compared to best practice requested in the PMC.
Numbers of porpoise sightings and vessels recorded per scan session were compared.
Out of all factors that influence porpoise presence and behavior, the only known variable is tidal state in this study. Therefore porpoise and vessel sightings during the peak periods (3-5 h after high tide and 8-10 h after high tide) were analyzed separately in order to show how the number of porpoise sightings fluctuated in accordance with vessels present.

5. Results

5.1. Vessel movement patterns, types, speed

The total number of vessels that were observed throughout the field period was 502. Most vessels in the sound (57%/ 288)) were observed between 11.00 am and 2.00 pm (fig. 5). with most recordings between 12.00 am and 1.00 pm. Not much traffic was registered in the mornings between 8.00 and 10.00 am and in the afternoon and evenings after 4.00 pm.

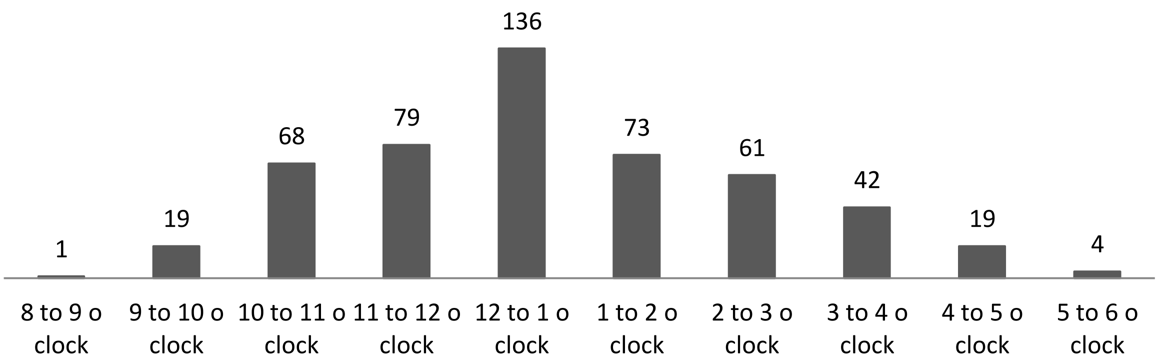


Fig 5: Numbers of vessels observed depending on the time of the day (includes all days of fieldwork), n= 502.

Out of all vessels recorded, 95% were motorized and 5 % were non motorized vessels. More than half of the boats observed (Fig. 6) were wildlife watching vessels(58%). 7 wildlife watching boats are operated by 4 companies.

6 vessels are rigid inflatable boats (RIBs) with 2 having jet propulsion and the others using outboard propeller engines. 1 vessel is a solid hull vessel which is also used as ferry. The ferry trips to and from Ramsey island accounted for 13% of all vessel activity. Fishing vessels accounted for 10%. However it needs to be said that only 1 vessel actively fishes in Ramsey sound. It sets lobster traps which are checked usually once a day. Other fishing vessels cross the sound from N-S or vice versa.

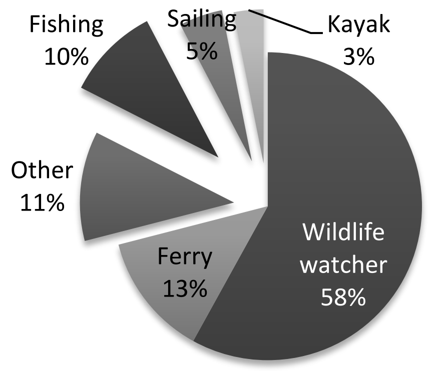


Fig 6: Proportion of vessel types observed in Ramsey sound (n=502)

Most sailing boats travelled with a running engine and were therefore noted as motorized vessels. They make up 5% of all traffic in Ramsey sound. 3% of the observed vessels were kayaks many of which cross the sound to use the rapids of the Bitches reef for whitewater kayaking. "Other" vessels were coast guard vessels, research vessels that did transects and small zodiacs that were used for SCUBA diving, leisure fishing or individuals going to and coming from Ramsey island.

The following map (Fig. 7) shows movement patterns of vessels in the sound. An average of 12. 2 vessels were observed per scan session. The highest number of vessels encountered in one day was 33, on some days however none or only one vessel were observed. 73 % of all vessel sighted crossed the sound from E-W or W-E. Most of these are either wildlife watchers or the ferry to Ramsey island (Fig. 8). These are also the vessels moving the fastest (Fig. 10). 11% pass through the sound from N-S or S-N and 16% of all vessels observed go to the area in which porpoise preferably forage or pass through it (PSA).

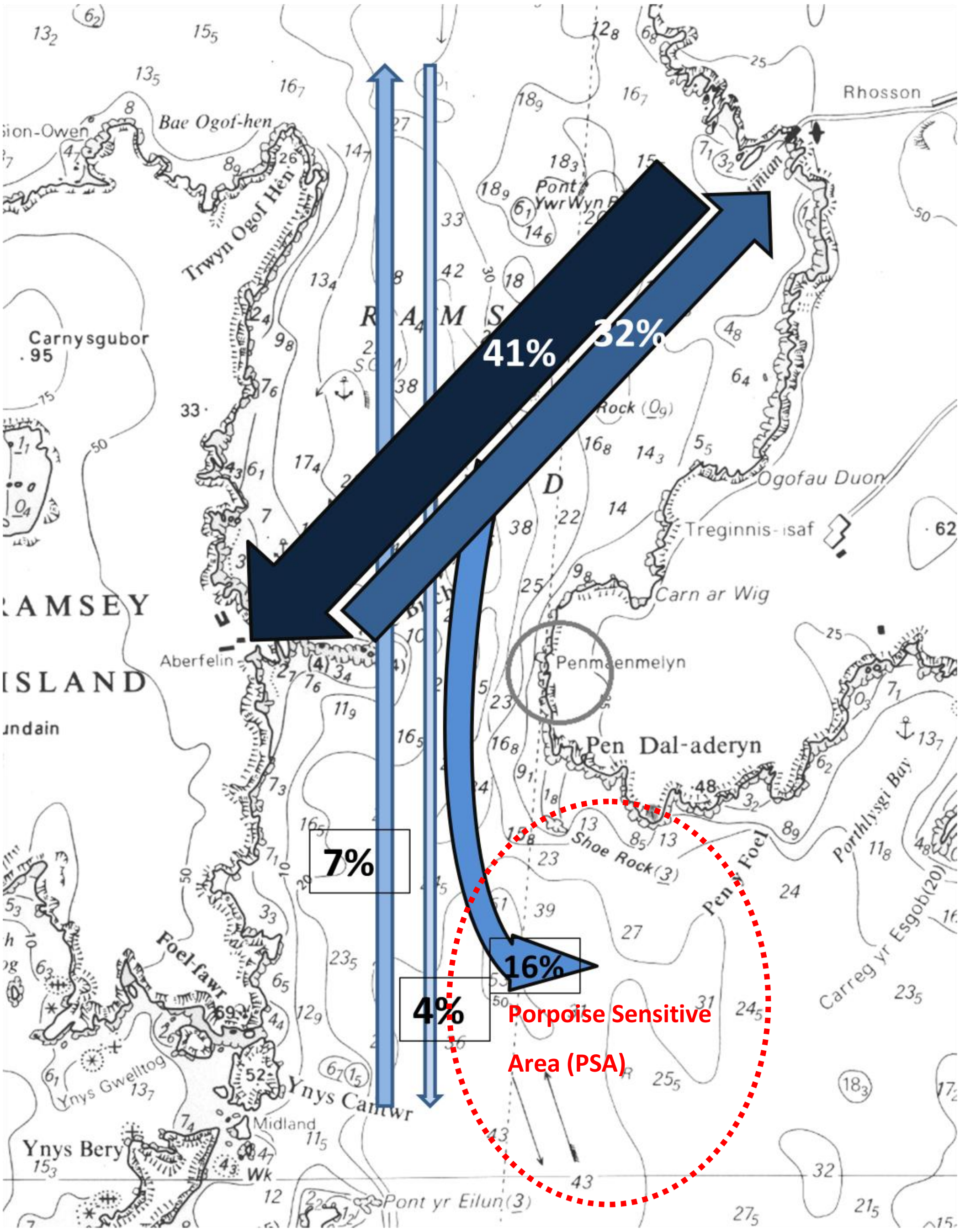


Figure 7 Travel directions and density of vessels in Ramsey sound (n= 502)

Fig. 8 displays the types of vessels that were recorded in each particular travel direction. Travelling west- east and east west were mainly wildlife watching vessels and the ferry. They rarely travelled through the length of the sound (S-N, N-S). A large number of wildlife watchers was also recorded in the PSA.

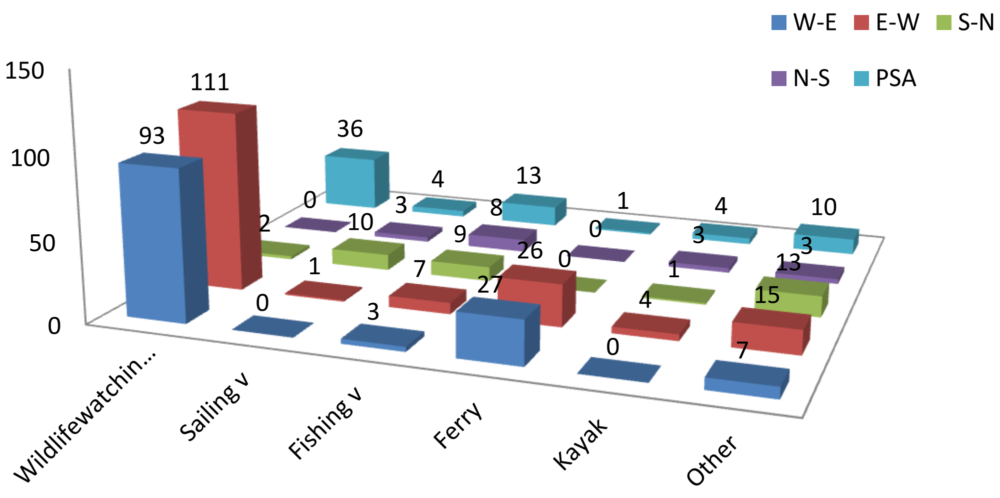


Fig 8: Vessel types and their prevailing travel direction within the sound (West-East, East-West, South-North, North-South and to the Porpoise sensitive area (PSA).

In total, over half (58%) of the observed vessels travelled through the sound at planing speed (Fig. 9). Only 1% were observed at idling speed. 32% moved at plowing speed and 9% at slow speed. For 35 crossings of the sound the speed was measured. The slowest speed measured was 11 knots and top speed was 42 kn. Average speed for crossing the sound was 21 kn. However it should be noted that this only includes wildlife watching vessels and the ferry.

41% of the vessels measured crossing Ramsey sound W-E or E-W travelled at 15- 20 knots. 15% travelled at each 10-15 or 25- 30 kn. However 12% travel at fast speeds of 30 kn and more.

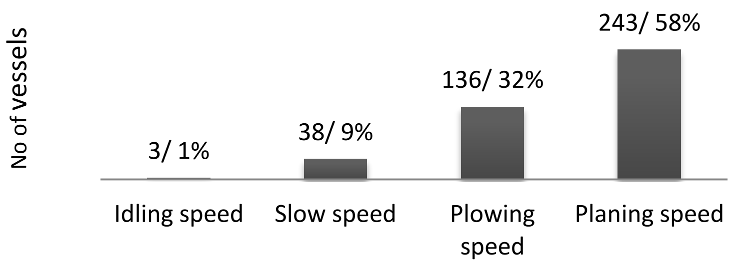


Fig 9: Vessel speed observed in Ramsey sound (includes data from the entire field period, n= 502))

The chart below (Fig 10) shows how many vessels of a particular type travelled how fast. Wildlife watchers travelled at high speed most often with 166 out of 243 (68%) observed wildlife watching vessels travelling at planing speed. 23% of all wildlife watchers travelled at plowing speed and 9 % at slow or idling speed. Sailing vessels usually navigated through the sound at slow speed (84%).

89% of all fishing vessels moved at plowing speed. However, they account for only 10 % of all traffic observed in Ramsey sound. Both ferry and "other" vessels were observed 21 times to travel at planing speed which is 42% and 35% respectively. Both also travelled at plowing speed frequently (42% ferry and 35% other). All kayaks travelled at slow speed.

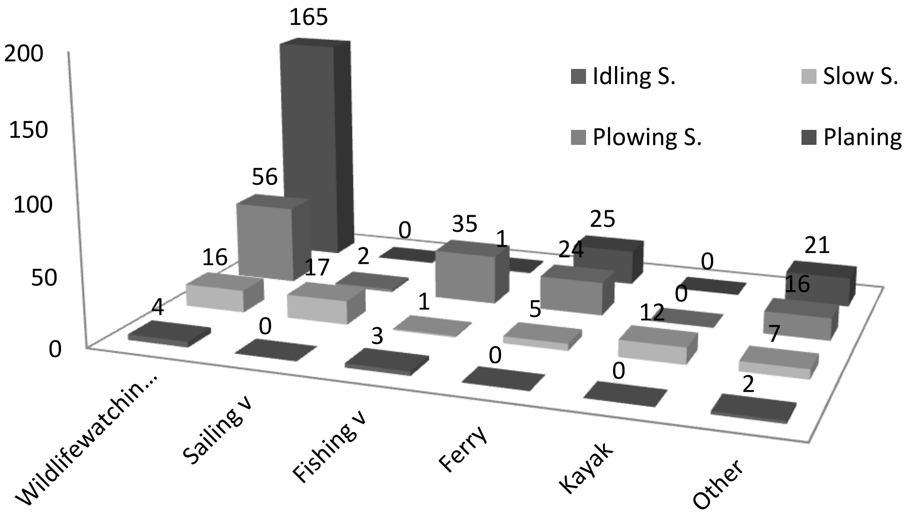
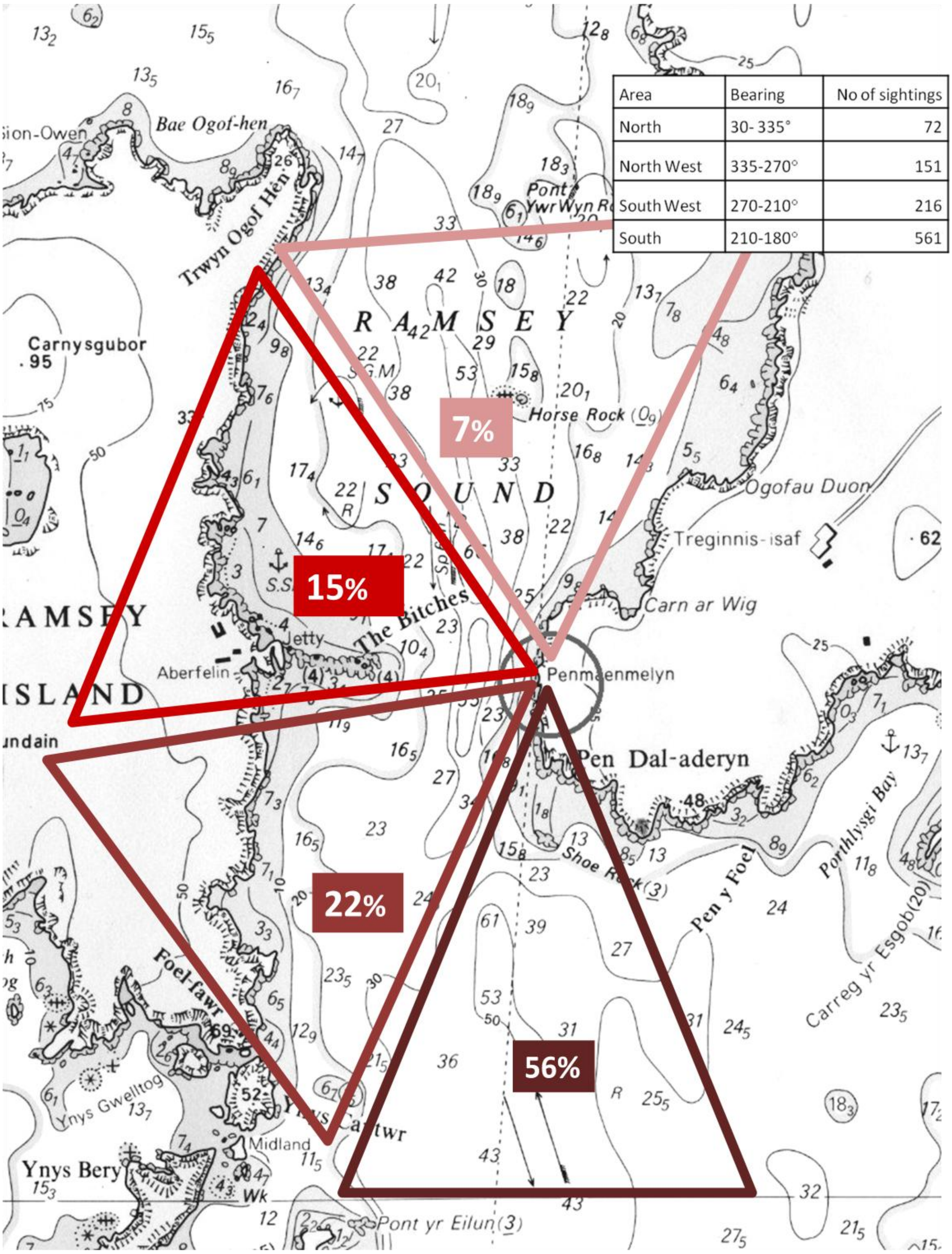


Fig 10: Vessel speed per vessel type (n=502)

5.2. Porpoise movement pattern & behavior

In total, 1021 sightings of porpoise were recorded.. 56 % of porpoise sightings were recorded in the southern sector of Ramsey sound (Fig. 11). Another 22% of the observations were made in the south west. 15 % of sighting were made north of the Bitches reef and only 7 % of porpoise were observed in the north eastern part of the sound.



Area	Bearing	No of sightings
North	30- 335°	72
North West	335-270°	151
South West	270-210°	216
South	210-180°	561

Fig 11 Distribution of all porpoise sightings throughout Ramsey sound (n= 1021)

2 peaks of numbers of porpoise sightings became apparant (Fig. 12). One between three and five hours after high tide and one between eight and ten hours after high tide. Hardly any porpoise were observed around high tide (11 h after until 3 h after high tide). Highest numbers of porpoise were observed at 5 h after high tide (176 sightings) and ten h after high tide (230 sightings).

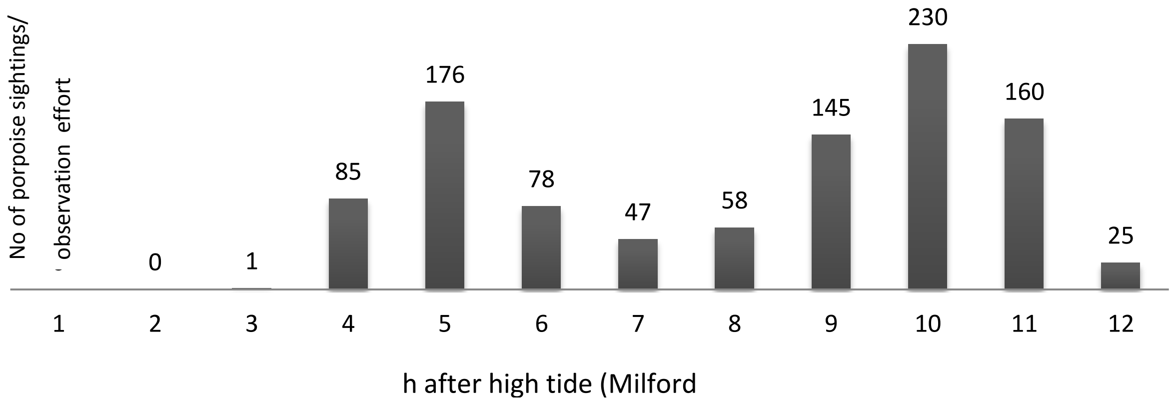


Fig 12:No of porpoise sightings depending on time after high tide (includes data from the entire field period) n: 1021

Porpoise were observed travelling through the sound south- north about 2-4 after high tide, foraged in an area at the southern outlet of the sound and then travelled north between 7 and 10 h after high tide. These results agree with previous studies (Baradell (unpublished), Pierpoint, 2008). Porpoise sightings were grouped into 4 tidal periods as mentioned before. These are: 0-3 hours after high tide, 4-6 hours after high tide, 7-9 hours after high tide and 10-12 hours after high tide. The 4 tables in Appendix IV show number and location of porpoise sightings including the prevailing surfacing direction of the animals for each of these periods.

Porpoise travelled individually or in small groups of 2-3 animals. A few times larger groups of up to 8 individuals were observed. 33% of all (1021) porpoise sightings were individual animals and 67% were groups of more than one animal.
When travelling, porpoise usually surfaced 2-4 times and then dove for a few minutes. Individuals travelling as a group adopted a collective surfacing pattern. Especially juveniles stayed close to their mothers and usually surfaced slightly after her.

When in the (assumed) foraging area multiple porpoise surfaced in one spot repeatedly with varying orientation. Most of the time multiple individuals could be observed in the area. Foraging activity usually lasted for multiple hours (3-10 hours after ht, table 3&4).

24 times a full passage, starting with appearing of the first animal and ending with disappearing of the last animal presumably crossing the sound on that particular day, could be observed with north-south= 15 times and south - north=9 times.

On average the passage north- south took 100 minutes with the longest being 180 minutes and the shortest being 52 min. The passage south- north took on average 102 min with the longest being 132 and the shortest being 60 min. Porpoise opportunistically were observed to spend more time in the sound socializing and foraging when travelling north. However the research design and the inconspicuous nature of harbor porpoise did not allow data collection on individual animals in order to prove that as a fact.

5.3. Vessel- porpoise interactions and vessel behavior in proximity to porpoises

Out of 1021 porpoise sightings, 69 times a vessel was less than ≈200 m away from the animals. That is 7% of all porpoise observations. Fig. 14 shows where these encounters took place throughout the sound. 62% were observed in the southern part of the sound which is the PSA. 32% were recorded in the northwest and southwest and only 6% in the northern part of the sound.

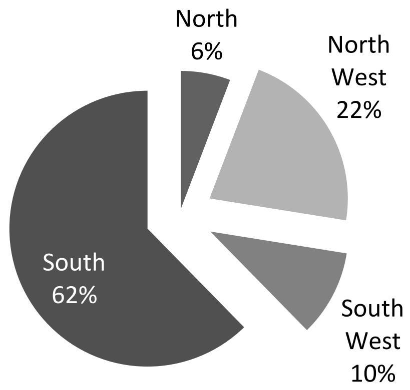


Figure 14: Vessel- porpoise interactions within the areas of Ramsey sound (includes 69 (7%) out of a total of 1021 porpoise sightings)

64% of the vessels observed in close proximity to porpoise (Fig 15) were wildlife watching vessels. 8% were each sailing and fishing vessels. In 10% of the cases it was the ferry that came close to the cetaceans and in each 5% it were either kayaks or other vessels.

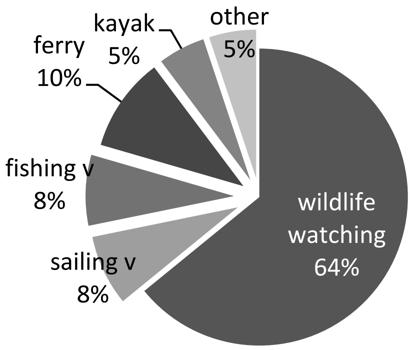


Figure 15: Types of vessels recorded close (<≈200m) to harbor porpoise.

The figure below (Figure 16) gives an overview over porpoise sightings and numbers of vessels recorded per scan session/ day. It shows that on some days high numbers of porpoise sightings coincided with low numbers of vessel but on other days with high numbers of vessels were recorded. No statistic correlation was found between the two factors (Pearson Regression analysis= 0.334).

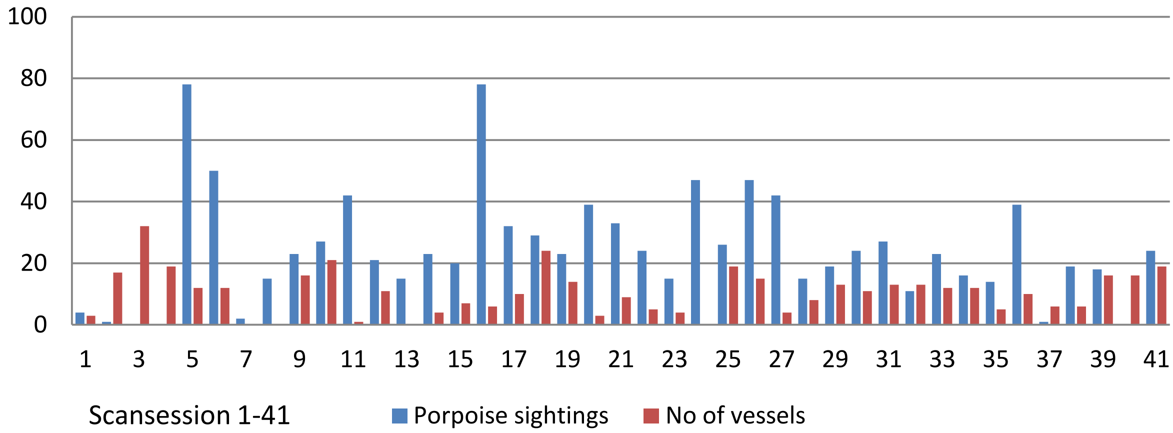


Figure 16 Vessel numbers and porpoise sightings recorded per scan session

Figure 17 displays the correlation between the number of vessels and the number of porpoise sightings that were recorded in Ramsey sound. A total of N= 41 scan sessions was entered. Minimum number of observations for both vessels and porpoise was 0. Maximum for porpoise was 78 sightings and 32 sightings within one session.

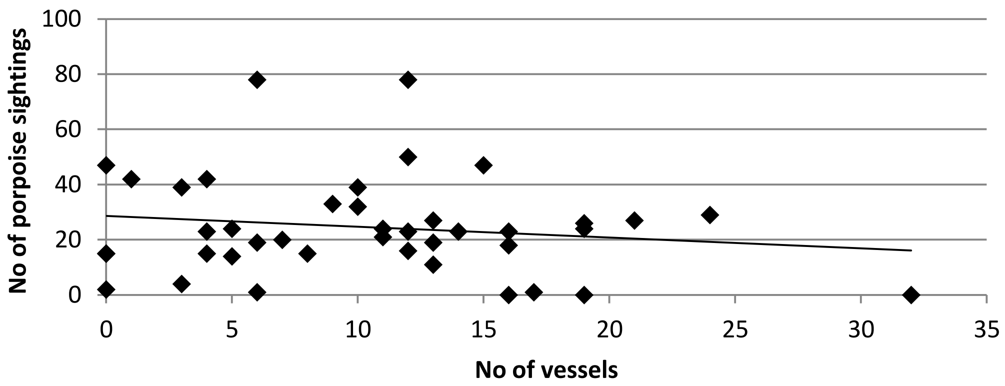


Figure 17: Correlation between the number of vessels and porpoises sightings recorded in the sound.

Figures 18 & 19 show porpoise abundance in relation to vessel numbers during the two peak periods (3-5 h after ht & 8-10 h after high tide). The earlier peak (3-6 h after high tide) shows lower average numbers of porpoise sightings(16.1) and higher numbers of vessels (9.7). The later period (8-10 h after ht) displays higher numbers of porpoise activity (28) and lower average numbers of vessel (7.9) present.

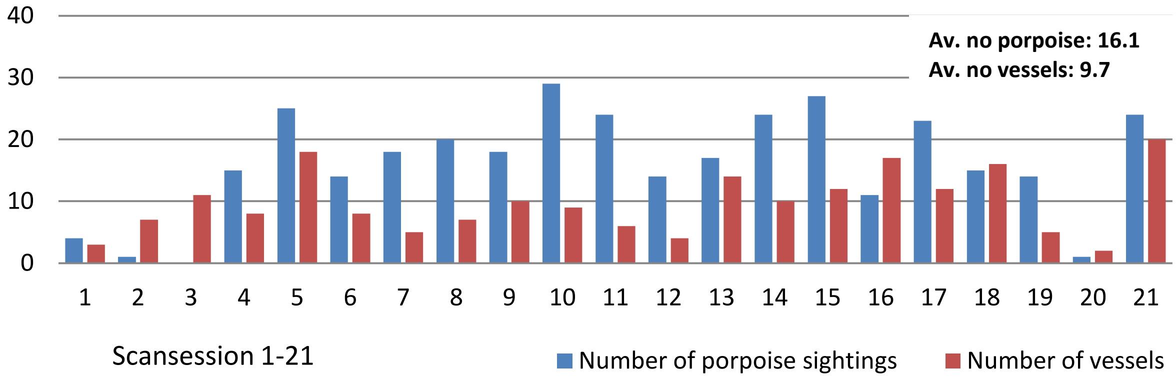


Figure 18: No of vessels and porpoise sightings between 3-5 h after ht.

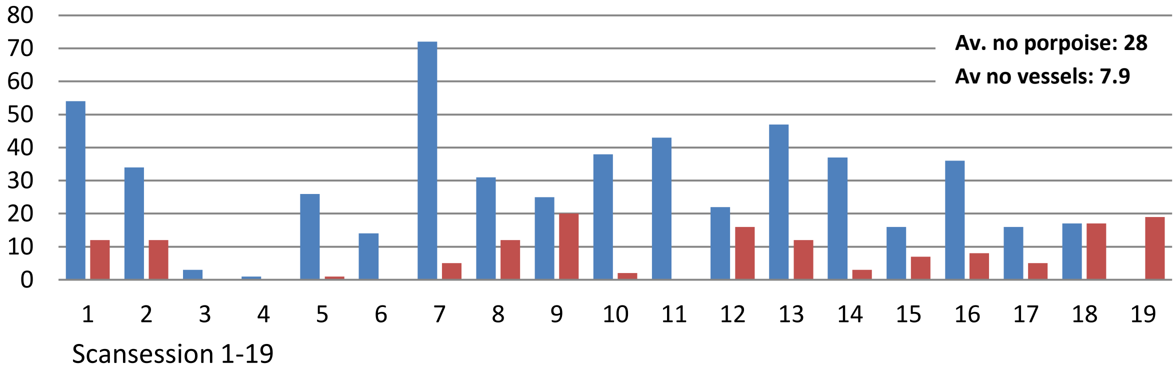


Figure 19: No of vessels and porpoise sightings 8- 10 h after high tide

Figure 20 displays the correlation between the number of vessels recorded and porpoise activity 3-5 h after high tide. A total of 21 scan sessions was analyzed. The minimum number of porpoise sightings was zero and of vessels two. Maximum was 29 respectively 20. A Pearsson Regression analysis test brought up a significance of 0.080.

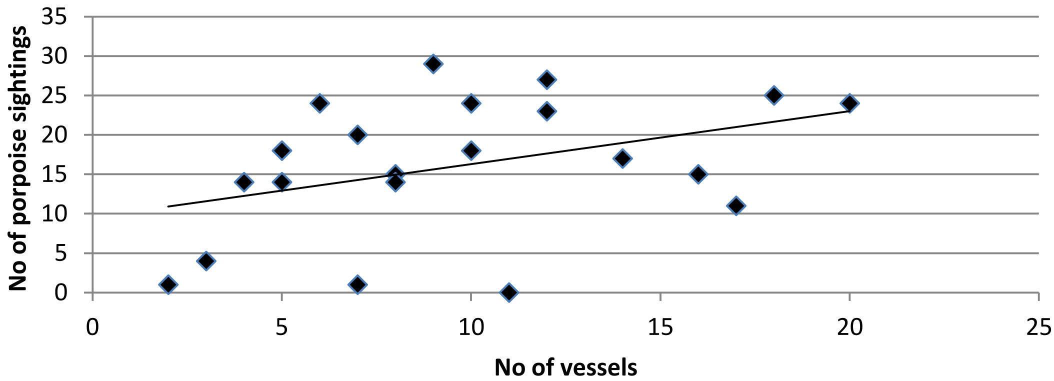


Figure 20: Correlation between vessel presence and porpoise activity 3-5 h after high tide

Figure 21 displays the correlation between the number of vessels recorded and porpoise activity 8-10 h after high tide A total of 19 scan sessions was analyzed. The minimum number of porpoise sightings and of vessels recorded was zero. Maximum was 72 respectively 20. A Pearsson Regression analysis brought up a significance of .941.

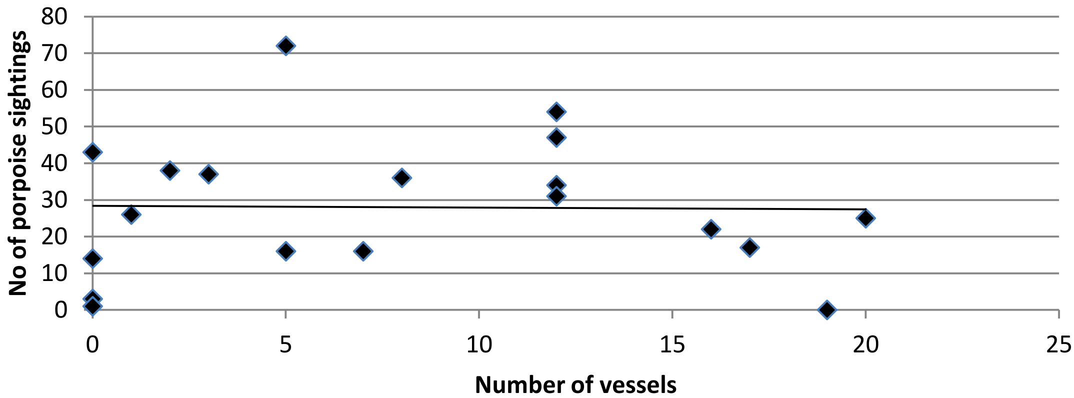


Figure 21: Correlation between vessel presence and porpoise activity 8-10h after high tide

The porpoise sensitive area is frequently crossed by vessels (Fig. 22). In total 77 cases were observed. 54% of those vessels are wildlife watchers that spend some time (on average 6.8 min) and 19% are fishing vessels that mostly just pass through the area. The ferry never approached the area. It has been observed that wildlife watchers only approach the porpoise sensitive area during times when porpoise are foraging with peaks at 4 and 8 h after high tide.

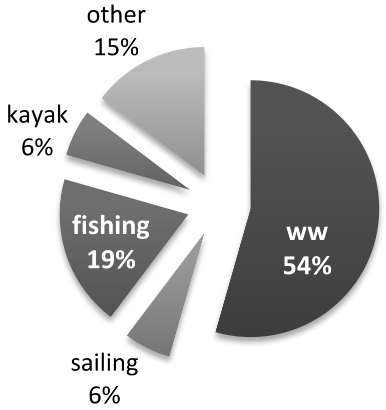


Figure 22: Vessel types traveling to or through the porpoise sensitive area (n=77)

The speed mostly being observed in the porpoise sensitive area was plowing speed (39%) (Fig. 23). 44% however travelled at slow or idling speed and 17% were observed traveling at planing speed. Most wildlife vessels approached the porpoise sensitive area at plowing or slow speed and then drifted at idling speed. However if porpoise were spotted in a different area of the porpoise sensitive area, vessels travelled there usually at slow speed. When leaving they moved away at slow speed gradually speeding up to planing speed.

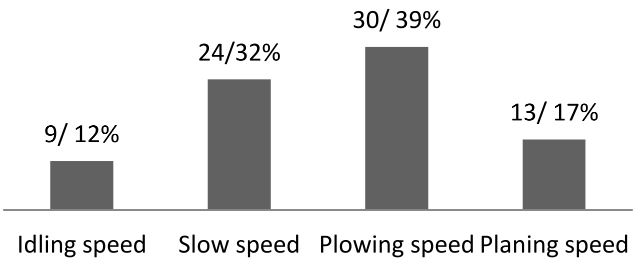


Fig 23: Vessel speed observed in the porpoise sensitive area (PSA) (n=77)

At no time, more than 1 vessel was observed in the porpoise sensitive area at the same time. Boats were frequently observed crossing the sound (including porpoise sensitive area) at high and very high speeds.

No direct response of foraging porpoise to vessels has been observed. They continued their activity with vessels in close proximity.

On several occasions porpoise were observed travelling through the sound showing a regular surfacing pattern until a vessel crossed their path and they dived for a number of minutes or disappeared

6. Discussion

Harbor porpoise, vessel traffic and their interactions in Ramsey sound were observed in order to reveal the need for management measures to provide better protection for the animals.

6.1. Vessel activity and code compliance

Only 15% of all vessels observed travelled at slow or idling speed. This percentage seems low in an area of conservation where 5 knots (IS/ SS) are the requested speed for cetacean encounters. However the high speeds could be necessary in the strong tidal currents which make it hard and even dangerous for most non motorized vessels to maneuver in the sound. This could explain why 95% of all recorded vessels were motorized. However high speeds were observed throughout all tidal stages whereas strong currents only exist temporarily. One might ask whether vessels need to travel through the sound at all tidal states but most tour operators sell whitewater adventures and rides through rapids as part of their tours.

Vessels were frequently observed to approach porpoise or areas where porpoise had been observed surfacing.

In some cases the vessels slowed down, however all of them were wildlife watching vessels with customers on board. Therefore it is hard to say whether slowing down was an act of code compliance or of customer satisfaction. The vast majority of vessels observed did not change their speed or travel direction when encountering porpoise. After all it should be noted that the vantage point gave a much better overview and skippers possibly were not aware of the presence of the porpoise. However the fact that 90% of all recorded vessels travelled at planing or plowing speed raises the question whether porpoise can be detected at that speed in order to reduce speed if necessary.

No vessels were observed to split groups of porpoise or mother-calf pairs. However multiple observations of vessels travelling or drifting through the PSA were made. There is potential that groups of porpoise that were socializing or hunting in collaboration were driven apart or disturbed in their activity. Yet not much is known about collaborative foraging in harbor porpoise (Pierpoint, 2008).

Overall, the vessels behavior in the PSA can be regarded as sound. However potentially only wildlife watching vessels were aware of the fact that porpoise were present in that area because the PMC is not widely promoted and enforcing powers are absent in Ramsey.

After all, one could argue that the area as it is known to be a key habitat and an important feeding ground for harbor porpoise should be closed to boating activities in the first place. Several vessels were observed traveling through spots where porpoise had been surfacing seconds before in the PSA as well as other areas of the sound, thereby disregarding codepoint 2 and 3*:*

" 2. Allow groups of cetaceans to remain together and avoid deliberately driving through them.

3. Leave cetaceans with young alone and avoid coming between a mother and calf." (PMC)

In addition wildlife watching vessels were observed to perform erratic changes of their travel direction (codepoint 1). At a few occasions vessels were observed to follow porpoises at slow speed. These events however could not be classified as "chasing" (codepoint 4). Fishing vessels usually just travelled through the area, possibly unaware of porpoise presence. They mostly travelled at plowing speed on a steady course.

At one occasion a group of 3 porpoise were "boxed" in the centre of the sound by three vessels. They moved closer together and escaped by diving. For the rest of the field period , there was never more than 1 vessel close to porpoise and escape routes were open (codepoint 4). This could be different in peak season (July-August) when more nature tours take place due to summer vacation and more favorable weather conditions.

No compliance with code point 6 (higher porpoise abundance 1 h +- slack water) was found. The speed at which vessels travelled did not correlate with the tidal state. Vessels and especially wildlife watching vessels were observed travelling through the sound at planing speed throughout all tidal stages.

As the bulk of traffic was observed between 11.00 -14.00 h of the day (57%) one might argue that the rest of the day is relatively quiet, giving porpoise room and protection. Additionally, on many days these few h did not overlap with a time of porpoise passage. At the same time, boats were observed between 9.00 and 17.00 as well only in lower numbers. Altogether that are 8 h of traffic per day in the sound that potentially causes disturbance. Additionally, during peak season, the number of boat tours sometimes increase to up to 80 tours/ day (Strong & Morris 2010). Within this season in late spring and early summer which is calving and nursing season in Pembrokeshire the animals are particularly vulnerable because their calves decrease their ability to dive for extended periods of time or escape through strong currents.

6.2. Porpoise behavior

Porpoise have been found foraging in Ramsey sound on a daily basis. Observation of two female porpoise with newborn calves suggests that the area is also important for nursing offspring, thus not only as feeding ground.

The results of this study agree with results found in previous studies (e.g. Pierpoint, 2008), Baradell (unpublished)) finding that the animals follow the tidal cycle in their daily migration through the sound and predominantly use an area in the southern region of the sound for foraging. This shows that this behavior has not changed since 1992-1994 when Pierpoint collected data for his study. Possibly vessel activity has not had a significant enough impact to cause abandonment of the area or the area is of such importance for the animals that they cope with existing disturbance. Nonetheless it should be kept in mind that "the potential effects of nature based tourism on cetaceans are rarely as evident as the mortalities brought about by such activities as whaling and fisheries by-catch" (Bejder & Samuel in Gales et al. 2003).

The findings disagree with Baradell (unpublished) who stated that "the North to South movement was recorded as being made over a longer time period, with an indication of more foraging activity". Within this study the South to North movement was observed to be more extensive one with the maximum duration being 180 min whereas maximum duration for the North- South passage was 130 min. Porpoise showed behavior that suggested foraging when travelling north in the center of the sound (in the tidal races that form close to the Bitches reef and in the central southern part and also in the southern outlet of the sound). However this did not happen on every passage. It is assumed that their behavior depends on the state of the tide (spring or neap tide-> strength of the currents).

Vessel activity is likely to play a role as well because several times, animals stopped surfacing and left after a vessel passed a spot where they had displayed foraging behavior for several minutes (up to 20 min) before. Porpoise were observed daily travelling through and feeding in the sound regardless whether boats were present or not suggesting that a disturbing effect does not necessarily result in an abandonment of the area.

The type of boats used in the sound have been found to produce sounds at a frequency comparable to that of porpoise echolocation clicks and "significantly above their auditory thresholds"(Koschinski, 2008, Roussel 2002).

Disturbance is therefore likely to be present but porpoise stay in the area assumingly for one of the following reasons:

1. The animals do not feel (heavily) disturbed by the vessels
2. The sound is visited by different individuals every day (that have not experienced the disturbance before)
3. The animals have habituated (gotten used) to the boats. With a lifespan of circa 10 years the porpoise presently observed in the sound probably grew up with the boats sharing the sound.
4. The animals have no alternative feeding (and nursing) ground. This again can be due to the fact that they cannot find suitable prey species elsewhere because they have been overfished or porpoise are being outcompeted by other predators or other porpoise populations.
5. Porpoise have specialized their foraging strategies to the unique conditions in the sound (as observed in bottlenose dolphins (Mann & Sargeant in Fragaszy & Perry, (2003))) and are therefore not able (or willing?) to shift to other areas

Option 2 is unlikely because one animal was identifiable due to a distinctive notch in its dorsal fin and was observed to return to the sound several times thereby suggesting that the same individuals return to on a regular basis. Such an individual had been observed for several years before (Ernst & Schrijver (2010) Baradell (unpublished).

Habituation in turn could make the animals more vulnerable to injury or death through collision as they no longer regard the vessels as threat.

Option 4 and 5 would imply that porpoise are likely more stressed which in turn makes them more vulnerable to other pressures that they might encounter in or outside the sound.

T Pod data (not published) revealed increased activity of porpoise in the sound during wintertime compared to summertime. A possible explanation could be the increase of boat traffic during summer time.

6.3. Porpoise vessel interactions

Harbor porpoise and motorized vessels were observed in close proximity to each other numerous times (69), 25 out of which the vessels were wildlife watching boats.
No significant correlation between the number of vessels and activity of porpoise in Ramsey sound was found (Pearsson Regression analysis= > 0.05)).

Many other factors contribute to the presence or absence of porpoise including tidal state, presence and abundance of prey species and potentially unknown factors outside the sound.
Porpoise were not observed to significantly change their behavior while foraging in the PSA when boats approached. They continued surfacing at the same speed and frequency. On a few occasions the animals dove for a longer time when a vessel came close. However it cannot be proven that this behavior was related to the boats.
While travelling through the sound porpoise seemed to disrupt their breathing pattern or avoid spending time within the sound to forage if vessels came close. Again, the research design did not allow collection of sufficient data on these specific behaviors to statistically prove a correlation. Yet, the findings agree with Lirets results ((2001) in David 2002)) where he found that "the minimal distance of response is imposed by the type of place: lower in a narrow channel and higher in a more open area". The foraging area is much larger than the rather narrow passage between the mainland and the Bitches reef (400m). This makes the animals more vulnerable to disturbance and produces "lower minimal distance of response"(Liret, 2001). In addition they might be less sensitive when foraging being distracted by their prey. Another point is that vessels crossing the sound travel at much higher speeds (Fig 10) sometimes performing erratic changes of course (to excite customers) and might often be unaware of the presence of porpoise. The wildlife watching vessels travelling to the PSA do so because they know that the animals are there. Skippers therefore try to avoid disturbance in order to provide their customers with a rewarding experience. Vessels that are potentially not aware of the animals usually are fishing or sailing vessels that travelled at slow or plowing speed and a steady course. Furthermore their (larger) engines produce lower frequency sounds as suggested by Richardson (1995) that are less likely to mask porpoise vocalization.

Comparing figures 7 and 11 (p. 16 & 19), one can see that in the area with the largest number of vessels crossing the sound, porpoise density is relatively low. This corresponds with Herr et al`s results (2005) who (on a larger scale) found that porpoise density in areas of the North Sea with much shipping traffic was lower than in less frequented parts. Whether porpoise would (or used to) spend more time in this area if no or less vessels were present needs yet to be investigated. Possibly anecdotal reports from residents could be called on (stakeholder involvement). Another reason (other than traffic) for little porpoise activity in the area could be that their preferred prey cannot be found there or not in sufficient abundance.

Recovery from disturbance has been found to rarely take longer than 1/2-1 h after a single vessel passed. (Richardson & Würsig 1997) During the busiest times of the day and year multiple vessels travel through the porpoise habitat, causing disturbance at a higher rate than 1/h or even 1/ 1/2h.

That means constant stress for the animals, likely making them more vulnerable to other pressures (accumulative effects).

Johnson and Norris ((1986) in Gales et al. (2003)) state that "groups of cetaceans bunch together in situations of surprise, threat or danger". This behavior has been observed in Ramsey sound in three situations when vessels were close to travelling animals suggesting that the animals felt threatened or surprised by the boat/s approaching.

6.4. Current management

The current management of vessel traffic and cetacean protection in Ramsey sound is minimalistic. According to the Relevant Authorities Group for the SAC, "there is no single relevant authority with statutory responsibility for controlling sea-based forms of recreation." (PMSAC summary, 2008) and Steven & Associate stated in 2005 that the National Parks Management Plan mainly focuses on the "landward side of the coast".

The boat tours developed gradually and no Environmental Impact Assessment (EIA) was carried out. Nowadays proof is necessary that an activity or project is not harmful. This is proven by a tidal energy plant that is to be employed in the sound. An extended EIA has to be performed beforehand including monitoring of potential changes in porpoise behavior. Bearing that project in mind there is a chance that this additional disturbing factor in the sound could add to disturbance caused by vessel traffic being the final straw. However that is the authors opinion and purely speculative.

The fact that 95% of all observed vessels were motorized, many of which travelling at high speeds shows that disturbance of wildlife and other recreational users of the area has been accepted.

The PMC is hardly promoted throughout Pembrokeshire. Other than on the website, it was displayed on one site (but might be in others that were not visited by the author). This could be due to the fact that it has been accepted to be ineffective and effort and financial resources are now invested in more productive activities.

Point 5 of the code (*Leave if you notice any signs of disturbance; such as erratic changes in speed and direction, or lengthy periods underwater*) seems impossible to follow as even after month long dedicated observations recognition of certain behavior stays challenging.

6.5. Study limitations

Certain aspects that posed limitations to this study will be described briefly in the following paragraph. The period between April and early July presented only the beginning of the tourist season in Pembrokeshire. Therefore the highest density of vessel traffic could not be observed which would possibly bring up different results. Several rainy days and exceptionally cold temperatures during the field period additionally reduced the numbers of wildlife tours taking place. Nevertheless a number of bank holidays with abundant traffic gave a good idea of boat activity in Ramsey sound during high season and fair weather.
Perry ((1998) in Roussel (2002)) noted the difficulties in establishing "a baseline against which effects of disturbance (of cetaceans) can be compared". Porpoise are often solitary and inconspicuous.

Their surfacing behavior is brief and erratic and their blow is virtually impossible to see or hear. Juveniles are either very small or hard to distinguish from adults. In addition it is almost impossible to identify individuals. These factors make it very hard to recognize and distinguish certain behaviors and detect changes. Especially changes in surfacing, ventilation and dive patterns, which are thought to be "the most sensitive indicators of whale response to vessels" (Baker and Herman ((1989) in Gales et al. (2003)). Filming the animals can be a solution however only to a limited distance. Collaboration and communication between individual people studying the same population or location at different times can help understanding that particular group of animals in a location and their habits and behavior better.

Apart from recognition of behavior, it is unlikely to detect all animals present because some porpoises can be missed due to scan errors or because they are submerged. This results in less accurate estimates of porpoise density and activity. However a large enough database and comparison with other studies or observers can minimize that error. Also comparing the results of two independent observers can reveal and correct errors.

For a single observer it is sometimes hard to keep an eye on all objects and events, especially in busy conditions. It is recommendable to either videotape situations or work with an assistant.

In Ramsey sound on sunny days, the sun produces strong glare on the southern half of the sound after 2 pm which makes observation complicated. However observation times fell within this period only a few times on a sunny day.

Porpoise and vessel sightings cannot easily be compared because for boats it was possible to count the total number (vessel density).

For porpoise only surfacing events (porpoise activity) could be recorded but not the number of individuals present in the sound (for reasons mentioned above). However these variables allowed comparison between vessel density and porpoise activity.

7. Conclusion

In conclusion, this study has shown that the boating activity in Ramsey sound is dominated by wildlife watching tours. Close encounters with harbor porpoise happen on a regular basis. Porpoise and vessels were observed together in the sound on most days. No correlation has been found between the number of vessels present and porpoise activity recorded.

The reactions of porpoise were hard to detect but did not seem dramatically negative. Nevertheless, of greater concern than short term disturbance in this scenario is repeated disturbance.

Especially during high season when numbers of vessels crossing the sound and visiting the PSA increases. After all, field work was not carried out during the busiest time of the year. Whatsoever the situation in Pembrokeshire shows that porpoise tolerate boat traffic to a certain degree.

Most porpoise activity and porpoise-vessel encounters were recorded in the southern end of the sound. However vessel behavior there was mostly in agreement with the code and porpoise showed little signs of disturbance. Most vessels travelled at planing speed and move erratically in other parts of the sound that are important for the animals daily passage. These areas would possibly be used more frequently by porpoise if fewer vessels were around. Management efforts should be focused on these areas.

Porpoise were observed to continue foraging even with motorized vessels in close proximity. They seemed to pass through the sound more briefly or interrupted their breathing pattern when encountering vessels on their passage. However more specific data on this behavior will be necessary in order to prove these observations. Disturbance by vessel traffic could not be proven.

To date very limited protection is provided to the harbor porpoise in Ramsey sound. They are not listed marine SAC feature because they have not been proven to be resident. Before the background that a major constructional project (tidal energy plant) is about to be realized in the sound special attention should be focused on accumulating disturbing impacts on the cetacean because apart from their intrinsic value, they are of major ecological and economical and conservational importance to the region. As top predators they influence populations in lower trophic levels and are also a target species for many visitors (pers. comm. Malcolm Baradell, Tom Luddington, 2012, pers. observation).

After much conflict and discussion on the topic, this study has assessed and summarized the current situation in Ramsey sound after the PMC failed to bring together stakeholders involved with marine wildlife in the region.
From here recommendations can be made for future management and research that will be needed in order to ensure a sustainable use and effective protection of the region with all its ecological features.

8. Recommendations

In the following section, recommendations for future management and research will be made, based on the results of this study. Because of many uncertainties that come with complex scenarios like this, the precautionary principle should be used as a baseline for future decision making.

8.1. Recommendations for improvement of the situation/ management

The southern part of the sound seems to be the major feeding ground of the porpoises especially during low tide. Special attention should therefore be given to that region and time. A dynamic no take zone (dynamic in timing and boundaries) that prohibits entering of the area at certain times would give the necessary protection.

It has been found that ferries and wildlife watchers which leave from St Justinian account for 71% of all boats that cross the sound. In comparison few other vessels types were recorded. Management efforts should thus focus on nature tour operators who all leave from Port St Justinian. If porpoise are known to travel through the sound at certain times this could easily be communicated to all vessels leaving from that point. Boats then could accordingly maneuver more carefully. Collaboration with land based observers could help to detect porpoise presence in the sound because an elevated position on land provides better overview. Such an observer could be financed through an "eco contribution" by nature tour customers.

This leads to the matter of "burden of proof". In this case conservationists and the responsible authorities are responsible to prove a negative effect an activity has on the porpoise. This responsibility should be shifted to the individuals and institutions that perform the potentially disturbing activity. In this case the boat operators. An official EIA should be carried out.

A (dynamic) system that allows only limited numbers of vessels (or trips) in the sound per day could make it easier to control vessel density (and an increase of it) and thereby pressure on wildlife depending on the abundance and vulnerability (e.g. presence of calves) of the animals.

In addition, licenses for boat operators could help to regulate numbers of operators in the sound and provide them with information about the ecosystem and their positive or negative effects on it.
It has been found that the highest density of vessels and the fastest speeds accumulate in the center and narrowest part of the sound where porpoise are most vulnerable due to limited escape routes. Special attention should be given to this sector and compulsory speed limits are needed.

Financial support should to a certain degree be provided by the boat operators who obtain all their income from the living and non living features of the sound.

Continued monitoring of the vessel porpoise interactions is recommended in order to detect changes in behavior in time.

8.2. Recommendations for future study

This study was designed very broad and looked at many connected but widespread points. Several recommendations for future studies can be based on the findings. Again, continued monitoring of porpoise population size and activity should be performed.
In order to prove that the porpoise in Ramsey sound are a resident population it is necessary to identify one ore multiple individuals and track their activities for a certain period of time (days, weeks, months, years). This can be done either by radio or satellite tagging or by establishing a way to identify the animals visually (Photo ID).
In order to detect whether or not vessel presence influences porpoise presence and behavior it would be interesting to know their position and activity in all weather and light conditions. Thus also in foggy and stormy condition (often winter) and at nighttime when usually no or very few boats are present. This could be achieved through further acoustic monitoring with a T or C pod (passive acoustic monitoring system).
Acoustic examinations could also help to find out in how far vessels noise masks sounds produced by porpoise.

Surveys should assess the way customers experience the vessel tours, whether or not they feel that the porpoise are being harassed and what they expect from a wildlife watching tour. Their opinion could influence the boat operators who might think that most customers look for speed and excitement. In addition questionnaires could assess the way visitors of the region that are not involved with boat tours experience the presence of the vessels in a national park and area of conservation (Wilderness experience).

Being on sea level, the skippers have a very different perspective than a land based, elevated observer. In collaboration with the skippers, it could be studied in how many cases animals are being overlooked and whether porpoise are missed easier at different speeds and sea states.

Further studies should focus on the separate components that were recorded within this study including:

- Focus attention on situations of encounters in order to detect whether porpoise change their behavior when being confronted with vessels.
- Focus attention on the foraging area (PSA) in order to detect whether porpoise change their behavior when being confronted with vessels.
- Focus attention on the duration of the passage (north-south and south- north) depending on vessel presence and behavior.
- Even if porpoise show no obvious behavioral reactions to vessels, they might react physiologically. Studying changes in heart rate, respiration and hormone levels could answer this question.

After all, as Gjerdalen and Williams (2000, in Garrod and Fennell, 2004) suggest, codes that "do not appear to make sense to the potential user, or expect them to adopt forms of behavior that appear ill founded or irrelevant, are unlikely to be effective".
It would therefore be recommendable (by means of communication potentially involving a facilitator) to assess the relevant stakeholders idea of legitimate measures "that make sense" to them, in order to increase effectiveness of the code through better agreement with its content. Thereby it could be checked, whether the PMC meet the needs of animals, tourists and operators.

References

Allan, Mark C., Read, Andrew J. (2000) Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. Marine Mammal Science, (16) 4, pp. 815-824.

Baradell, Malcolm (2009) Fine Scale Use of Ramsey Sound, Pembrokeshire, West Wales, by Harbour Porpoise (*Phocoena phocoena*), not published.

Berg van den, A.C.Y. Schrijver, E.E. (2010) Distribution and movement patterns of harbour porpoise (Phocena phocena) along headlands of the northwest Pembrokeshire coast. Bachelors thesis Van Hall institute, Leeuwarden

Culik, Boris M., Koschinski, Sven, Tregenza, Nick, Ellis, Graeme (2001) Reactions of harbor porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms, Marine Ecology Progress Series. (211), pp. 255–260, 2001.

David, L. (2002) Disturbance to Mediterranean cetaceans caused by vessel traffic. In: G. Notarbartolo di Sciara (Ed.), Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A report to the ACCOBAMS Secretariat, Monaco, February 2002. Section 11, p. 21.

Evans, P.H.G., Anderwald, Pia, Baines, Mick E. (2003) Uk Cetacean Status Review Report to English Nature & Countryside Council for Wales

Evans, P.G.H., Carson, Q., Fisher, P., Jordan, W., Limer, R. & Rees, I. (1994) A study of the reactions of harbour porpoises to various boats in the coastal waters of S.E. Shetland. *European Cetacean Society* Newsletter 21.

Evans, P.G.H. (1996) Human disturbance of cetaceans. In: N. Dunstone & V. Taylor (eds) Exploitation of mammals. Principles and problems underlying their sustainable use. Cambridge University Press, London, pp. 376-394.

Evans, P.H.G, Hammond, Phillips (2003) Monitoring Cetaceans in European Waters. Mammal review, (34) 1-2, pp. 131-156.

Evans, P G.H. Wang, J. (2009) Harbour porpoise spatial modelling to identify possible hotspots for Marine Protected Areas. 6th Meeting of the Parties to ASCOBANS, pp 43-50

Fontaine, Michaël C, Tolley, Krystal A, Siebert, Ursula, Gobert, Sylvie, Lepoint, Gilles, Bouquegneau, Jean-Marie and Das, Krishna(2007) Long-term feeding ecology and habitat use in harbour porpoises. BMC Ecology, (**7**)1

Fragaszy Dorothy, Perry M.,Susan (2003) The Biology of Traditions: Models and Evidence. Cambridge, New York. pp 236

Gales, Nicholas, Hindell, Mark, Kirkwood, Roger (2003). Marine mammals: fisheries, tourism and management issues. CSIRO, Collingwood, Australia. p. 240

Garrod, Brian, Fennel,l David A. (2004) An Analysis of Whalewatching Codes of Conduct. Annals of Tourism.Research (31) 2, pp. 334–352,

Goodwin, L., Speedie, C., (2008) Relative abundance, density and distribution of the harbour porpoise (Phocoena phocoena) along the west coast of the UK l. Journal of the Marine Biological Association of the United Kingdom, 2008, (88)6, pp. 1221–1228.

Gorzelany, Jay F. (2004): Evaluation of Boater Compliance with Manatee Speed Zones along the Gulf Coast of Florida, Coastal Management, (32)3, pp. 215-226.

Gregory, Paul R., Rowden, Ashley A.(2001) Behaviour patterns of bottlenose dolphins (*Tursiops* truncatus) relative to tidal state, time-of-day, and boat traffic in Cardigan Bay, West Wales. Aquatic Mammals (27) 2, 105–113

Hammond, P.S., Macleod, K. (2006) Progress report on the SCANS- II project, ASCOBANS Advisory Committee, Finland

Herr, Helena, Gilles, Anita, Scheidat, Meike, Siebert, Ursula (2005) Distribution of harbour porpoise (*Phocoena phocoena*) in theGerman North Sea in relation to density of sea traffic (Document AC12/Doc.8) ASCOBANS 12th Advisory Committee Meeting (P) Brest, France,

Koschinski, Sven (2008) Possible Impact of Personal Watercraft (PWC) on Harbor Porpoises (*Phocoena phocoena*) and Harbor Seals (*Phoca vitulina*). Society for the Conservation of Marine Mammals, Quickborn

Lemon, Michelle, Lynch, Tim P., Cato Douglas H., Harcourt Robert G. (2006) Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. Biological Conservation, (12) pp 363-372

Liret C. (2001) Domaine vital, utilisation de l'espace et des ressources: les garnds dauphins, Tursiops truncatus, de l'île de Sein. 155pp

Lusseau, D (2008) Understanding the Impact of Noise on Marine Mammals in Marine Wildlife and Tourism Management. CABI, Oxfordshire, p. 206.

Marine Code Group (2012) The Pembrokeshire Marine Code Review 2002- 2012. www.pembrokeshiremarinecode.org.uk/wp-content/uploads/2011/12/PMC-10-year-review.pdf (20.06.2012)

Marubini, Francesca, Gimona, Alessandro, Evans, Peter G. H., Wright, Peter J.,Pierce, Graham J. (2009) Habitat preferences and interannual variability inoccurrence of the harbour porpoise *Phocoena phocoena* off northwest Scotland. Marine Ecology Progress Series (381) pp 297–310

National Research Council. 2003. Ocean noise and marine mammals. The National Academies Press. Washington D. C. / USA. 192 pp.

Ng, Sai Leung, Leung, Sze (2003) Behavioral response of Indo-Pacific humpback dolphin (Sousa chinensis) to vessel traffic, Marine Environmental Research (56): 555–567

Nowacek, Douglas P., Thorne, Lesley H., Johnston, David W., Tyack, Peter L.(2007) Responses of cetaceans to anthropogenic noise. *Mammal Rev*. (37) 2, 81–115

Nowacek, Stephanie M., Wells, S Randall (2001) Short-term effects of boat traffic on Bottlenose dolphins, (*tursiops Truncatus,* in Sarasota bay, Florida,Marine Mammal Science, 17(4):673-688

National Institute of Polar Research, 1-9-10 Kaga, Itabashi,Papale Elena, Azzolin Marta And Giacoma Cristina (2011) Vessel Traffic Affects Bottlenose Dolphin (*Tursiops Truncatus*) Behaviour in Waters Surrounding Lampedusa Island, South Italy, Journal of the Marine Biological Association of the United Kingdom, p 1 of 9.

Otani, Seiji, Naito, Yasuhiko, Kawamura, Akito, Kawasaki, Masahiro, Kato, Akiko (1998) diving behavior and performance of Harbor porpoises, *phocoena* phocoena, in Funka Bay**,** Hokkaido, Japan. MARINE MAMMAL SCIENCE, 14(2):209-220

Pierce G.J, Santos M.B., Cerviño S. (2007) Assessing sources of variation underlying estimates of cetacean diet composition: a simulation study on analysis of harbour porpoise diet in Scottish (UK) waters. Journal of the Marine Biological Association (87) 213–221

Pembrokeshire Marine SAC Relevant Authorities Group (2008) Pembrokeshire Marine Special Area of Conservation Summary Management Scheme. p. 1.

Perrin, William F., Würsig, Bernd , Thewissen (2008) Encyclopedia of Marine Mammals, 2nd Edition. Elsevier Burlington USA. p. 532

Pierpoint, C. (2008) Harbour Porpoise (Phocena phocena) foraging strategy at a high energy, near shore site in southwest Wales, UK. Journal of the Marine Biology Association of the United Kingdom 88(6), pp. 1167-1173.

Polacheck, T. and Thorpe, L. (1990) The swimming direction of harbor porpoise in relationship to a survey vessel. Report International Whaling Commission 40, pp. 463-470.

Relevant Authority Group PMSAC (2008) Pembrokeshire Marine Special Area of Conservation Summary Management Scheme. (PDF) www.pembrokeshiremarinesac.org.uk/english/downloads/PMSAC%20summary%20ManScheme%202008.pdf (24.06.2012)

Richardson, Greene W. J., C. R., Malme C. I., Thomson D. H.. 1995. Marine mammals and noise. Academic Press. San Diego. 576 pp.

Richardson, W. John, Würsig, Bernd (1997): Influences of man-made noise and other human actions on cetacean behavior, Marine and Freshwater Behavior and Physiology, (29)1-4, pp. 183-209.

Roussel, Erwan (2002) Disturbance to Mediterranean Cetaceans caused by noise. ACCOBAMS-Cetaceans of the Mediterranean and Black Sea: State of Knowledge and Conservation Strategies, Section 13.

Santos, M. B., Pierce, G. J., Learmonth, J. A., Reid, R. J., Ross, H. M., Patterson, I. A. P., Reid, D. G. and Beare, D. (2004), Variability in the diet of harbor porpoises (*phocoena phocoena*) in Scottish waters 1992–2003. Marine Mammal Science, 20: 1–27.

Warburton, Caroline (1999) Marine Wildlife Tourism and Whale Watching on the Island of Mull, West Scotland. Hebridean Whale and Dolphin Trust. (Journal?)

Wells, R. S., & M. D. Scott. 1997. Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota,Florida. Marine Mammal Science (13): 475-480.

Westgate, A.J., Read, A.J., Berggren, P., Koopman, H.N. & Gaskin, D.E (1995) Diving Behaviour of harbour porpoise (*Phocoena phocoena)*. Canadian Journal of Fisheries and Aquatic species (52), 1064-1073.

Figures

Fig 1: Strong, Powell & Morris, Steve Richard (2010): Grey seal (Halichoerus grypus) disturbance, ecotourism and the Pembrokeshire Marine Code around Ramsey Island, Journal of Ecotourism, 9:2, pp. 117-132.

Fig. 2: United Kingdom Hydrographic Office (1999) West Coast of England and Wales, Pilot NP37, 14th edition, Taunton United Kingdom in Baradell Malcolm (unpublished) Fine Scale Use of Ramsey Sound, Pembrokeshire, West Wales, by Harbor Porpoise (*Phocoena phocoena*), (not published)

Fig. 3: Pembrokeshire Outdoor Charter Group (2003)Pembrokeshire Marine Code. (PDF) www.pembrokeshiremarinecode.org.uk/wp-content/uploads/2011/02/The-Pembrokeshire-Marine-Code.pdf

9. Appendices

Appendix I: Codes used in the field

Codes used in the field		
Object		
	Harbor porpoise	**1**
	Motorized vessel	**2**
	Non motorized vessel	**3**
No of porpoise		
	1	**1**
	> 1	**2**
Porpoise activity		
	Foraging	**1**
	Travelling	**2**
Vessel close to porpoise (< 100m)		
	Yes	**1**
	No	**2**
Vessel type		
	Wildlife watcher	**1**
	Sailing vessel	**2**
	Fishing vessel	**3**
	Ferry	**4**
	Kayak	**5**

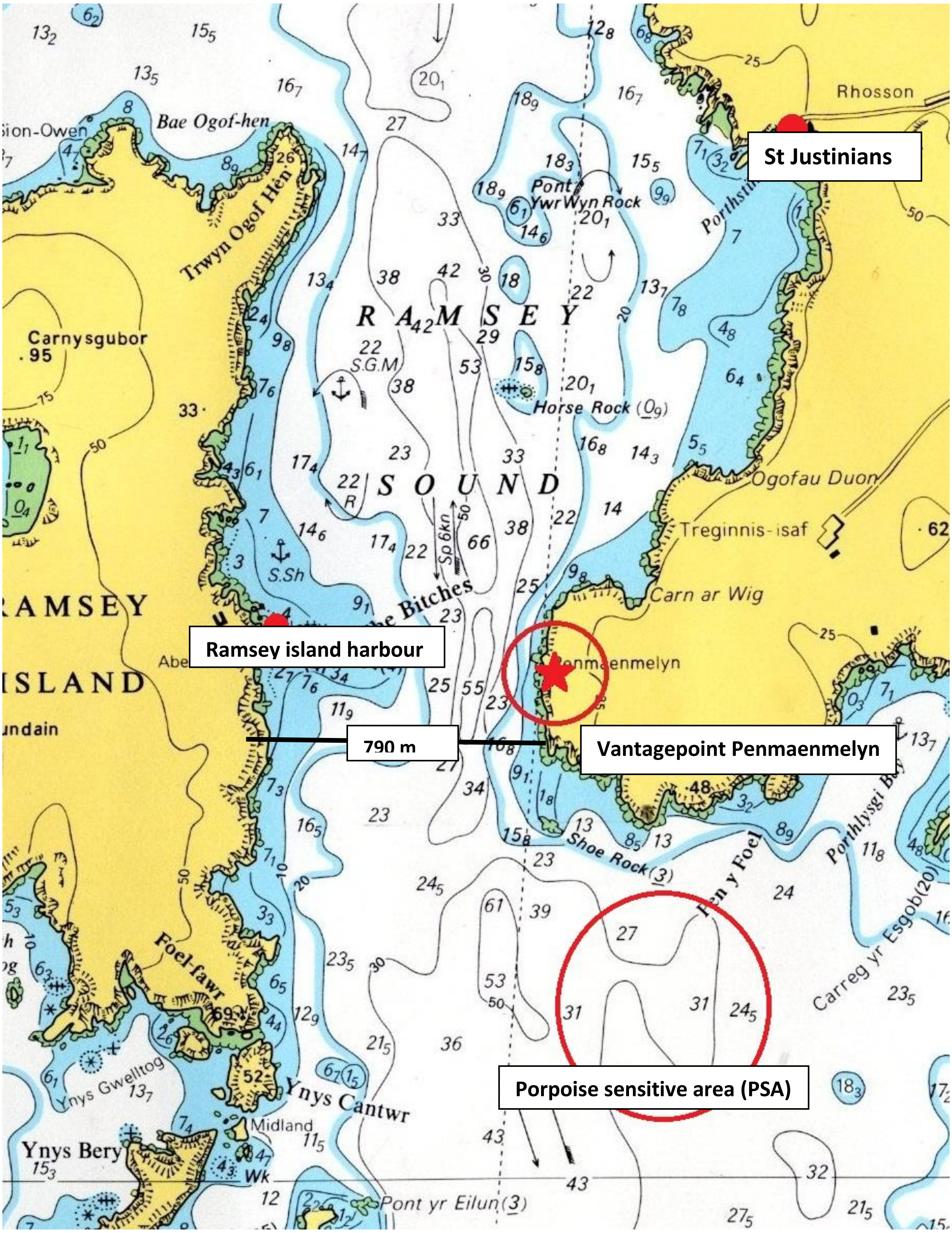
	Other	**6**
Vessle speed		
	Idling speed	**0**
	Slow speed	**1**
	Plowing speed	**2**
	Planing speed	**3**

Appendix II

Speed categories Gorzelany (2004)

- **Idle Speed (IS)**: The minimum speed that maintains steerage of a vessel, or the speed at which a vessel is normally docked. Little or no displacement of water is observable from either the bow or stern, and the vessel remains level in the water at all times. This speed has also been defined as approximately 1 to 3 miles (1.6 to 4.8 km) per hour (Sarasota County, 1994).
- **Slow Speed (SS)**: The speed at which all vessels are completely off plane and fully settled in the water. Some minimal water displacement at either the bow or stern (or both) may be observed. This speed has also been defined as approximately 5 to 7 miles (8 to 11.2 km) per hour (Sarasota County, 1994).
- **Plowing Speed (PS)**: An intermediate speed between planing speed and slow speed. The bow of the vessel typically rides higher than the stern, and substantial displacement of water occurs. Depending on the size and type of vessel, plowing may occur at a variety of speeds, but is most often observed between 10 and 15 miles (8 to 11.2 km) per hour (Gorzelany, 1996).
- **Planing Speed (PLS)**: A vessel traveling at sufficient speed to partially raise the bow out of the water during travel. Vessel planing speeds vary widely depending upon hull design; however, the majority of planing vessels travel at speeds in excess of 15 miles (24 km) per hour (Gorzelany, 1996). (adopted from: Gorzelany, 2004

Appendix III: Ramsey sound and points of importance



Appendix IV

0
1
2
3
4 -5
6 -10
10 -20
20-30
>30

Fig 13: Coloration of cells displaying numbers of sightings in the distribution tables. Low porpoise numbers are resembled by light blue cells and high porpoise numbers by increasingly dark blue, purple and brown cells.

Table 3 shows how in the period between 1 and 3 h after high tide only few porpoise were observed in the sound. Most sightings were made in the northern part (330°.350°) and relatively far away namely 900- 1000 m. Another cluster can be noted between 260° and 280° quite close to shore (100-200 m). Very few porpoise were sighted in the southern part of Ramsey sound.

1 to 3 h after high tide

Number of sightings: 84

Prevailing surfacing direction: South 72%, Various 22%

	Distance (m)															
Bearing(°)	**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**550**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
180																
190													2			
195																
200								1								
205																
210								1		1						
215										1						
220																
230					1	1		1								
240											1					
250						1										
260			1		2			1								
270			5		1											
280			2		3					1						
290	1		2		2	1										
300						3		1								
310						2										
320			1													
330										1			1			
335										2	2	3	1	1	1	
340						1		2			2	5	2	4		
345													1	4		2
350														2	1	2
360														1		

Table 3: Bearing and distance (Position) of porpoise sightings between 1 and 3 h after high tide.

The table (Table 4) below shows the distribution of porpoise sightings 4 to 6 h after high tide. The majority of sightings was made in the area between 180° and 210° and between 500 m and 1200 m away. Another large number of spottings was made between the vantage point and the Bitches reef (260°-290° and 100m- 300 m away). Only very few porpoise were sighted in the northern part of the sound in this period.

4- 6 h after high tide

Number of sightings:299

Prevailing surfacing direction: South 69% East 26%

	Distance (m)															
Bearing(°)	**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**550**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
180											1		3	5	1	1
190												8	102	15	1	6
195													1			
200						1		2		1	5	2	4	3		
205											1	1				
210								2		4	3					
215										1						
220					1	1		6		1	1					
230			1					2								
240						2		1								
250					1	2										
260	3		4		2	2										
270	9		11		6											
280	4		5		1	1		1			1					
290	2		4		2	1										
300	1		1	1		3		1		1	1					
310	2		1					1								
320	2							1								
330	1		2					1			1					
335			2					2		1	1		1			
340						1		1		1	1		2			1
345								1	1			1		1	1	
350													2			1
360								1								

Table 4 Bearing and distance of porpoise sightings between 4 and 6 h after high tide

Table 5 displays porpoise sightings between 7 and 9 h after high tide. Most sightings were made within this period (433). The largest number of porpoise were sighted between 180° and 220° and 500 and 1000 m. Some animals were observed around the Bitches reef between 260° and 270° between 100 and 300 m away. Only a few individual sightings were made in the northern half of the sound.

7-9 h after high tide

Number of sightings: 433

Prevailing surfacing direction: North: 65% Various: 23%

	Distance (m)															
Bearing(°)	**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**550**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
180												3	2	4	1	
190	1										11	26	135	23	1	
195										1	1	2	1	1		
200					1	1		5		12	13	23	7	2	1	2
205						3		3		1	2	2	3			
210						1		4		8	6	2	5	2		
215										2						
220	1					2		1		1	4	1				
230						2		2		1	2					
240	1							2		3	1	1				
250					2	1		3		1						
260	3	1	2		7	1				1						
270	6		4		1	2										
280	2		1		1	1										
290	2				1	1		1								
300	1				2	1		3		1						
310			1			1										
320	1				1							1				
330						1					1					
335						1						1	1			
340						1				1		1				
345																
350																
360																

Table 5 Bearing and distance of porpoise sightings between 7 and 9 h after high tide

Below porpoise sightings between 10 and 0 h after ht are displayed (Table 6). Total number of sightings is 185 with most porpoise being observed around 200° and 190° and 900m. However a large number was also seen between 250° and 289° between 100 and 400 m away. The number of porpoise in the northern part of the sound is larger than in the two periods before with quite a few sightings between 330° and 350° and 500 and 1000 m.

<u>10- 0 h after high tide</u>

Number of sightings: 185

Prevailing surfacing direction: North: 56% Various: 26% South: 16%

	Distance (m)															
Bearing(°)	**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**550**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
180																
190								1					15	2		
195																
200						1		1		4	6	6	2			
205								1		1						
210					1	2		2		5		3				
215										2						
220			1			2		3		2		1				
230			1				1	1		1						
240			1		1	1				1	1					
250	1		3		3	2						1				
260			3		3	3		2								
270	3		15		2	2										
280	2		3		3	2										
290			2					1				1				1
300	1		2			2		3								
310								1								
320					1	1				1		2				
330								2		2						
335										2	2		1			
340	2		1		1			1			1	1	1	4		
345												1	1	1	1	
350	2							1							1	
360						2				1			1	1		

Table 6 Bearing and distance of porpoise sightings between 10 and 12 h after high tide

Below (Table 7), all sightings of porpoise in the sound are displayed. It shows that in total, the largest number of sightings was made between 180° and 210° and 500 and 1000m. Several sightings were also recorded around 270° at 100- 300 m distance. Porpoise activity in the northern area of the sound was very little.

Position and bearing of all porpoise sightings

Prevailing surfacing direction: North: 32%, East: 1%, South:39%, West:3%. Various:25%

	Distance (m)															
Bearing(°)	**100**	**150**	**200**	**250**	**300**	**400**	**450**	**500**	**550**	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**
180											1	6	7	**13**	3	1
190	2										**22**	**60**	**374**	**61**	3	6
195										2	2	4	3	2		
200					2	3		**13**		**25**	**31**	**48**	**18**	7	2	4
205						6		6		2	5	5	6			
210						2		**13**		**31**	**15**	4	10	4		
215										6						
220	2				1	5		8		3	9	2				
230			1		1	5		7		2	4					
240	2					2		5		6	3	2				
250					5	5		6		2						
260	9	2	9		**18**	4		1		2						
270	**21**		**24**		9	4										
280	8		9		6	3		1		1	1					
290	7		6		6	4		2								
300	3		1		4	8		8		3	1					
310	2		3			4		1								
320	4		1		2			1				2				
330	1		2			2		1		1	3		1		1	
335			2			2		2		3	3	6	4	1		
340						4		3		3	3	7	4	4		
345								1				1	1	5	2	2
350													2	2		2
360								1						1		

Table 7 Positions of all porpoise sightings recorded