SMRU MARINE

understand • assess • mitigate

Seal Telemetry Inventory

Authors:	Carol Sparling
Report Code:	
Date:	Monday, 14 March 2016

Document Control

Please consider this document as uncontrolled copy when printed

Rev.	Date.	Reason for Issue.	Prep.	Chk.	Apr.	Client

Contents

Contents 2
1 Introduction 3
2 Seal Telemetry Data Sets 3
2.1 Harbour seals 3
2.2 Grey seals 3
3 Summaries 4
3.1 Strangford Lough 4
3.1.1 General behaviour 5
3.1.2 Turbine related effects 6
3.1.3 Summary 6
3.2 Sound of Islay 7
3.2.1 Summary 8
3.3 Pentland Firth 9
3.3.1 Summary 10
3.4 Kyle Rhea 11
3.4.1 Summary 11
3.5 Welsh studies of juvenile grey seals 12
3.5.1 Summary 12
4 Synthesis 13
5 References 14

1 Introduction

Due to the expansion of the tidal energy industry and the concern surrounding the risks posed to marine megafauna, there is a requirement for knowledge on how marine animals use tidal environments. Potential interactions are poorly understood, largely due to the complexity of tidal stream environments that make traditional survey and monitoring methods challenging. Although tide patterns have long been known to influence seal haul out behaviour, the behaviour of seals within fast flowing, turbulent environments is less well known. In the UK in recent years much interest has focussed on understanding how seals use tidal environments and a number of datasets are starting to emerge. The purpose of this report is to review these studies with a view to synthesising the current state of knowledge, to identify similarities and differences across datasets and to determine whether there are common factors across studies, which shape seal behaviour and explore the extent to which we can generalise across sites and between species.

2 Seal Telemetry Data Sets

2.1 Harbour seals

Location	Year	# of tags	Age class	Comments	Ref
Strangford Lough, Northern Ireland	2006 2008 2010	12 10 12	Adults	Deployments prior to, during and after the installation of the MCT SeaGen tidal turbine in 2008	Lonergan et al. In review
Sound Of Islay, Scotland	2011 2014	17 8	Adults	Site of Scottish Power Renewables Demonstration Tidal array	
Pentland Firth	2011	14	Adults	Site of MeyGen's Tidal array	
Kyle Rhea	2012 2013	9 10	Adults	Site of Marine Current Turbines' proposed Demonstration Tidal array (project now on hold)	

2.2 Grey seals

Location	Year	# of tags	Age class	Comments
Anglesey, Bardsey and Ramsey Island, Wales	2009 2010	5 12	Juveniles	Close to Tidal Energy Limited's Deltastream deployment, MCT's Anglesey Skerries and the Anglesey tidal demo zone

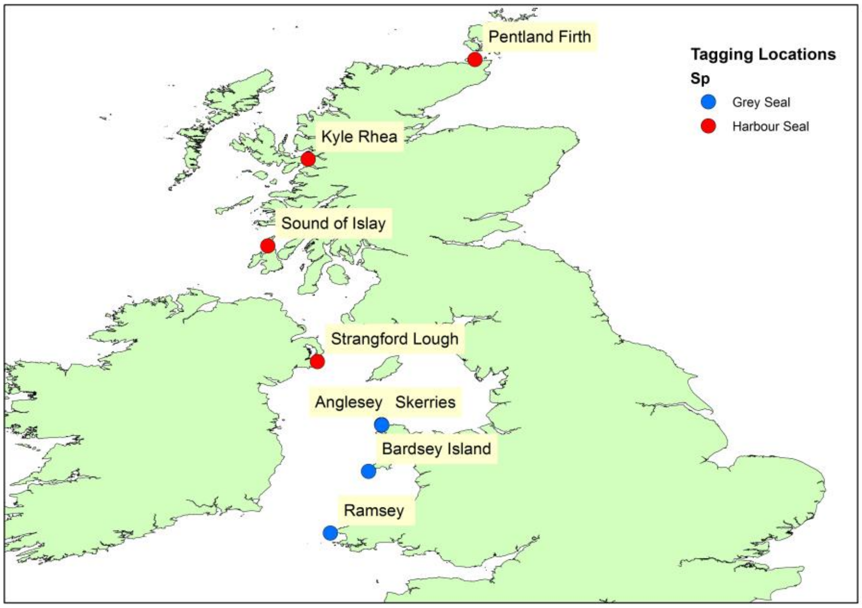

Figure 1. Map of all tagging sites featured in this review.

3 Summaries

3.1 Strangford Lough

Table 1. Summary of Strangford Lough harbour seal telemetry dataset

Data	Description
Tagged animals	2006: 7 males, 5 females (all adults) 2008: 7 males, 5 females (all adults) 2010: 8 males, 4 females (all adults)
GPS data	In 2006 and 2008 GPS/GSM tags were programmed to attempt a GPS location every 20 minutes. In 2010 tags were programmed to attempt a GPS location every 10 minutes.
Haul Out data	The tag initiates a haulout record if the wet/dry sensor is continuously dry for 10 minutes. The record is terminated when the tag is continuously wet for 40 s.
Depth data	1 Hz sample rate; split dive into 1/10th intervals
Number of datapoints	17470 in 2006, 9441 in 2008, 8656 in 2010
Covariate data available	Modelled tidal velocity (Kregting and Elsasser, 2014), POLTIPS tidal predictions.

3.1.1 General behaviour

Harbour seals were tagged at haul out sites in Strangford Lough as part of an investigation into Marine Current Turbine's SeaGen tidal turbine, situated in Strangford Narrows (Figure 2) (McConnell & Isojunno, 2009 and Lonergan et al., In review). The narrows are formed by an inlet between the Irish Sea and Strangford Lough where tidal speeds can reach 4m.s^{-1}. Seals haul out at a number of sites in the Lough itself. Thirty-six seals were tagged with GPS phone tags (Sea Mammal Research Unit, UK) over three deployments in 2006 (April-July, pre-installation), 2008 (March – July, during installation and commissioning) and in 2010 (April-July, operation). The seals were captured at sites in Strangford Narrows and the southern islands in Strangford Lough. All were adults, weighing between 70 and 104 kg, and a mix of males and females were caught each year.

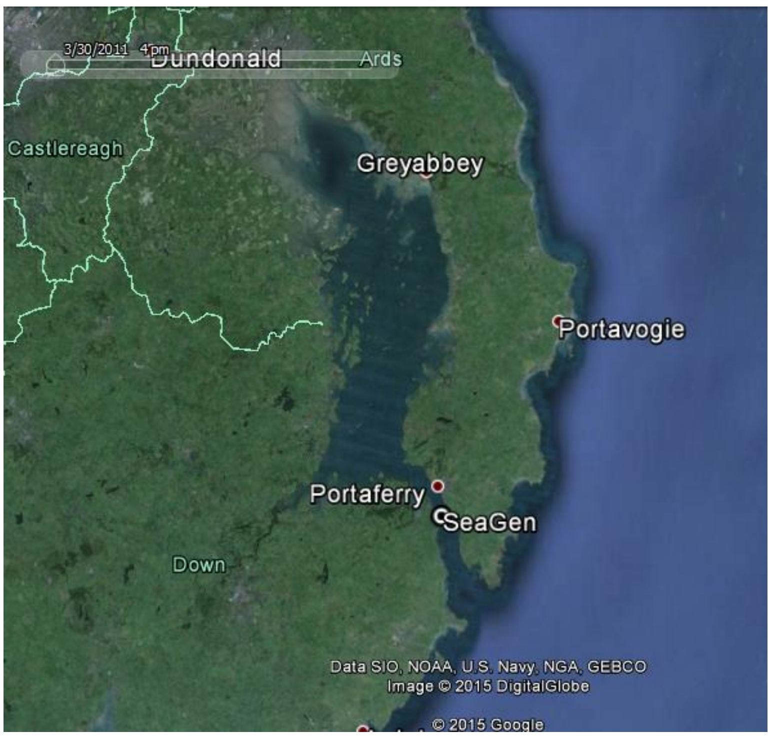

Figure 2. Strangford Lough showing the position of the SeaGen tidal turbine.

Across all three years of tagging (2006, 2008 and 2010) patterns of movement were roughly similar. In all years there was a great deal of inter-individual variation but each individual demonstrated consistent patterns of behaviour. In all years there was significant use of the narrows tidal areas by some individuals.

Baseline (pre-construction) telemetry data demonstrated that many of the seals that haul out and breed within the Strangford Lough Special Area of Conservation (SAC: a conservation area designated under European Commission Habitats Directive) and also spend time in the Irish Sea (McConnell, 2009). Some seals spent their entire time within Strangford Lough, others never went past the narrows to enter the Lough proper and some seals spent the entire time transiting up and down the Narrows. One seal (pv33_11_10) remained in the Narrows and within 4 km of the turbine for the whole of the study period.

These data have not been exhaustively analysed with respect to describing seal behaviour within the tidal environment. Analysis to date (Keenan et al., 2011 and Lonergan et al., in review) has focussed on the detection of turbine related effects. However Lonergan et al., (in review) did note that over all three years of data seals did transit through the narrows significantly more at slack tide than during flood or ebb states of the tide.There was a very high inter-individual variability in the rates at which animals moved through the areas of highest flow – see Figure 3.

In an earlier analysis covering only 2006 and 2008 deployments, the probability of being in the water (i.e. not hauled out) was higher at night, over high water and earlier in the tagging deployment (March-May). The probability of an animal being in a buffer zone around turbine site was also higher at night and earlier in season. The patterns of usage of the water column near the turbine site suggests that the animals preferentially used the surface and deepest water, indicative of benthic diving.

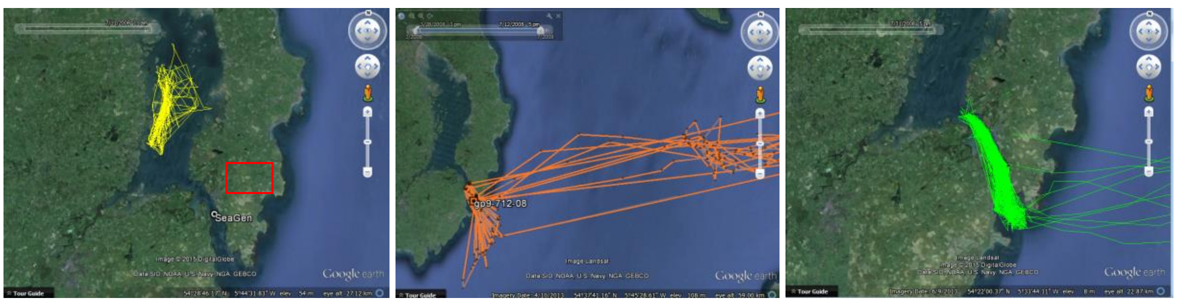

Figure 3. Individual variation in behaviour between tagged seals at Strangford Lough: (a) a seal which never left the Inner Lough during the tag deployment, (b) a seal which spent a large proportion of time away from the Lough and the Narrows and (c) a seal which spent most of its time in the Narrows.

3.1.2 Turbine related effects

The telemetry deployment in 2010 is a unique dataset in that it represents the only data describing the behaviour of tagged seals in proximity to an operational tidal turbine anywhere in the world. Basic analyses have been carried out to examine the potential effect of the turbine on seal behaviour. Although there was not a significant difference between pre-installation and operation deployment in the average rate which seals transited through the narrows there was a reduced transit rate (average of ~20%) within individuals during periods when the turbine was operating compared to periods when it was not (once tidal state had been controlled for). There were also apparent differences in the spatial pattern of movements between deployments that could be analysed to derive a quantitative measure of avoidance.

3.1.3 Summary

Features of dataset which have relevance to strike risk:

- High inter-individual variability in use of tidal areas
- Most dives to the seabed
- More transits during night and slack tide
- More likely to be in vicinity of turbine later in year (nearer breeding season)

Analyses to date and key findings:

- No barrier effect – seals continue transiting when turbine installed and operating

- Reduced transits when the turbine was operating relative to periods when the turbine was not operating due to maintenance periods (matched for tidal conditions).
- Telemetry derived estimates of close range encounter rates were similar to sonar derived encounter rates
- Collision model using telemetry estimates of close range transits has been used to inform the Habitats Regulations Assessment for the removal of mitigation

Potential future analyses/weaknesses of the dataset

- Data not fully analysed for avoidance, likely able to use data to estimate scale of avoidance
- Data not fully analysed to understand behaviour in relation to tidal covariates
- Interpolation between depth and location data difficult due to low sampling rate

3.2 Sound of Islay

Table 2. Summary of Sound of Islay harbour seal telemetry dataset

Data	Description
Animals tagged	All adults: 10 males, 7 females
GPS data	GPS/GSM tags were programmed to attempt a GPS location every 10 minutes.
Haul Out data	The tag initiates a haulout record if the wet/dry sensor is continuously dry for 10 minutes. The record is terminated when the tag is continuously wet for 40 s.
Depth data	1 Hz sample rate; split dive into 1/10th intervals
Number of datapoints	36772
Covariate data available	POLTIPS tidal predictions

17 adult harbour seals were tagged at Islay in 2011 and 2012. These data were collected by the Sea Mammal Research Unit under contract to the Scottish Government and SNH. A full report on this study is not currently available although a basic analyses of the track information is currently in preparation (D. Thompson pers comm). A very basic presentation of the tracks was presented as part of the baseline environmental studies for Scottish Power Renewables' (SPR) Sound of Islay tidal array development. Seven seals were tagged at the SE Islay SAC in 2011, two at Bunnahabhain Bay in the north west of the Sound in 2011 and a further eight tagged at haul outs on the Islay coastline on the western side of the Sound of Islay – approximately 500m north of the proposed cable landfall site for the development (3 in 2011, 5 in 2012). Movements were a mixture of local movements between haul outs a few kms apart with a degree of interchange to other areas to the north of Islay with some seals from the Sound travelling as far afield as Mull and Tiree. Some individual seals demonstrated very high use of the Sound (e.g. Figure 4) and it is likely that this represents foraging activity in the Sound. An additional 8 tags were deployed in 2014; in general these data demonstrated similar patterns to the earlier deployments with individuals demonstrating high usage of the sound with some further afield movements between distant haul out (some as far as the outer Hebrides and the Mull of Kintyre). No analysis has been

carried out to date of fine scale temporal and spatial patterns in movements in relation to tide or other environmental covariates.

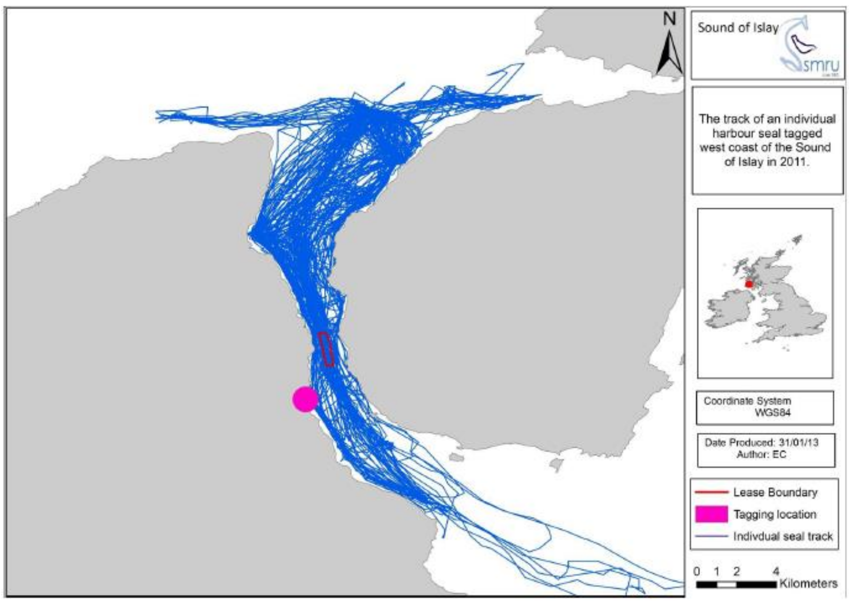

Figure 4. Example track of a seal tagged on the coast of Islay demonstrating relatively high use of the Sound. The red area shows the lease area for a proposed tidal array development.

3.2.1 Summary

Features of dataset which have relevance to strike risk:

- High inter-individual variability in use of tidal areas

Analyses to date and key findings:

- None

Potential future analyses/weaknesses of the dataset

- Data not fully analysed to understand behaviour in relation to tidal or other environmental covariates
- Interpolation between depth and location data difficult due to low sampling rate

3.3 Pentland Firth harbour seal telemetry dataset

Data	Description
Tagged animals	8 adult males, 2 juvenile males, 4 adult females
GPS data	GPS/GSM tags were programmed to attempt a GPS location every 10 minutes.
Haul Out data	The tag initiates a haulout record if the wet/dry sensor is continuously dry for 10 minutes. The record is terminated when the tag is continuously wet for 40 s.
Depth data	1 Hz sample rate; split dive into 1/10th intervals
Number of datapoints	53133
Covariate data available	High resolution bathymetry (25cm) for part of the Inner Sound, modelled tidal velocity (MeyGen project). POLTIPS tidal predictions.

Eight harbour seals were caught and tagged between 29th and 31th March 2011 and six were caught and tagged between the 24th and 26th September 2011 (Thompson, et al., 2014). Seals were caught at haulout sites in Gills Bay, the haulout sites closest to the proposed MeyGen tidal turbine array site in the Inner Sound. All bar two of the seals continued to use haulout sites close to their capture sites on the mainland coast and concentrated their foraging effort within high tidal energy area of the Pentland Firth. The two exceptions moved temporarily to haulout sites on the west coast of Orkney Mainland and spent their time foraging on the open shelf area to the west of Orkney. Preliminary examination of individual tracks and diving behaviour suggests that seals resident in the Pentland Firth dive mainly to the sea bed and spend a large proportion of their time transiting through the area very close to shore. Swimming tracks within the main channel of the Pentland Firth are clearly influenced by tidal flows. Tracks of foraging seals are similar to predicted tracks of inanimate objects floating with the tide. The majority of seals in the autumn/winter sample and all seals in the spring sample spent most of their time in the Pentland Firth and appeared to spend a substantial proportion of their time either in or close to the high tidal energy areas of the main channel. The two seals that moved to haulout site on the west side of Orkney spent very little time in high tidal energy areas, apparently only foraging in offshore waters with slight tidal flows.

The depth distribution data from the tags suggests that most if not all dives were to the seabed. Scaled use of the water column resulted in an estimated 18% time at surface, 30% at the bottom with the remainder spent transiting between, (1-2% at each 5% step in depth). These data were used to predict strike risk by plotting the rate of transit through the proposed turbine locations. Only 6% of the total number of crossings were within the boundary of the hypothetical array site and only 11% were included if the boundaries were extended by 200m on either side of the turbine array. However, it is clear from the fact that several crossing points had estimated depths that exceeded the local water depth that there is substantial interpolation error in the location of the dives and therefore also in the water depth estimates assigned to each dive.

In the analysis, any crossing that coincided with one of the proposed turbines (represented by a disc of 20m diameter positioned at the proposed turbine site, centred 15m above the seabed, giving 5m clearance between the blade tips and the sea bed, each disc was separated by 45m intervals) was assumed to represent a transit through the swept area of the turbine. These estimates of transit were then scaled to provide estimates of collisions. Models to date have assumed that movement is random with respect to the orientation of the turbines. These data were analysed to provide a frequency distribution of the bearings of the swimming tracks that passed through the turbine array, the resulting distribution was not uniform and is concentrated in two distinct directions – however as most angles were >25% the assumption was made that angle is relatively unimportant and time at risk is a function of body length and animal swim speed in relation to rotor speed.

This predicted transit rate combined with rotation rate of the turbine rotors allowed the calculation of the probability of a strike. The authors took the precautionary approach of assuming top speed across all operating conditions, which resulted in an average probability for a three bladed turbine of strike of 0.67 for each transit. The rates of transit through the swept area from the tagged sample were then scaled up to the local population size. This resulted in an estimate of 155 passes through a turbine, or 1.8 seals passing through each turbine per year. Combining this with the collision probability provides an estimate of 1.2 collisions per turbine per year and a total of 104 collisions per year (approx. 95% ci 66-171). The SRSL model for the array development were much higher – between 6.5 and 7.7 seals per year depending on which datasets were used to estimate local density.

The data presented in this study clearly shows that the assumptions generally made in collision risk estimates of uniform distribution and random movement relative to turbines do not hold within the Inner Sound. Telemetry data from harbour seals at locations around the UK suggest that such assumptions will be unrealistic in any area and may be particularly unlikely to provide a useful description of seal behaviour in areas of high tidal energy.

3.3.1 Summary

Features of dataset which have relevance to strike risk:

- High inter-individual variability in use of tidal areas
- Most dives to the seabed

Analyses to date and key findings:

- Assumption of uniform distribution resulted in large overestimates of collision risk compared to using telemetry derived transit rates.
- The assumption generally adopted in collision risk models that transit angles are random with respect to the orientation of the turbine was not borne out by these data.

Potential future analyses/weaknesses of the dataset

- Estimates of collision risk could be refined further by incorporating a variable rotor speed in relation to the tidal cycle
- Data not fully analysed to understand behaviour in relation to tidal or other environmental covariates
- Uncertainty in track interpolation between subsequent locations due to low sampling rate – means that assigning a precise location to each depth is difficult and that there may be errors in transit locations and, approach angles and speeds.

3.4 Kyle Rhea harbour seal telemetry dataset

Data	Description
Tagged animals	6 adult males, 3 adult females
GPS data	GPS/GSM tags were programmed to attempt a GPS location every 10 minutes.
Haul Out data	The tag initiates a haulout record if the wet/dry sensor is continuously dry for 10 minutes. The record is terminated when the tag is continuously wet for 40 s.
Depth data	1 Hz sample rate; split dive into 1/10th intervals
Number of datapoints	25116
Covariate data available	SEAZONE-TRUDEPTH bathymetry data. POLTIPS tidal predictions

Kyle Rhea is a narrow channel or sound between mainland Scotland and the Isle of Skye. Seals were only present in the sound between April and August; no seals are recorded there the rest of the year. Nine harbour seals were tagged with GPS/GSM tags in 2012 - all were captured at haul out sites within Kyle Rhea (Thompson, 2013). Six animals were male, 3 female, weighed between 72 and 87 kg. These seals showed very intensive use of the sound, a total of 57% of all location fixes were within the channel. There was an extremely high density of tracks of animals foraging within the channel – an average of 2.2 transits per seal per day, although there was high individual variability with the maximum being 4.4 transits per day and the minimum 0.22 per day (not as variable as Strangford).

Within the Kyle Rhea narrows dives were restricted to depth of less than 40m, consistent with the local bathymetry in Kyle Rhea. In most dives the majority of time was spent at or close to the max depth (40%) or at the surface (20%) with rapid transit between the two. The extensive (in some cases exclusive) use of tidal race areas, seeming to move forwards and backwards with the tide and repeatedly diving to or close to the bottom suggests that the seals were using the tidal rapids for foraging. Individual dive profile plots appear to show that the majority of dive activity within the channel occurred on the flood tide.

3.4.1 Summary

Features of dataset which have relevance to strike risk:

- Very intensive use of the area of high tidal flow, particularly on the flood tide, by many individuals
- Highly seasonal presence in the sound, only present April to August
- Most dives to the seabed

Potential future analyses/weaknesses of the dataset

- Could compare collision risk estimates derived using telemetry data with those assuming uniform density – would be informative to see whether net result would be over or underestimation given variability in use over the tidal cycle and seasonal variation in abundance.

- Uncertainty in track interpolation between subsequent locations due to low sampling rate – means that assigning a precise location to each depth is difficult and that there may be errors in transit locations and, approach angles and speeds.

3.5 Welsh studies of juvenile grey seals

Data	Description
Tagged animals	All juveniles 2009: 2 males, 3 females 2010: 6 males, 9 females
GPS data	GPS/GSM tags were programmed to attempt a GPS location every 30 minutes.
Haul Out data	The tag initiates a haulout record if the wet/dry sensor is continuously dry for 10 minutes. The record is terminated when the tag is continuously wet for 40 s.
Depth data	1 Hz sample rate; split dive into 1/10th intervals
Number of datapoints	27153 in 2009, 106899 in 2010
Covariate data available	POLTIPS tidal predictions

Five weaned grey seal pups were tagged in Wales in 2009 (3 at the Skerries Island off the coast of Anglesey and 2 at Bardsey Island) and an additional 15 were tagged in 2010 (5 at the Skerries and 10 on Ramsey Island in Pembrokeshire) (Thompson, 2011). In 2009 detailed movement and dive behaviour records were received from all five tagged seals. Tracking periods lasted 234, 216, 183, 63 and 14 days. Continuous dive data were received for all five seals. In 2010 highly detailed movement and dive behaviour records were received from all five seals tagged at the Skerries and seven of the ten seals tagged at Ramsey. The movement patterns were similar in both years in that they showed a high degree of variability in both the extent of movement and the timing of the long range movements.
All tagged pups spent first month or so in waters close to breeding beaches, spending most of this time in tidal areas, drifting with the current and repeatedly diving to the bottom in a pattern characteristic of foraging. In several cases seals travelled further afield and found other high tidal current areas and appeared to drift and forage within these in a similar way. There was a wide variation in transit rate through tidal areas between individuals, for example, although most seals did transit through the tidal rapids, one seal at each of the sites performed approximately 70% of the transits. As is the case with the harbour seals where this individual variation was also high, this translates into a wide variation in the likely exposure to collision risk.

3.5.1 Summary

Features of dataset which have relevance to strike risk:

- Some individuals demonstrating intensive use of areas of high tidal flow
- Most dives to the seabed

Potential future analyses/weaknesses of the dataset

- Uncertainty in track interpolation between subsequent locations due to low sampling rate – means that assigning a precise location to each depth is difficult and that there may be errors in transit location estimates.

4 Synthesis

There were a number of features that were common across the seal data sets:

- High inter-individual variation in use of tidal areas– risk not equal across all individuals, suggests that there may be 'specialist' tidal rapid seals, (apart from at Kyle Rhea where a high proportion of seams appear to be tidal 'specialists').
- Tidal variation in local abundance – risk not equal over tidal cycle.
- Depth distributions very similar across all studies – patterns consistent with benthic dives where majority of time spent at the seabed or at the surface, relatively little time transiting between the two and very little mid water foraging. Therefore the adoption of a single proportional depth distribution, scaled by site specific depth will be applicable across most sites.

There were also features that were site specific:

- At Kyle Rhea all tagged seals demonstrated high use of the tidal current.
- Patterns of activity in relation to the tidal cycle varied between the sites where it has been characterised – e.g. more activity on flood tide at Kyle Rhea.
- Seasonal variation in use of tidal areas – seals present most of the year (Pentland Firth) compared to a very seasonal presence (Kyle Rhea).

Future analyses

More detailed analyses of activity in relation to tidal covariates would be useful to understand patterns at a wider range of sites and help to understand how collision risk models could be refined to take these patterns into account. It will also be important to know for predictive purposes whether generalised predictions are possible or whether site specific understanding is required each time. SMRU aims to carry out similar analyses using the Kyle Rhea and Sound of Islay data to those carried out with the Pentland Firth telemetry data to examine the effect of incorporating site specific telemetry data on collision rate estimates.

SMRU and SMRU Consulting are now working on a project with Marine Scotland which will involve the refinement of collision risk models based on the findings from these datasets. Key remaining uncertainties are the degree of avoidance, evasion and attraction to operating turbines. GPS/GSM tags may not allow data collection at the best resolution for understanding close range evasion but avoidance and attraction may be measurable – the Strangford dataset provides the best dataset for looking at this presently.

5 References

Lonergan, M. Sparling, C.E. & McConnell, B (In review). Behaviour of harbour seals (Phoca vitulina) around an operational tidal turbine

McConnell, B. & Isojunno, S. (2009). Seal tagging: Strangford Lough. SMRU Ltd report to Marine Current Turbines.

Thompson, D. (2011) Annex I: Movements and Diving behaviour of juvenile grey seals in areas of high tidal energy. JER3688. Report to the Welsh Government.

Thompson, D. (2013). Harbour Seal Behaviour in Kyle Rhea. Sea Mammal Research Unit Report to Scottish Natural Heritage and Marine Scotland.

Thompson, D., Onoufriou, J., Brownlow, A., & Morris, C. (2014). Data based estimates of collision risk: an example based on harbour seal tracking data around a proposed tidal turbine array in the Pentland Firth. Sea Mammal Research Unit Report to Scottish Natural Heritage and Marine Scotland.