Chapter 12

Seasonal and geographical variation of harbour porpoise (*Phocoena phocoena*) habitat use in the German Baltic Sea monitored by passive acoustic methods (PODs)

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Abstract

Harbour porpoises (*Phocoena phocoena*) were known to be common in the Baltic Sea. In the past several decades, the abundance and distribution has decreased, leading to national and international agreements on the protection of this species. Plans for offshore windmill constructions and proposals for Marine Protected Areas (MPAs) to implement NATURA 2000, led to an increased research effort on the harbour porpoise in the German Exclusive Economic Zones (EEZs) of the North and Baltic Sea. Within this scope, the harbour porpoise habitat use of the German Baltic Sea from Fehmarn to the *Pommeranian Bay* (*Pommersche Bucht*) was investigated with the help of self-contained submersible data logger (Porpoise detectors, T-PODs), which register harbour porpoise echolocation click trains.

Comparison of the T-POD data from different measuring stations located throughout the Baltic Sea revealed a decrease of porpoise registrations from the west of the island of Fehmarn to the east of the island of Rügen. Seasonal variation of habitat use, and therefore of relative porpoise density, was seen around the island of Fehmarn and the *Kadet Trench* (*Kadetrinne*), with many days of porpoise registrations in the summer and fewer registration days in the winter months.

The results prove the regular use of the western part of the German EEZ of the Baltic Sea by harbour porpoises from Fehmarn to the *Kadet Trench* including adjacent coastal waters. The low amount of porpoise registrations east of the *Darss Sill* (*Darsser Schwelle*) allows the assumption of a low harbour porpoise density in the eastern part of the German Baltic

Sea. Furthermore, a clear seasonal variation in the amount of porpoise registration proves porpoise migration out of the western part of the German Baltic Sea in wintertime.

1 Introduction

Harbour porpoises (*Phocoena phocoena*) have been very common in the North Sea and Baltic Sea up to the middle of the 20th century (Schulze 1996). In the past several decades, a drastic decrease in their population size – as indicated for some areas (Benke and Siebert 1994, Kinze 1995, Kröger 1986, Reijnders 1992, Siebert et al. 1996) – has led to the endangerment of the porpoise population (e.g., ICES/ACME 1997). Harbour porpoises are now protected by a variety of national and international laws and agreements: ASCOBANS, HELCOM, OSPARCOM, and Red list of mammals, Germany (Boye et al. 1998).

Former research on abundance and distribution of harbour porpoises (Benke et al. 1998, Hammond et al. 2002, Heide Jørgensen et al. 1993, Sonntag et al. 1999) gave neither a complete picture of the distribution pattern nor any information on seasonality in the German Baltic Sea. Therefore, plans for constructing offshore wind farms and proposals for MPAs to implement the European habitat directive NATURA 2000 led to an increased research effort on the harbour porpoise in Germany. Recent aerial surveys investigated the spatial distribution of harbour porpoises in the German part of the North and Baltic Sea (see chapter 11). Parallel to this, passive acoustic monitoring devices T-PODs (Porpoise Detectors) were deployed permanently on measuring positions throughout the German Baltic Sea from Fehmarn to the *Pommeranian Bay*.

The harbour porpoise, like other odontocete species, emit short-pulsed high frequency click sounds for echolocation (Au 1993). As an active sensory system, echolocation in porpoises is used for orientation as well as for foraging (Verfuß and Schnitzler 2002). Harbour porpoise echolocation clicks are very distinct and different from most dolphin echolocation clicks (Au 1993). Their main energy is focused on a small frequency bandwidth around 130 kHz (Goodson et al. 1995, Kamminga et al. 1999). The method of passive acoustic monitoring with T-PODs takes advantage of the highly specialised sonar system of porpoises. The distinct and easily distinguishable click structure provides a good opportunity to set up an automatic system that specifically monitors this species.

The advantage of this kind of acoustic monitoring is that, in contrast to aerial surveys which use snapshots of harbour porpoise sightings to determine distribution and abundance, T-PODs are for long-term deployment. They register the presence of harbour porpoises over months.

This paper presents the results of the first year (August 2002 to August 2003) of continuous monitoring for harbour porpoise echolocation activity in most parts of the German Baltic Sea.

2 Methods

2.1 Methodology

T-PODs are self-contained data loggers for cetacean echolocation clicks (for details, see www.chelonia.demon.co.uk/PODhome.html), consisting of a hydrophone, filter, and memory (figure 1). They register, in a 10-µsec resolution, the presence and length of high frequency click sounds matching specific criteria, logging for 24 hours a day for a period of eight to ten weeks. After this period, the data are downloaded and batteries have to be replaced.

Figure 1. A T-POD moored under water

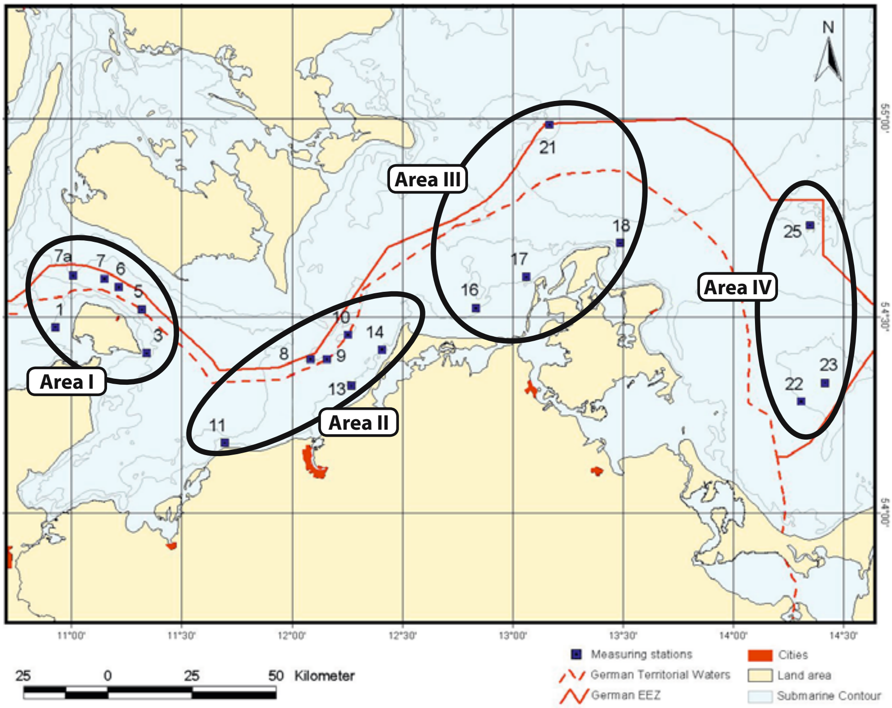

Figure 2. Locations of all utilised T-POD measuring stations in the Baltic Sea. The area of investigation was divided into four sub-areas (black circles): area I: stations 1, 3, 5–7a; area II: stations 8–11, 13, 14; area III: stations 16–18, 21; area IV: stations 22, 23, 25

2.2 T-POD application

Nineteen (19) measuring positions were selected to monitor the German Baltic Sea from Fehmarn to the *Pommeranian Bay* (figure 2). On each measuring position, one T-POD at a time was deployed on a mooring, fixed five to seven metres under the water surface. T-PODs of versions 2 and 3 were used. The mooring consisted of a 30-kg anchor connected to several surface buoys via a rope (figure 3).

The listening criteria of the T-PODs were set to "porpoise-only high sensitivity" as given in the T-POD programme (T-POD version 2: filter A = 130 kHz, filter B = 90 kHz, ratio A/B = 4, 'A' filter sharpness = 10, 'B' filter sharpness = 18, minimum intensity = 6, scan limit on number (N) of clicks logged = 240; T-POD version 3: filter A = 130 kHz, filter B = 90 kHz, ratio A/ B = 4, 'A' integration period = short, 'B' integration period = long, minimum

Figure 3. Surface markers of a T-POD mooring in the Baltic Sea

intensity = 6, scan limit on N clicks logged = 240). Where background noise did not allow these settings, the ratio A/B was set to 6, which reduced the registration of high frequency background noise. This change in the settings affected neither the sensitivity nor the comparability of the gathered data (Verfuß et al. 2004a). Data recorded with version 2 T-PODs were comparable with the data of version 3 T-PODs (Verfuß et al. 2004b).

The T-PODs were calibrated before deployment to determine the minimum receiving level of each T-POD. This is the level at which the device will start to register porpoise clicks. The minimum receiving level of the deployed T-PODs was in the range of 117 dB re 1 $V_{(pp)}$/µPa up to 144 dB re 1 $V_{(pp)}$/µPa. Lower receiving level means a more sensitive T-POD and vice versa.

2.3 Data analysis

The click sounds registered from the T-PODs were scanned for trains of clicks with a specific signal pattern by means of a Train Detection algorithm (V2.2), which was included in the T-POD software. Click trains classified by the algorithm as ″high probability cetacean click trains″ up to ″very doubtful trains″ originated from harbour porpoises, boat noise (e.g., sonar, propeller noise), or background noise. Those click trains were manually reviewed for harbour porpoise echolocation click trains as described in Verfuß et al. (2004a, 2004b). Click trains classified by the algorithm, and which were then manually attributed to porpoise origin, were included in the data set. Those that were manually attributed to other sources were rejected.

For further analysis, porpoise-positive days, defined as a day with at least one classified porpoise click train, were determined from all data recordings. The percentage of porpoise-positive days in the number of monitored days per month was calculated for each position. Months with less than five monitoring days were ignored.

The monitored area of the German Baltic Sea was divided into four sections each with the following T-POD positions:

- Area I: positions 1 to 7: western part of the German Baltic Sea, area around Fehmarn island
- Area II: positions 8 to 14: western part of the German Baltic Sea, *Kadet Trench* and adjacent coastal area
- Area III: positions 16 to 21: eastern part of the German Baltic Sea, area north of Darss and around Rügen island including EEZ
- Area IV: positions 22 to 25: eastern part of the German Baltic Sea, *Pommeranian Bay*

The mean of the percentages of porpoise-positive days per month from the included positions was calculated for each of the four areas.

2.4 Influence of T-POD sensitivity

An earlier work by the present authors (Verfuß et al. 2004b) showed that the difference in T-POD sensitivity of applied T-PODs could have an influence in the comparability of gathered data. Several T-PODs were simultaneously deployed in an area with high porpoise abundance. Those T-PODs had a range of sensitivities, comparable to the sensitivity range of the T-PODs used in this investigation. Analysis of porpoise-positive hours (i.e., hours with at least one porpoise registration), revealed a linear relationship between this parameter and the T-POD sensitivity. It was concluded that using the parameter of porpoise-positive days will have less influence on the data comparability since it does not depend on the amount of porpoise-positive hours whether a day is porpoise-positive or not.

To test for differences between areas while simultaneously controlling for T-POD sensitivity, an ANCOVA[1] was used. Since the data were not normally distributed, we applied this model to the original data as well as to the ranked data. The interaction between the covariate (T-POD sensitivity) and the factor (area) was initially included into the model. Since in both analyses the interaction term was not significant ($F_{3,107} \leq 1.498$, $P \geq 0.219$), we removed the interaction term from the model in both cases. Here we only report the results with the interaction term removed.

[1] ANCOVA: Statistical analysis of covariance which simultaneously considers the effect of two independent variables – one varying categorical, and the other one varying continuously – on a dependent variable (simplest model).

3 Results

Table 1 (overleaf) shows an overview of the number of monitored days per month and the corresponding percentage of porpoise-positive days per month for each T-POD position, as well as the sensitivity of the applied T-POD during the specific month. None of the positions were monitored for the entire time due to logistical reasons and to loss of moorings, in some cases. The total amount of observed days is indicated.

We found no significant relation between T-POD sensitivity and the percentage of porpoise-positive days per month (unranked data: $F_{1,110} = 0.488$, $P = 0.486$; ranked data: $F_{1,110} = 0.038$, $P = 0.846$). Areas clearly differed in the percentage of porpoise-positive days per month (unranked data: $F_{3,110} = 92.263$, $P<0.001$; ranked data: $F_{3,110} = 69.475$, $P<0.001$).

The results show a geographical as well as a seasonal variation in the percentage of porpoise-positive days from the total number of days on which data were obtained (figure 4):

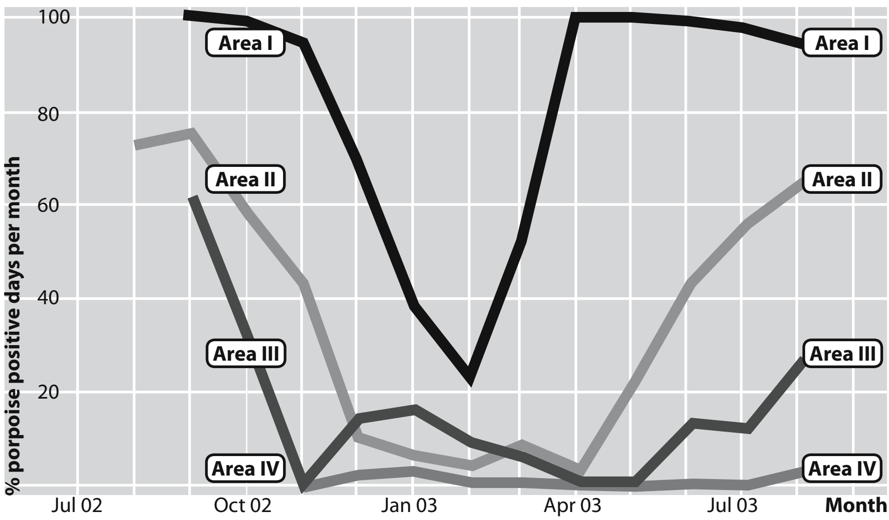

Figure 4. Mean percentage of porpoise-positive days per month for area I to area IV over a one-year period (August 2002 to August 2003). Measuring stations included: area I: stations 1, 3, 5–7a; area II: stations 8–11, 13, 14; area III: stations 16–18, 21; area IV: stations 22, 23, 25.

Table 1. An overview of the number of monitored days per month and the corresponding percentage of porpoise-positive days per month for each T-POD position, as well as the sensitivity of the applied T-POD during the specific month

		2002											
		Aug			Sep			Oct			Nov		
		obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity
Area I	**1**							9	100.0	119.3	30	96.7	119.3
	3							9	100.0	117	30	90.0	117
	5							23	95.6	121	18	100.0	121
	6										18	94.4	121.7
	7a												
	7				19	100.0	118.1	17	100.0	118.1			
	n/aver.	**n = 0**			**n = 1**	aver. 100.0		**n = 4**	aver. 98.9		**n = 4**	aver. 95.3	
Area II	**8**	31	64.5	146	30	80.0	146	31	58.1	146	30	73.3	146
	9	31	64.5	144.2	30	73.3	144.2	22	45.5	144.2			
	10	31	77.4	140	30	66.7	140	31	64.5	140			
	11				18	77.8	120	19	52.6	120	8	12.5	120
	13				18	83.3	119.1	16	62.6	119.1			
	14	31	83.9	127.7	15	72.0	124.95	16	62.5	122.2			
	n/aver.	**n = 4**	aver. 72.6		**n = 6**	aver. 75.5		**n = 6**	aver. 57.6		**n = 2**	aver. 42.9	
Area III	**16**												
	17				13	61.5	127.7	30	33.3	127.7			
	18							10	30.0	123.1	30	0.0	123.1
	21												
	n/aver.	**n = 0**			**n = 1**	aver. 61.5		**n = 2**	aver. 31.7		**n = 1**	aver. 0.0	
Area IV	**22**												
	23										15	0.0	117.2
	25										16	0.0	127.7
	n/aver.	**n = 0**			**n = 0**			**n = 0**			**n = 2**	aver. 0.0	

Note

n = total number of T-PODs applied in each area during a specific month
aver. = average percentage of porpoise-positive (pp) days per month in a specific area

		2002 continued					2003					
		Dec			Total	Total	Jan			Feb		
		obs days	pp days (%)	T-POD-sensitivity	2002 obs days total	2002 pp days total (%)	obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity
Area I	**1**	31	41.9	119.3	**70**	**79.5**	13	38.5	119.3	26	23.1	117
	3	17	52.9	117	**56**	**81.0**						
	5	18	88.9	121	**59**	**94.8**						
	6	18	94.4	121.7	**36**	**94.4**						
	7a											
	7				**36**	**100.0**						
	n/aver.	**n =** 4	aver. 69.6		**n =** 5	aver. 90.0	**n =** 1	aver. 38.5		**n =** 1	aver. 23.1	
Area II	**8**	31	19.4	146	**153**	**59.1**	31	3.2	146	28	3.6	146
	9				**83**	**61.1**						
	10				**96**	**69.5**						
	11	31	0.0	120	**76**	**35.7**	11	9.1	120			
	13				**34**	**72.9**						
	14				**66**	**72.8**						
	n/aver.	**n =** 2	aver. 9.7		**n =** 6	aver. 61.9	**n =** 2	aver. 6.2		**n =** 1	aver. 3.6	
Area III	**16**											
	17				**43**	**47.4**						
	18	31	22.6	123.1	**71**	**17.5**	31	9.7	123.1	28	3.6	123.1
	21	19	5.3	128.9	**19**	**5.3**	31	22.6	128.9	28	14.3	128.9
	n/aver.	**n =** 2	aver. 13.9		**n =** 3	aver. 23.4	**n =** 2	aver. 16.1		**n =** 2	aver. 8.9	
Area IV	**22**											
	23	26	0.0	130.7	**41**	**0.0**	31	0.0	144.2	28	0.0	144.2
	25	31	3.2	127.7	**47**	**1.6**	31	6.5	127.7	28	0.0	127.7
	n/aver.	**n =** 2	aver. 1.6		**n =** 2	aver. 0.8	**n =** 2	aver. 3.2		**n =** 2	aver. 0.0	

Table 1 continued. An overview of the number of monitored days per month and the corresponding percentage of porpoise-positive days per month for each T-POD position, as well as the sensitivity of the applied T-POD during the specific month

		2003 continued								
		Mar			Apr			May		
		obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity
Area I	**1**	31	51.6	117	30	100.0	117	31	100.0	117
	3									
	5				16	100.0	121	31	100.0	121
	6				16	100.0	118.1	31	100.0	119.9
	7a				16	100.0	125	31	100.0	125
	7									
	n/aver.	**n =** **1**	aver. 51.6		**n =** **4**	aver. 100.0		**n =** **4**	aver. 100.0	
Area II	**8**	12	16.7	146						
	9									
	10	14	7.1	126.2	30	6.7	126.2	31	12.9	126.2
	11									
	13									
	14	14	0.0	126.9	30	0.0	126.9	16	31.3	126.9
	n/aver.	**n =** **3**	aver. 7.9		**n =** **2**	aver. 3.3		**n =** **2**	aver. 22.1	
Area III	**16**							6	0.0	118.1
	17				5	0.0	129	31	0.0	129
	18	18	11.1	123.1	30	0.0	123.1	31	3.2	123.1
	21	10	0.0	128.9	30	0.0	128.9	31	0.0	128.9
	n/aver.	**n =** **2**	aver. 5.5		**n =** **3**	aver. 0.0		**n =** **4**	aver. 0.8	
Area IV	**22**									
	23	31	0.0	144.2	30	0.0	144.2	31	0.0	144.2
	25	31	0.0	127.7	30	0.0%	127.7	31	0.0	127.7
	n/aver.	**n =** **2**	aver. 0.0		**n =** **2**	aver. 0.0		**n =** **2**	aver. 0.0	

Note

n = total number of T-PODs applied in each area during a specific month
aver. = average percentage of porpoise-positive (pp) days per month in a specific area

		2003 continued										
		Jun			Jul			Aug			Total	Total
		obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD-sensitivity	obs days	pp days (%)	T-POD -sensitivity	2003 obs days total	2003 pp days total (%)
Area I	**1**	20	100.0	117	14	100.0	125	31	100.0	125	**196**	**76.6**
	3											
	5	30	100.0	121	31	96.8	121	31	90.3	121	**139**	**97.4**
	6	30	100.0	121.7				17	94.1	126	**96**	**98.5**
	7a	30	96.7	125							**79**	**98.9**
	7											
	n/aver.	**n =** **4**	aver. 99.2		**n =** **2**	aver. 98.4		**n =** **3**	aver. 94.8		**n =** **4**	aver. 75.7
Area II	**8**				11	54.5	126.2	31	48.4	126.2	**113**	**25.3**
	9											
	10	30	43.3	126.2	31	61.3	126.2	31	77.4	126.2	**167**	**34.8**
	11				11	36.4	126.9	15	53.3	126.9	**37**	**32.9**
	13											
	14				17	70.6	121.7	23	82.6	121.7	**100**	**36.9**
	n/aver.	**n =** **1**	aver. 43.3		**n =** **4**	aver. 55.7		**n =** **4**	aver. 65.4		**n =** **4**	aver. 32.5
Area III	**16**	30	23.3	118.1	31	29.0	118.1	27	40.7	118.1	**94**	**23.3**
	17	30	13.3	129	20	10.0	129	28	39.3	129	**118**	**12.5**
	18	29	13.8	123.1	31	6.5	123.1	31	19.4	123.1	**229**	**8.4**
	21	30	0.0	128.9	31	3.2	128.9	31	9.7	128.9	**222**	**6.2**
	n/aver.	**n =** **4**	aver. 12.6		**n =** **4**	aver. 12.2		**n =** **4**	aver. 27.3		**n =** **4**	aver. 12.6
Area IV	**22**				16	0.0	122.6	31	3.2	122.6	**47**	**1.6**
	23	30	0.0	144.2	14	0.0	144.2				**195**	**0.0**
	25	11	0.0	127.7							**162**	**1.1**
	n/aver.	**n =** **2**	aver. 0.0		**n =** **2**	aver. 0.0		**n =** **1**	aver. 3.2		**n =** **3**	aver. 0.9

In area I, the average percentage of porpoise-positive days per month was around 100% in September to November 2002, and in April to August 2003. It dropped to 70% in December 2002, to 39% in January 2003, and had its minimum of 23% in February 2003. In March 2003 the average percentage of porpoise-positive days per month rose to 52%.

In area II, the average percentage of porpoise-positive days per month was above 70% in August and September 2002; it declined to values below 10% for December 2002 to April 2003, and rose again above 60% until August 2003.

In area III, the average percentage of porpoise-positive days per month started with 62% in September 2002, dropped and stayed below 20% from November 2002 to July 2003, with minimum values for November 2002 and April/May 2003, and a rise in the winter months of 2002/2003.

In area IV, the average percentage of porpoise-positive days per month was near 0%, with one or two porpoise-positive days (resulting in up to 3%) in December 2002, as well as in January and August 2003.

4 Discussion

Our results show a clear decrease in the percentage of porpoise-positive days per month from the western part of the German Baltic Sea around Fehmarn to the eastern part up to the *Pommeranian Bay*, as well as seasonal changes around Fehmarn (area I) and in the *Kadet Trench* and adjacent coastal waters (area II). Verfuß et al. (2005) showed the importance of echolocation for harbour porpoises. Porpoises which were living in a well-known, semi-natural outdoor pool, permanently used echolocation even in easy orientation tasks during daylight regardless of the season. Therefore, a regular use of echolocation by harbour porpoises is likely. The changes in the amount of porpoise registrations in the course of the year and differences across areas are assumed to be caused by temporal changes and geographical differences in harbour porpoise density.

A decrease in harbour porpoise density from west to east in the German Baltic Sea is also confirmed by aerial surveys in 2002 and 2003 (see chapter 11). During the 2002 surveys, when Scheidat et al. (2004) observed aggregations of harbour porpoises in the *Pommeranian Bay*, no T-POD was deployed in this area. T-PODs deployed from November 2002 onwards showed only a few harbour porpoise registrations. Scheidat et al. (2004) registered no sighting in the *Pommeranian Bay* during their surveys after September 2002.

Morphological and genetic studies revealed the existence of a separate subpopulation of harbour porpoises in the Baltic proper, i.e., east of *Darss Sill* (*Darsser Schwelle*) (Huggenberger et al. 2002, Tiedemann et al. 2001). Low density of this subpopulation (see chapter 11) raises deep concern for the survival of the population, which is especially emphasised in the recovery plan for Baltic harbour porpoises (Jastarnia Plan, ASCOBANS). The T-POD data confirm a very low density of harbour porpoises in the German part of the Baltic proper. Any negative anthropogenic influence (e.g., incidental fishery by-catch, chemical or noise pollution) on this very small and therefore highly endangered subpopulation might sooner or later lead to its extinction.

Until the mid-20th century, migration of harbour porpoises was assumed for the North and Baltic Sea (reviewed in Koschinski 2003). In spring, the porpoises were thought to have followed movements of herring, passing Danish waters into the Baltic Sea. In late autumn and winter, when the Baltic tended to freeze over in some years, the porpoises may have migrated back out of the Baltic Sea. Nowadays, the porpoise stocks are too small to easily prove such migrations. Teilmann et al. (2004) could prove seasonality in the use of areas in Danish waters with the help of satellite tags on porpoises. Siebert et al. (in preparation) showed seasonality in incidental sightings and stranding rates in the German Baltic Sea, with a peak in the summer months. The data of incidental sightings might be biased by a lower effort in winter (e.g., less sailing boats), whereas stranding events can be biased by a longer submersion time of carcasses when water temperature is low (Moreno 1993, in Siebert et al. in preparation). The T-PODs proved seasonal changes in the use of the Baltic Sea areas around Fehmarn and the *Kadet Trench*.

The method of T-POD deployment proved to be a valuable tool for investigating the habitat use by harbour porpoises of the German Baltic Sea in a temporal and geographical scale. The results of this work revealed a regular use of the area around Fehmarn and the *Kadet Trench* for harbour porpoises in German waters. This showed the importance of these areas for these animals in Germany. A continuation of T-POD deployment, like the one presented in this study is necessary to confirm the revealed seasonal changes and geographical differences in harbour porpoise registrations, which is assumed to reflect differences in harbour porpoise densities. As a future goal, the inclusion of the *Kiel Bight* (*Kieler Bucht*) and the area around the island of Usedom is important for receiving a complete picture of the use of the German Baltic Sea by harbour porpoises. For investigating the highly endangered harbour porpoise subpopulation of the Baltic proper, the use of T-PODs has to be extended within the *Pommeranian Bay* by adding more T-POD measuring stations.

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