Chapter 95
The Use of Deep Water Berths and the Effect of Noise on Bottlenose Dolphins in the Shannon Estuary cSAC

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Abstract The Shannon Estuary on the west coast of Ireland is one of Europe's premier deepwater berths catering for ships up to 200,000 deadweight tonnage. It is also Ireland's only designated candidate special area of conservation for bottlenose dolphins under the EU Habitats Directive. Long-term static acoustic monitoring was carried out at a number of intensive shipping sites. In 2012, noise monitoring took place over a 6-month period (at 1 site) as part of Ireland's requirements under the Marine Strategy Framework Directive (MSFD). This is the first assessment of the potential effect of vessel traffic on the behavior of this discrete dolphin population.

Keywords Noise monitoring • Special area of conservation • Shipping • LIDO • Marine Strategy Framework Directive

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1 Introduction

Ocean noise has always existed in both natural and biological forms, including natural geophysical sounds, precipitation, wave action, lightning, cracking ice, and undersea earthquakes. The dominant source of natural geophysical noise at low frequencies is wave action (National Research Council 2003). This can increase ocean noise levels by more than 20 dB in the 10-Hz to 10-kHz frequency band (Wilson et al. 1985). Biological noise is also emitted into the marine environment from a number of marine taxa. One of the most well-studied and notable biological contributions to marine noise comes from marine mammal vocalizations. These sounds cover a very wide range of frequencies, with dominant components between 20 Hz and 20 kHz (Richardson et al. 1995). Sources of anthropogenic noise that have come under recent scrutiny can include noise emitted from shipping, seismic, and geophysical surveying; construction; drilling and production; dredging; sonar systems; acoustic deterrents; and, more recently, the construction and operation of renewable energy platforms. For assessment purposes, anthropogenic noise sources are often characterized as impulsive if their duration is brief or continuous if the noise source persists for a prolonged time (Richardson et al. 1995). Shipping is a known continuous anthropogenic noise source and has been reported as the dominant source of anthropogenic sound in a broadband range from 5 to 300 Hz (National Research Council 2005), with the main cause of noise being propeller cavitation (Richardson et al. 1995). Characteristics of shipping noise, including frequency and source level, are roughly related to vessel size and speed, although this relationship is further complicated by vessel design and advances in ship technology (Richardson et al. 1995). Anthropogenic ocean noise can elicit a range of physical, physiological, and behavioral effects on the marine fauna.

A number of existing laws relevant to Ireland are in place to assess and mitigate the impacts of anthropogenic noise in the marine environment. The most relevant and recent EU legislation is the Marine Strategy Framework Directive (MSFD). The main aim of the MSFD is that Europe's seas achieve good environmental status (GES) by 2020. Under this directive, member states hope to reach a balance between utilizing the ocean as a natural resource and the ability to achieve and maintain good environmental status for marine waters. A problem faced by conservation actions is a lack of information about the effects of anthropogenic sound on marine species, which will enable member states to determine whether GES has been achieved.

The Shannon Estuary on the west coast of Ireland is an important habitat for *Tursiops truncatus* (bottlenose dolphin). It houses Ireland's only long-term resident group of dolphins and is currently the only designated candidate special area of conservation (cSAC; Lower River Shannon, site code 2165) for this species. Genetic and abundance studies of this population have found that it may be genetically discrete from other coastal dolphins and thus of a very high conservation value (Mirimin et al. 2011). The most recent abundance of estimate in the estuary was 107 individuals (95% CI = 83–131; Berrow et al. 2012).

The Shannon Estuary is also one of Europe's premier deepwater berths catering to ships up to 200,000 deadweight tonnage. It has six main terminals and handles up to 1,000 ships carrying 12 million tons of cargo per annum (Anon 2012). Additionally, a car and passenger ferry operates all year-round between Killimer, County Clare, and Tarbert, County Kerry, and the estuary also has two licensed dolphin-watching vessels operating between April and October. Fishing activity also takes place in the estuary, with potting being the most notable. Additionally, a significant number of pleasure crafts exist year-round in the estuary. Hence, this is an area exposed to high levels of anthropogenic noise from a range of vessel activity. The acoustic signature of a vessel depends on a number of characteristics including gross tonnage, draft, operating equipment, speed, and sea state (McKenna et al. 2012; OSPAR 2012). Small ships tend to be quieter at low frequencies but can approach or exceed noise levels of larger ships at higher frequencies (Hildebrand 2005). Source levels for vessels, in decibels re 1 μPa at 1 m, range from 140 dB for small fishing vessels to 195 dB for super tankers (Hildebrand 2005).

Tursiops truncatus have developed a sonar system whereby they use echolocation to extract information about objects' characteristics directly from returning echoes (Harley et al. 2003). Bottlenose dolphin's echolocation clicks are broadband, with a frequency range of between 200 Hz and 150 kHz, with a peak energy of 30–60 kHz and a source of level between 40 and 80 dB re 1 mbar at 1 m (Evans 1973). Although the noise from shipping is at a lower frequency and more likely to impact on baleen whales, it adds to the ambient noise levels of an area. Behavioral changes by *Tursiops* have been observed worldwide in response to vessel traffic, especially from smaller pleasure craft. Evans et al. (1992) found that pleasure craft traffic had an effect on the dive times of *Tursiops* in Cardigan Bay by avoiding approaching vessels, noting that quieter faster boats caused more disturbance than larger slower moving boats. In the Moray Firth, Hastie et al. (2003) noted increased breathing synchrony between group members in response to heavy boat traffic. While in New Zealand, vertical avoidance of tour boats coupled with an increase in time spent underwater was reported by Lusseau (2003).

Long-term static acoustic monitoring (SAM) of *Tursiops truncatus* in deepwater berths in the estuary has been ongoing under a strategic integrated framework plan (SIFP). This is an interjurisdictional land- and marine-based framework plan to guide the future development and management of the area. A strategic environmental assessment (SEA) and appropriate assessment (AA) were carried out to guide and inform the process. Additionally, to address Ireland's legislative requirements under the MSFD, a long-term (6-months) noise-monitoring network using the LIDO system supplied by Laboratory of Applied Bioacoustics (LAB-UPC, Spain), was deployed at Tarbert Jetty, County Kerry, as part of an EPA-funded program. This program was designed to test noise-monitoring equipment that could be used in Irish waters as part of a monitoring network to be established by 2014. Independent short-term noise measurements were also undertaken by Biopsheric Engineering at two other locations in the estuary. Also during this period, a short-term C-POD deployment was carried out at Tarbert. These two projects coupled together provide a means to generate noise measurements for the estuary and to assess, if any, the effects of vessel presence on dolphin behavior. Here we present the first noise measurements for the Shannon Estuary cSAC and a basic but first assessment on the effects of vessel activity on the resident group of dolphins.

2 Materials and Methods

Between June and September 2012, a noise-monitoring station was installed at Tarbert Jetty, consisting of the LIDO equipment supplied by LAB-UPC (Fig. 95.1). An SMID digital hydrophone was installed at the jetty (~15 m above chart datum), which was connected to an embedded SBC (computer system) that stored the data on a HDD and allowed, through an underwater connector, data transfer via Ethernet. Noise measurement took place in the third-octave bands centered at 63 and 125 Hz as required under the MSFD Indicator 11.2.1 of Descriptor 11; short tonal signals were between 2,500 and 20,000 Hz. Additionally, impulsive signals between 20 and 46 kHz were also monitored for dolphin sonar between 46 and 94 kHz. A real-time data stream was available for the general public at www.listentothedeep.com. An automatic information system (AIS) receiver connected to laptop computer running ShipPlotter was also installed at the jetty. Noise measurements, public data streams, and the AIS data were transferred to the LAB-UPC database server in Vilanova i la Geltru (Spain) over a 3G network connection.

Additionally, Biospheric Engineering made a number of short-duration noise measurements at two locations (Labasheeda Bay and Kilbaha Bay, County Clare). Calibrations were carried out at 250.12 Hz, 500 Hz, 1 kHz, 5 kHz, 10 kHz, and 20 kHz. Calibration was carried out using a Brüel & Kjær type 4,223 hydrophone calibrator and cross checked with a Brüel & Kjær type 2,250 sound level analyzer before and after each set of measurements. All recordings were carried out in 20 m of water.

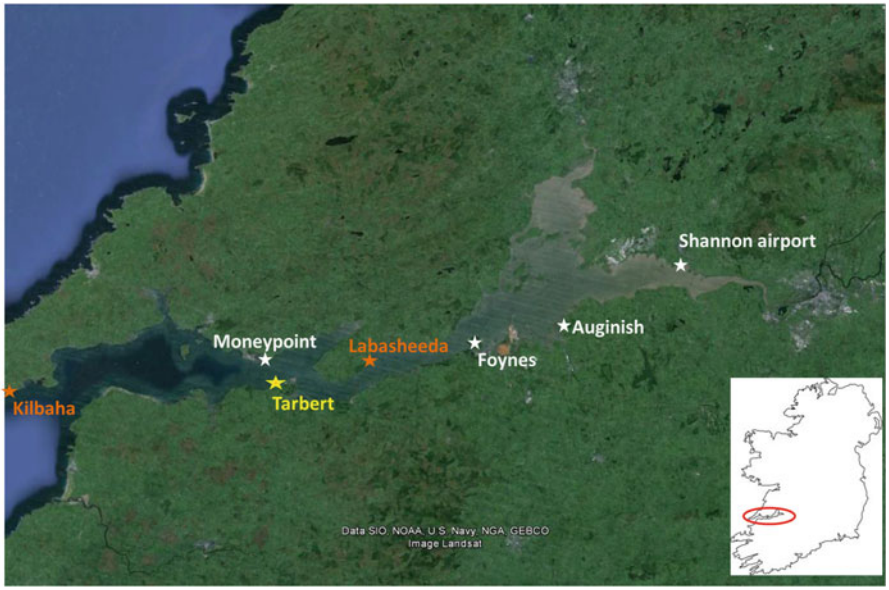

Fig. 95.1 Map of CPOD monitoring stations (*white*), LIDO noise monitoring network location (*yellow*), and Biospheric Engineering noise measurements (*orange*)

Weather conditions at each location were consistent during measurements, with fair weather and winds <10 kt. Deployment at each location involved placing the recording device in a protective cage (converted lobster pot). Data were in the form of 15-min-long WAV files providing a continuous audible record of the noise events. Each file was first analyzed to determine the root-mean-square (rms) noise level every 125 ms. This resulted in 7,200 rms values for each file. These rms values were analyzed in turn to determine the percentile values so that background levels could be isolated from events such as shipping noise.

Long-term SAM of deepwater berths in the Shannon Estuary using C-PODs commenced in 2010 (under the SIFP program) and is currently ongoing. C-PODs are self-contained click detectors that log the echolocation clicks of porpoises and dolphins. Once deployed at sea, the C-POD operates in a passive mode and is constantly listening for tonal clicks within a frequency range of 20–160 kHz. When a tonal click is detected, the C-POD does not record actual sounds but records information about the sounds including time of occurrence, center frequency, intensity, duration, bandwidth, and frequency of the click. Dedicated software (CPOD.exe), provided by the manufacturer, was used to process the data from the SD card when connected to a PC via a card reader. Using the dedicated CPOD.exe software, a train detection algorithm is run through the raw data to produce a CP.3 file. Through this process of train detection, C-PODs record a wide range of click types, but the train detection searches for coherent trains within them. All units were deployed at four deepwater berths from the Moneypoint power station upriver to Shannon Airport, ~80 km from the mouth of the estuary at Loop Head (Fig. 95.1). Lightweight mooring designs were employed during monitoring of each of the sites by attaching them to existing structures, e.g., jetties. A roped line was hung from the top of the jetty with a 20-kg weight attached to the end. At approximately midwater, a loop was etched in the line and the C-POD units were shackled secure. A fifth C-POD was deployed at Tarbert Jetty (June to August) simultaneous to the LIDO deployment, and this afforded the opportunity to assess the difference in dolphin acoustic behavior, if any, in the presence or vessel traffic. Click train properties (including train duration [ms], number of clicks per train, clicks per second, maximum interclick interval [ICI; ms], minimum ICI [ms], and minimum and maximum frequency) were extracted and analyzed to describe dolphin echolocation repertoire in the presence or absence of ships. Statistical analysis was carried out on all trains detected using R (R Development Core Team 2011), and a significance value of $P<0.05$ was used for all analyses. The dataset was found to be nonnormal ($k=12.42$, $P=0.00$); therefore, a Kruskal-Wallis nonparametric test was performed.

3 Results

The Shannon Estuary has a very complicated geometry and bathymetry. Through the LIDO measurements, an attempt was made to characterize the transmission loss in the channel using the received level measurements from ships passing the

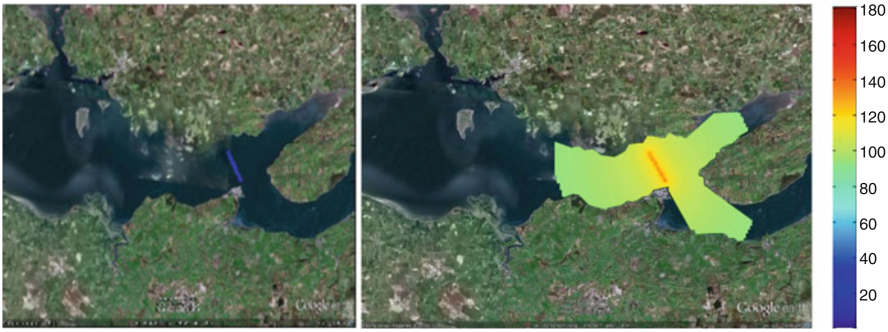

Fig. 95.2 Estimated sound pressure level (SPL) during ferry activities

hydrophone in combination with their positions taken from AIS data. Wide dispersion around the median was evident and most likely due to contributing noise sources (e.g., self-noise) and directivity of the source level at the local ferry. A ferry track consisting of 13 points was computed by averaging all available tracks for the month of September. An omnidirectional source level was taken from the literature where McKenna et al. (2012) list source levels for vehicle carriers of lengths between 173 and 199 m at ~170 dB re 1 μPa at 1 m for the third octave centered on 125 Hz. The ferries operating in the channel were smaller than this so a source level estimate of 160 dB was used. The ferry track and the estimated received sound pressure level of points around the track based on their proximity to the track and a transmission loss of 18 log(R) are shown in Fig. 95.2. From the model, it was expected that the ferry levels should have been measured more clearly, but it was likely that the source level estimation was too high.

To analyze shipping activity, histograms were made averaging the number of received AIS messages over each hour of the day during September 2012. Only movements with a speed over 1 kt were taken into consideration. The Shannon Estuary is a busy shipping area with both transiting and stationary vessels present at all times. On average, four ships transited the Tarbert monitoring station per day. This shipping activity appeared to be concentrated mostly in the mornings and evenings, with especially high activity from Thursday night to Friday morning. Results showed that shipping activity produced noise between 120 and 140 dB for the channel at Tarbert.

Analyses of measurements taken by Biospheric Engineering were made using Avisoft Bioacoustics SASLab Pro and Signal Lab's SigView 32 software packages. From this noise, levels could be divided into three main categories: (1) background noise level (no dominant sound, low noise level); (2) biological noise level (louder sounds not attributable to anthropogenic sources); and (3) shipping noise (louder sounds attributable to shipping traffic). Periods where either shipping noise, biological noise, or background noise was the dominant noise source were isolated. Each period was then analyzed, and a third-octave spectrum for the three main noise source types was prepared. To get a greater understanding of the noise level on a longer term, the rms noise level was plotted for each of the 15-min monitoring periods. Along with the rms value, instantaneous noise levels were evaluated to calculate percentile noise levels. All results were broadband (5 Hz to 20 kHz) rms values. The mean noise level for the Shannon Estuary was calculated at 100 ± 7.5 dB re 1 µPa.

From CPOD data, *Tursiops* were regularly recorded at all of the sites monitored during the long-term SIFP study, ranging from 80 to 21% of days. Detections were recorded, on average, on 47% of days monitored across all sites. Over the 59-day period at Tarbert Jetty, dolphins were recorded on 55% of days. This totaled 614 click trains, which had an average number of 24 clicks/s and an average frequency of 103 kHz. From the AIS and noise data at Tarbert, it was determined if each click train detected was in the presence or absence of vessel activity. Results showed a significantly higher ICI in the presence of vessel activity at the Tarbert site ($\chi^2 = 4.9491$, $P = 0.02$).

4 Discussion

Because cetaceans are reliant on sound for critical survival activities such as navigating, orientation, foraging, and communicating with other group members, it makes them extremely vulnerable to noise disturbance. Clearly, the Shannon Estuary is a busy shipping area, but a variety of other vessel activities exists, including ferries, fishers, tour boats, and pleasure craft. Because these smaller crafts produce noise in the 1- to 50-kHz bracket, it is likely that they pose a higher risk to dolphins in terms of disturbance than lower frequency shipping. A reduction in the communication range of bottlenose dolphins of 26% was estimated within a 50-m radius of small vessels (Jensen et al. 2009). Foraging disruption caused by boat presence has been observed for *Orchinus orca* (killer whales; Williams et al. 2006) and *Delphinus delphis* (common dolphins; Stockin et al. 2008). This can have an effect on the daily life functions of animals and hence impact negatively, such as a reduction in the survival and condition of calves (Lusseau et al. 2006).

The results from SAM show that *Tursiops* regularly use deepwater berths that are the main shipping routes used in the estuary and so will be exposed daily to shipping. Noise-monitoring results show that the estuary is a noisy place (100 ± 7.5 dB) but is marginally quieter in comparison with the results generated by Beck et al. (2013) for Dublin Bay (113 ± 8.2 dB) and Galway Bay (103 ± 4.2 dB). These results are the first estimates of noise levels to be produced for the area and some of the first carried out in Irish waters.

The results presented in this paper are the first attempt to assess if vessel activity has an effect on dolphin behavior in this protected site. Admittedly, this is a crude investigation of the effect of vessel presence at the site but, at present, is our only means of assessment. Although the results show a significant increase in the ICI in the presence of vessels, it is uncertain if this behavioral shift is a negative response as a possible interim mechanism for managing an increase in ambient-noise levels. This study will serve to focus future research in the Shannon Estuary, where simultaneous land-based visual monitoring combined with techniques to describe the whistle repertoire during exposure to a variety of vessel types could provide further insight into the effects of shipping noise. The present study served as a means for Ireland to test noise-monitoring equipment necessary to meet the requirements under MSFD but also assess noise levels in a busy industrial area which is the target of future proposed works such as the development of a liquid nitrogen gas (LNG) terminal and tidal energy. Moneypoint and Tarbert are strategic energy sites and are treated as key strategic drivers of economic growth in the region. The results will serve to inform protocols of best practice for such working areas to ensure that these Annex II species are not impacted negatively.

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