



Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Editorial

Mitigation of underwater anthropogenic noise and marine mammals: the 'death of a thousand' cuts and/or mundane adjustment?



The illustrious marine scientist and explorer, Sylvia Earle, once said of anthropogenic (man-made) noise: '*Undersea noise pollution is like the death of a thousand cuts. Each sound in itself may not be a matter of critical concern, but taken all together, noise from shipping, seismic surveys, and military activity is creating a totally different environment than existed even 50 years ago. That high level of noise is bound to have a hard, sweeping impact on life in the sea.*' The subtle, but key phrase in that quote is 'bound to'. There is negligible doubt that some noise activities are detrimental to marine mammals (and, in some cases, will cause death), but quantifying this doubt is hard.

In 2012, Cork, Ireland, at the conference on *Effects of Noise on Aquatic Marine Life*, following a talk on the response of deep-diving whales to military sonar noise, a leading marine mammal scientist stated that, in the ideal experiment, military sonar noise levels would be ramped-up sufficiently to drive these animals onto the beach. This ad lib, yet controversial comment, dispensed under duress of peer questioning, elicited a sharp concert of indrawn breaths from the stunned audience, but it also drove home the magnitude of the problem: how can we determine the effects of any anthropogenic noise on marine mammals? And a corollary to that is: how can we mitigate effectively for any noisy operation offshore? There are no simple answers to these two questions, but in terms of quantifying effects to devise mitigation protocols, numerous scientific studies are being undertaken on captive and wild animals (e.g. Finneran et al., 2003; Kastelein et al., 2011, 2014; Thompson et al., 2013; Tougaard et al., 2015).

Noise from anthropogenic sound sources can be intermittent, impulsive, continuous, high or low intensity, or simultaneous combinations thereof. Increased use of the marine environment for a range of activities, such as geophysical exploration for Oil & Gas (O&G), wind-farm construction, military exercises, and commercial shipping, has resulted in underwater noise levels that are estimated to be at least ten times higher today than a few decades ago. In terms of effects on marine mammals, studies have suggested that, for some species, impacts can be temporary or chronic, encompassing a whole host of behavioural modifications, changes in habitat usage or migration, communication masking, and auditory and non-auditory physiological impacts. As may also be expected in any evolving animal population over time, generations of species have learned (or been obliged) to adjust (e.g. Miller et al., 2000), move temporarily out of noisy areas (e.g. Thompson et al., 2013), compromise between perceived risk and cost of leaving disturbed areas by habituating (e.g. Houser et al., 2013), sometimes risking exposure to loud sounds to gain access to resources (e.g. Tixier et al., 2015). Some even use anthropogenic signals to find food (e.g. Stansbury et al., 2015). We should be extremely careful to avoid

misapplication of the terms 'habituation', 'sensitisation' and 'tolerance' in impact studies (Bejder et al., 2009) for certain types of anthropogenic noise, but an animadversion is that not all anthropogenic noises in isolation are likely to be fatal, or cause issues in all conditions, or to all species. Given the versatility of life in general, there may be isolated instances where some species of marine mammal are sympatric with certain types of low-level noise activities, without any quantifiable detrimental effect. For example, compared to other O&G activities, such as seismic exploration/profiling and conductor driving, drilling and production noise emanating from fixed, metal-legged offshore O&G installations is considered generally to be relatively low level (120 dB re 1 μ Pa) and in the frequency range of dominant tonals of 0.002–1.4 kHz, with little radiated noise over 8 kHz (Todd and White, 2010). It is thus unsurprising that elevated nocturnal levels of inferred acoustic feeding behaviour of high frequency odontocete species, such as the harbour porpoise (*Phocoena phocoena*), have been found around offshore O&G drilling rigs and platforms throughout routine drilling and production operations (Todd et al., 2009), potentially befitting from enhanced fish prey abundance of a 'rig-to-reef' effect (Fujii, 2015). Other species of whale, dolphin, seal, and shark are also observed in regular close proximity to O&G installations (Robinson et al., 2013; Todd et al., 2015b), and in some cases, even targeting offshore anthropogenic structures (Arnould et al., 2015; Russell et al., 2014). Indeed, the majority of marine mammal populations (especially in coastal areas and smaller seas) have never experienced anything other than a cluttered and noisy habitat, since many noise-producing activities are congenial. For example, in the daily life of a North Sea porpoise feeding on the Dogger Bank, routine industry noise sources include fishing vessels trawling, jack-up drilling rigs pinning, construction and support vessel thrusters, Remotely Operated Vehicle (ROV) multibeam sonar, and general cargo, and ferry shipping lanes. Consequently, combined-noise effects in the long term are most likely to be detrimental to marine mammal health overall, but it is important to note that any noise-spectral characteristics, including frequency and sound Source Level (SL), are specific to each industrial activity, as are any possible effects on individual marine mammal species.

In an ideal world, prior to, during, and following industrial activities, these operational-specific noises should be factored into the design of an appropriate Environmental Impact Assessment (EIA), but in terms of formulating associated guidelines and requirements, governmental regulators are faced with limited burden-of-proof baseline data sets, which are needed to be able to make informed decisions about species statuses, trends and sensitive habitats, including those that are rare or particularly vulnerable to noise impacts. Empirical scientific evidence

in the form of hearing curves (audiograms) have been conducted for only a small number of individuals from around 20 marine mammal species (no baleen whales). Notwithstanding the increased scientific focus on the problem of ocean noise, marine acoustic pollution has received relatively little global legal attention (e.g. Scott, 2004 for a good précis on noise regulations). In the absence of data, as a form of Best Practice Not Entailing Excessive Costs (BATNEEC), industry has been obliged to cooperate with regulators to develop a series of operationally feasible mitigation measures to minimise acoustic and physical disturbance to marine mammals and other protected species during certain industrial activities and ensure compliance with relevant legislation. Since 1998, when the United Kingdom's Joint Nature Conservation Committee produced guidelines concerning acoustic mitigation measures for marine mammals during seismic surveys (JNCC, 1998), advisory and regulatory bodies worldwide have adopted similar standards, which now exist for a number of regions and for a range of industrial activities. Guidelines may appear to lack statute, but regulatory authorities increasingly ensure they are binding legally via their licencing agreements for industrial activities; consequently, failure to comply with these requirements can result in substantial fines and/or influence future licencing decisions. These JNCC guidelines, however, have been criticised recently (Wright and Cosentino 2015).

Common to guidelines are the involvement of Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM) Operators, to confirm visually or acoustically the absence of marine mammals in a designated exclusion or 'mitigation' zone prior to activating any anthropogenic noise source. Requirements for MMOs and PAM Operators encompass many types of commercial activity, so data collected by scientifically qualified, trained and experienced (and passionate) MMOs and/or PAM Operators has the potential to increase existing knowledge of species distribution, ecology, behaviour, and responses to offshore operations. Surprisingly, however, only a handful of MMOs dedicate non-remunerated time and effort into publishing their findings (e.g. Johnson et al., 2007; Todd et al., 2015b; Weir, 2008), despite most O&G companies being prepared to release non-commercially sensitive data from non-disclosure agreements. One reason for this dearth of peer-reviewed MMO and PAM publications is industries' continued use of inappropriately qualified and experienced environmental personnel, because of increasing progression to reduce costs to meet shareholder-profit obligations in the face of O&G economic vicissitudes. This has enabled school leavers and new entrants from entirely different occupations, without any scientific qualifications, environmental training or professional experience, to qualify as MMO and/or PAM Operators, in some cases with only a day of training. Consequently, there continues to be a deluge of highly paid, but immensely underqualified and inexperienced MMO and PAM operators (and in some cases, sub-standard PAM equipment) into the market. The uneducated argue that it is not in industries' best interest to hire competent and independent personnel, since detection of animals within mitigation zones can require cessation in commercial operations, and elevated costs; however, the reality is that inexperienced observers mistake waves for marine mammals, misidentify species, and underestimate ranges of sightings to within mitigation zones, thus leading to an elevated level of operational delays. Irrespective of the rationale behind this troubling trend, there continues to be little incentive for industry to acknowledge the importance of appropriate personnel to maintain consistent standards. Moreover, industry 'self-regulation' also occurs, since some marine contractors use their own personnel to provide both the industrial service and associated MMO and PAM monitoring services, thus benefitting from at least two contentious income streams, which, surprisingly, has never been challenged by environmental authorities.

An attempt to tackle these problems, and the actual profession of being an MMO or PAM operator, had not been consolidated into any single, accessible, document, so the Marine Mammal Observer and Passive Acoustic Monitoring Handbook (Todd et al., 2015a) is the first attempt. The Handbook concerns potential interferences of anthropogenic noise

sources with the acoustic spectra exploited by marine mammals, and the mitigation steps taken by industry, regulatory authorities, and ultimately MMOs and PAM Operators. The Handbook also attempts to educate the neophyte or new entrant to a competent and acceptable level of knowledge on acoustics and marine mammal biology, and endeavours to explain where MMO and PAM practices, and equipment, are inadequate. This is not a resource for the high-level-specialist academic, but it contains useful information, such as updating the Richardson et al (1995) marine mammal hearing and vocalisation tables.

In summary, the problem of continued elevated anthropogenic noise and the use of underqualified and inexperienced MMOs and PAM Operators to mitigate these effects are not going to be solved overnight. As one high-level industry representative said of the Todd et al. (2015a, 2015b) first attempt to tackle this: 'While we might wish that the book turns on the light bulb over everyone's head and that's-that, I think we understand that people are not that easy to bring together on any issue, even which brand of coffee to buy. I see the book more as a great big push toward getting people to confront and attempt to resolve the issues we all know exist. Until we start talking, we won't get to the bottom of these problems. It is too much to expect that one book would solve all the issues, but the authors of the book should take considerable pride in stimulating people to do more than just exchange anecdotal complaints. Though it is frustrating, I feel confident that if we are patient and wait for the book to have its full impact, we will see how the book has moved this field forward and can be proud of the role that the book has played in the maturation of MMO/PAM.' Therefore, in conclusion, underwater noise, its mitigation, and regulation continues to be a serious problem for marine mammals... but to quote Nancy Meyers, writer and director of 2009 American romantic comedy: it's complicated.

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