Gorgan University of Agricultural Sciences and Natural Resources

Environmemtal Resources Research (ERR)

Print ISSN: 2783-4832
Online ISSN: 2783-4670

Anthropogenic sound as an emerging threat in the Caspian Sea: The potential effects of sound on aquatic animals

Saeed Shafiei Sabet[1*]

[1] Assistant Professor, Fisheries Department, Faculty of Natural Resources, University of Guilan, Sowmeh Sara, Iran, Email: shafiei.sabet@guilan.ac.ir

Article Info

Article type:
Short Cmmunication

Article history:
Received: February 2022
Accepted: June 2022

Corresponding author:
s.shafiei.sabet@guilan.ac.ir

Keywords:
The Caspian Sea
Anthropogenic sound
Aquatic habitats
Sound impact

Abstract

Ambient sound levels have risen dramatically over recent decades due to sound-generating human activities, so-called anthropogenic sound, in marine and freshwater habitats. In accordance with the World Health Organization (WHO), anthropogenic sound is recognized as a significant global pollutant. Anthropogenic sounds can vary in terms of temporal, spatial and structural patterns. Aquatic animals may use sounds to communicate with individual conspecifics, detect prey and avoid predators in their natural habitats. The Caspian Sea is a brackish-water habitat and the largest lake in the world. There is a diversity of aquatic animals that inhabit the Caspian Sea. However, to our knowledge, soundscapes and the potential effect of anthropogenic sound pollution on aquatic animals of the Caspian Sea has not been investigated. In this paper, we argue that we need to prioritize acoustic studies to understand the soundscape and bioacoustics criteria of the Caspian Sea, and assess the potential impacts of acoustic stimuli on aquatic animals at the individual and community level.

Cite this article: Saeed Shafiei Sabet. 2022. Anthropogenic sound as an emerging threat in the Caspian Sea The potential effects of sound on aquatic animals. *Environmental Resources Research*, 10 (1), 105-114. DOI: 10.22069/IJERR.2022.6043

DOI: 10.22069/IJERR.2022.6043
Publisher: Gorgan University of Agricultural Sciences and Natural Resources

Introduction

Sound pollution

Human activities have introduced a wide range of sound sources in terrestrial and aquatic habitats (Radford, Kerridge & Simpson 2014; Sabet, Neo & Slabbekoorn 2016; Slabbekoorn et al., 2010). Anthropogenic sound is increasing in, on and near marine and freshwater habitats (Brumm 2010; Kunc, Mclaughlin & Schmidt 2016; Rako-Gospić & Picciulin 2019). Moreover, anthropogenic sound has now been recognized as a critical pollutant and a major conservation problem, having negative impacts and serious consequences on aquatic animals (Radford, Kerridge & Simpson 2014; Shafiei Sabet et al., 2015; Slabbekoorn et al., 2010). Underwater sound comes from a range of sound-generating human activities that add to ambient sound levels in the marine environment (Slabbekoorn et al., 2010; Duarte et al., 2021). Therefore, it is essential to monitor underwater soundscapes and to investigate how this elevation in ambient sound levels may affect aquatic animals in underwater environment.

In the Middle East, Iran is one of the most important countries for its biodiversity and habitats. As such, a wide range of animals live in the country (Farashi and Shariati, 2017). It has been shown that aquatic environments are full of sounds originating from abiotic, biotic and

anthropogenic sources, and therefore aquatic animals are prone to be widely affected by these acoustic stimuli (Slabbekoorn et al., 2010; Williams et al, 2015; Shafiei Sabet et al., 2016). However, in the current literature, almost no data could be found that show the temporal and/or spatial distribution of sound sources and soundscapes in the Caspian Sea. Moreover, there is a lack of knowledge on the potential effects of anthropogenic sound on the biodiversity of the Caspian Sea.

The Caspian Sea region and its importance

The Caspian Sea is the largest inland body of water in the world (Figure 1) and is surrounded by six countries (Jafari, 2010; Nouri, Karbassi and Mirkia, 2008). The area of the sea exceeds 390000 km2 and the water volume reaches 78000 km3 at a mean depth of 208m; the maximum sea depth is 1025 m whilst approximately 130 rivers enter the Caspian Sea (Kostianoy and Kosarev, 2005). The Caspian Sea is approximately 27 m below mean sea level, whilst the length of its coastline reaches approximately 7500 km including the coastlines of the islands (Kostianoy and Kosarev, 2005). The Caspian Sea is distinguished by special natural conditions, contains rich natural resources and boasts unique world reserves of many valuable endemic species, plus commercial fish stocks and other renewable bioresources (Kostianoy and Kosarev, 2005). The considerable meridional extension and the broad range of the sea have led to natural biodiversity in different regions of the sea.

Figure 1. Map of the Caspian Sea and the five countries in the region. Picture copyright from worldatlas.com.

Moreover, the Caspian Sea is a geographically important place for the different socio-economic and ethno-political interests of the regional countries, it is of economic importance for fishing activities and, more recently, because of its underground energy resources. Unfortunately, the Caspian Sea is one of the most polluted seas in the world and the number of pollutants varies both temporally and spatially (Kosarev, 1966). However, pollution dispersal in the Caspian Sea is less than that of open seas because the sea is non-tidal and confined (Jafari, 2010), meaning

that hydrocarbon extraction spills can remain localized and become an immense threat to aquatic life unlike the situation in the rough sea where they are broken up and dispersed more easily.

Different types of pollution affect aquatic habitats in the Caspian Sea, especially those close to coastal areas which are of interest for both aquatic animals and humans. Studies reveal anthropogenic impacts in the region. It has been stated that the biggest environmental problem in the Caspian region (basin) has been the economic development in the sea, coastal territories, and watershed basins of the rivers flowing into the sea (Zonn, 2005). Another study revealed that the main environmental issues of the Caspian Sea are the impact of water level fluctuations on coastal settlements; a decline in sturgeon populations; and water pollution from oil and gas operations, industry, households and agriculture (Jafari, 2010). Although there are many sound sources caused by human activities in the Caspian Sea, there is currently no data to show whether anthropogenic sound, produced by human activities, may also cause impacts on aquatic life at an individual or community level.

Sound in aquatic habitats: sources and temporal patterns

Marine and freshwater ecosystems are similar to terrestrial habitats in that they are filled with a variety of sound sources (Wenz 1962; Wysocki; Amoser & Ladich, 2007). Firstly, natural abiotic (physical) sound sources such as running water, wind, waves and tides, surf, submarine volcanic eruptions and seismic activity are prevalent and are known as geophony (Hildebrand, 2009). Secondly, there are also many biotic sources such as animal vocalizations, sound produced during feeding and other activities, which are known as cacophony (Hildebrand, 2009). Furthermore, anthropogenic sound sources which can spread in time and space include shipping activities and recreational vessels, as well as naval sonars, seismic surveys and pile driving, which over the last century have become much more prominent and are known as anthropophony (Andrew et al., 2002; Slabbekoorn et al., 2010). Anthropogenic sound is now recognized as a potential driver of environmental changes in many aquatic habitats (Slabbekoorn et al., 2010).

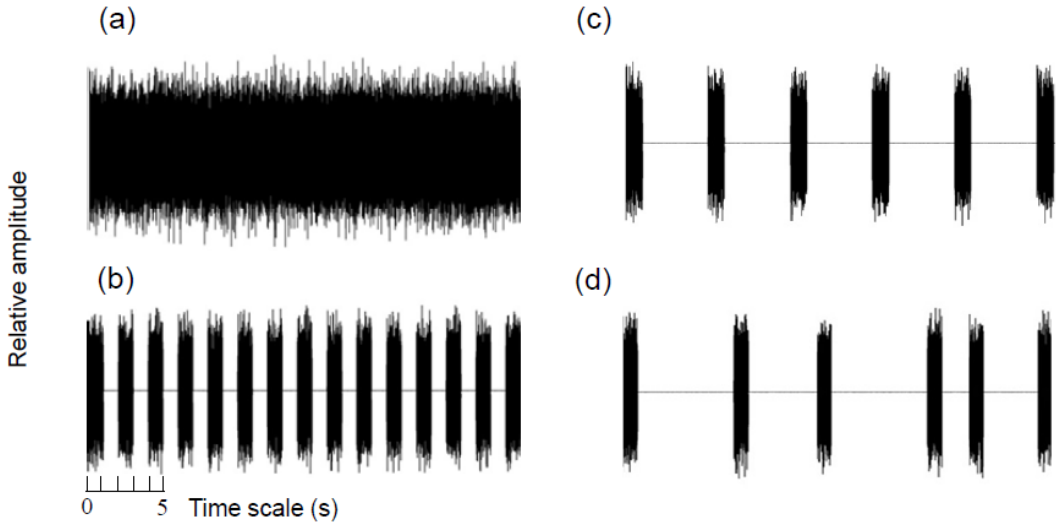

Figure 2. Amplitude waves showing temporal variation in the four sound treatments used in the exposure experiments: (a) Continuous sound (CS); (b) intermittent regular (1-1) with a high pulse rate of 1s sound and 1s interval; (c) intermittent regular (1-4) with a low pulse rate of 1s sound and 4s interval; and (d) intermittent irregular (1-7) with 1s sound and variable intervals randomly selected from the range of 1-7s (7 different whole-second durations, on average 4s) (See Shafiei Sabet et al., 2015).

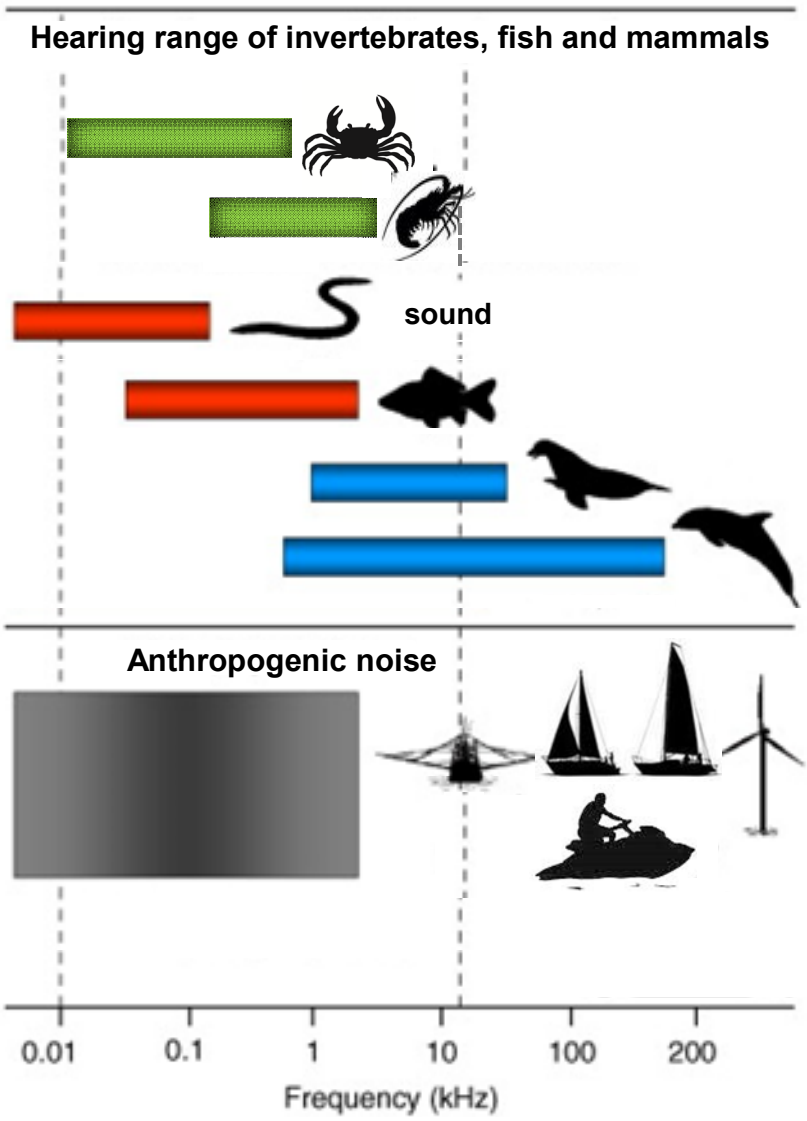

Figure 3. Hearing range of invertebrates, fish and mammals in aquatic habitats. The crab and prawn are representative of aquatic invertebrate species (Lovell et al., 2005; Morley, Jones & Radford 2013). The eel is representative of fish species with a bias to low-frequency sensitivity. The goldfish is representative of the cyprinid fish, which also includes zebrafish (*Danio rerio*) which are a large, relatively sensitive group of fish. Anthropogenic sound largely overlaps the hearing range of aquatic animals and especially those of invertebrates and fish. Modified from Slabbekoorn et al., (2010).

Anthropogenic sounds vary considerably in temporal pattern (Figure 2). For instance, recreational boats and shipping activities, huge pumping systems and wind farms are well known as major sources of relatively continuous sound exposures. Conversely, naval sonars, seismic surveys, pile driving and air guns are typical examples of intermittent sound sources. The pulse rate interval (PRI) of these intermittent sounds is usually 1–4 s for pile driving (Hall, 2013; Matuschek and Betke, 2009) and 5–15 s for seismic surveys (McCauley et al., 2000). It has already been shown that variation in temporal patterns in acoustic stimuli causes behavioural responsiveness in fish (Neo et al., 2014; 2015; Shafiei Sabet et al., 2015).

Sound impacts on aquatic animals

In addition to abundance of sounds from various sources in the aquatic environment, there are several other reasons why sounds may play an important role in the life of aquatic animals, and why the artificial

elevation of ambient noise may have detrimental consequences. Firstly, sound travels almost five times faster in water than in air (Urich, 1984) and therefore can potentially spread over a large area and be capable of conveying information to animals over great distances (Slabbekoorn et al., 2010). Secondly, as sound has the capacity to carry information, species may extract signals and exploit cues from ambient sounds to find prey and avoid predators (Brumm & Slabbekoorn, 2005), especially in dark and murky waters (Figure 3).

Thirdly, given the importance of sound transmission and distribution in the aquatic environment and the limited visibility of waters in the region, many aquatic animals produce sound as a tool for numerous different functional processes (van Opzeeland and Slabbekoorn, 2012). For instance, some invertebrates, fish and marine mammals use sound for their conspecific communication during territory defence (Myrberg 1981), navigation (Slabbekoorn and Bouton,2008), mate choice (Amorim, Vasconcelos & Fonseca 2015), foraging (Versluis et al., 2000), habitat selection (Simpson, 2005) and reproduction (Mann and Lobel, 1997; Maruska, Ung & Fernald 2012).

Aquatic animals – including invertebrates, fish and marine mammals – rely on their auditory sense, and other sensory modalities such as visual and olfactory signals, for collecting information in their habitats (Slabbekoorn et al, 2010, Radford et al., 2014; Williams et al., 2015). Anthropogenic sound could have a variety of negative effects on marine animals across taxa. The presence of anthropogenic sound may negatively affect auditory detection and recognition thresholds in fish and marine mammals, subsequently interfering with these functions through causing permanent or temporary hearing threshold shifts (Amoser and Ladich, 2003; Smith et al., 2004; Erbe, 2012;), influencing their calling behaviour (Buckstaff, 2006; Radford et al., 2014; Putland et al., 2018), and masking and altering signals produced by fish and marine mammals (Hawkins and Chapman, 1975; Ladich and Schultz-Mirbach, 2013; Wysocki and Ladich, 2005; Vasconselos et al., 2007; Weilgart, 2007; Clark et al., 2009). A variety of studies have already revealed several effects of acute and chronic anthropogenic sound pollution on marine fauna ranging from physical damage, spatial displacement to subtle changes in behaviour (Southall et al., 2007; Götz et al., 2009; Southall et al., 2019; Mortensen et al., 2021).

The spatial and temporal distribution and effects of anthropogenic sound in marine environments are extensive (Halpern et al., 2008). Over the past few decades, it is estimated that shipping noise have chronically increased ambient sound levels by 12 dB (Hildebrand, 2009). It has already been shown that elevated ambient sound levels affect the physiology and behaviour of aquatic animals in a variety of taxa and at different life cycles under laboratory and field conditions (Popper, 2001; Popper et al., 2003; Hildebrand, 2005; Popper and Hastings, 2006; Radford et al., 2016). Physiological effects of anthropogenic sound have been studied in invertebrates, fish and marine mammals (Holt et al., 2015; Popper et al., 2003; Wysocki et al., 2006). Behavioural investigations are often seen as critical to evaluate individual and population-level impacts (Hubert et al., 2020). Therefore, assessments of the effect of anthropogenic sound on behaviour and understanding of the biological consequences of anthropogenic sound are necessary for wildlife conservation and management in the region.

Call for cooperative investigations and direction for future research

Soundscape assessment is an emerging discipline that can be defined as characterising the distribution and aggregation of sound sources consisting of natural sounds (including sounds related to natural physical processes and animal sounds) and anthropogenic sounds (Hildebrand, 2009; Erbe et al., 2016). There is a growing awareness of the potential adverse effects of anthropogenic sound on different taxa among invertebrates, fish and marine mammals (Popper et al., 2004; Popper and Hastings, 2009; Slabbekoorn et al., 2018). Recently, many oil and gas building constructions have taken place in

the Caspian Sea region (Kubicek, 2013). However, as yet, there is no evidence or well-documented data on soundscapes that demonstrate the potential impacts of anthropogenic sounds produced by oil and gas industry constructions on endemic species and fragile habitats of the Caspian Sea. Therefore, in the current paper, the author calls for comprehensive assessments to enhance our understanding of the Caspian Sea soundscape in the region and its effects on biodiversity in two ways: firstly, to measure background sound conditions, sources of underwater sound and their characterization in the Caspian Sea; and secondly, to incorporate biological monitoring – such as visual observations, passive acoustics and tagging instruments – with behavioural results under laboratory conditions.

Conclusions

The Caspian Sea is the largest lake in the world and has rich aquatic biodiversity. However, there is a lack of knowledge about the potential impacts of anthropogenic sound in such a unique environment in Iran (Shafiei Sabet, 2021). Human activities in the Caspian Sea may potentially cause short- and long-term changes in the behaviour of aquatic animals. Marine biodiversity monitoring and ecosystem functioning can be assessed by soundscape measurements and acoustic monitoring of the environment (Shafiei Sabet, 2018). However, empirical data on species acoustic behaviour and soundscape assessment studies in the Caspian Sea are still extremely scarce and unknown. Thus, it is necessary to assess acoustic characteristics and the potential impacts of sounds on animal species in captivity under laboratory conditions and in the field at the individual and community level. It is important to understand that experimental results and acoustic measurements based on tests under laboratory conditions should not be extrapolated directly to outdoor conditions in the field (cf. (Slabbekoorn 2016)). Moreover, any environmental assessments of the impacts of anthropogenic sound on aquatic species in the Caspian Sea and other aquatic habitats must be based on species-specific hearing abilities and their behavioural characteristics.

Acknowledgments

The author would like to thank anonymous referees for their insightful comments, and Rebecca King for her editorial assistance and helpful comments. I have been supported as a member of the International Society for Applied Ethology.

References

Amorim, M.C.P., Vasconcelos, R.O. and Fonseca, P.J. 2015. 'Fish Sounds and Mate Choice'.

Amoser, S., and Ladich, F. 2003. Diversity in noise-induced temporary hearing loss in otophysine fishes. The Journal of the Acoustical Society of America. 113(4), 2170-2179.

Andrew, R.K., Howe, B.M., Mercer, J.A., and Dzieciuch, M.A. 2002. Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online. 3, 65–70.

Brumm, H. 2010. 'Anthropogenic Noise: Implications for Conservation', Encyclopedia of Animal Behavior. 89–93.

Brumm, H. and Slabbekoorn, H. 2005. Acoustic Communication in Noise, Advances in the Study of Behavior. 35, 151–209.

Buckstaff, K.C. 2004. Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, Tursiops truncatus, in Sarasota Bay, Florida. Marine Mammal Science. 20(4), 709-725.

Clark, C.W., Ellison, W.T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., and Ponirakis, D. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series. 395, 201-222.

Duarte, C.M., Chapuis, L., Collin, S.P., Costa, D.P., Devassy, R.P., Eguiluz, V.M., Erbe, C., Gordon, T.A., Halpern, B.S., Harding, H.R. and Havlik, M.N. 2021. The soundscape of the Anthropocene ocean. Science. 371(6529), eaba4658.

Erbe, C. 2012. Effects of underwater noise on marine mammals. In The effects of noise on aquatic

life (pp. 17-22). Springer, New York, NY.
Erbe, C., McCauley, R., and Gavrilov, A. 2016. Characterizing marine soundscapes. The Effects of Noise on Aquatic Life II, 265-271.
Götz, T., Hastie, G., Hatch, L.T., Raustein, O., Southall, B.L., Tasker, M., Thomsen, F., Campbell, J., and Fredheim, B. 2009. Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Biodiversity Series. 441, 1-134.
Jafari, N. 2010. Review of pollution sources and controls in Caspian Sea region. Journal of Ecology and the Natural Environment. 2(2), 025-029.
Hall, M.V. 2013. A quasi-analytic model of the underwater sound signal from impact driving of an offshore semi-infinite pile. In Proceedings of Meetings on Acoustics ICA2013. 19(1), p. 070039). Acoustical Society of America.
Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., d'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E. and Fujita, R. 2008. A global map of human impact on marine ecosystems. Science. 319(5865), 948-952.
Hawkins, A.D., and Chapman, C.J. 1975. Masked auditory thresholds in the cod, Gadus morhua L. Journal of Comparative Physiology. 103(2), 209-226.
Hildebrand, J.A. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series. 395, 5–20.
Hildebrand, J.A. 2005. Impacts of anthropogenic sound. Marine mammal research: Conservation Beyond Crisis. 101-124.
Holt, M.M., Noren, D.P., Dunkin, R.C., and Williams, T.M. 2015. Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. The Journal of Experimental Biology. 218(11), 1647-1654.
Hubert, J., Neo, Y. Y., Winter, H.V., and Slabbekoorn, H. 2020. The role of ambient sound levels, signal-to-noise ratio, and stimulus pulse rate on behavioural disturbance of seabass in a net pen. Behavioural Processes. 170, 103992.
Kosarev, A.N., and Gyul, A.K. 1966. Pollution of the Caspian Sea. Assessment of environmental stress in European Russia: factors, zoning, consequences. MGU, Moscow. 141.
Kostianoy, A., and Kosarev, A. 2005. The Caspian sea environment (p. 80).
Kubicek, P. 2013. Energy politics and geopolitical competition in the Caspian Basin. Journal of Eurasian Studies. 4(2), 171-180.
Kunc, H.P., Mclaughlin, K.E., and Schmidt, R. 2016. 'Aquatic noise pollution : implications for individuals , populations , and ecosystems', no. August.
Kunc, H.P., McLaughlin, K.E., and Schmidt, R. 2016. 'Aquatic noise pollution: implications for individuals, populations, and ecosystems', Proceedings of the Royal Society B: Biological Sciences. 283(1836), 20160839.
Ladich, F., and Schulz-Mirbach, T. 2013. Hearing in cichlid fishes under noise conditions. PLoS One, 8(2), e57588.
Lovell, J.M., Findlay, M.M., Moate, R.M. and Yan, H.Y. 2005. 'The hearing abilities of the prawn Palaemon serratus', Comparative Biochemistry and Physiology - A Molecular and Integrative Physiology. 140(1), 89–100.
Mann, D.A., and Lobel, P.S. 1997. Propagation of damselfish (Pomacentridae) courtship sounds. The Journal of the Acoustical Society of America. 101(6), 3783-3791.
Maruska, K.P., Ung, U.S. and Fernald, R.D. 2012. 'The African cichlid fish astatotilapia burtoni uses acoustic communication for reproduction: Sound production, hearing, and behavioral significance', PLoS ONE.
Matuschek, R., and Betke, K. 2009. Measurements of construction noise during pile driving of offshore research platforms and wind farms. In Proc. NAG/DAGA Int. Conference on Acoustics (pp. 262-265).
McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., and McCabe, K. 2000. Marine seismic surveys—a study of environmental implications. The APPEA Journal. 40(1), 692-708.
Morley, E.L., Jones, G., and Radford, A.N. 2013. 'The importance of invertebrates when

considering the impacts of anthropogenic noise', Proceedings of the Royal Society B: Biological Sciences. 281, 1776.
Mortensen, L.O., Chudzinska, M.E., Slabbekoorn, H., and Thomsen, F. 2021. Agent-based models to investigate sound impact on marine animals: bridging the gap between effects on individual behaviour and population level consequences. Oikos. 130(7), 1074-1086.
Myrberg, A.A. 1981. 'Sound Communication and Interception in Fishes'.
Neo, Y.Y., Seitz, J., Kastelein, R.A., Winter, H.V., ten Cate, C., and Slabbekoorn, H. 2014. Temporal structure of sound affects behavioural recovery from noise impact in European seabass. Biology Conservation. 178, 65–73.
Neo, Y.Y., Ufkes, E., Kastelein, R.A., Winter, H.V., Ten Cate, C., and Slabbekoorn, H. 2015. Impulsive sounds change European seabass swimming patterns: Influence of pulse repetition interval. Marine Pollution Bulletin. 97(1-2), 111-117.
Nouri, J., Karbassi, A.R. and Mirkia, S. 2008. 'Environmental management of coastal regions in the Caspian Sea', International Journal of Environmental Science and Technology,5(1), 43–52.
Popper, A.N. 2001. The impacts of anthropogenic sounds on fishes. The Journal of the Acoustical Society of America. 110(5), 2750-2750.
Popper, A.N., Fewtrell, J., Smith, M.E., and McCauley, R.D. 2004. Anthropogenic sound: effects on the behavior and physiology of fishes. Marine Technology Society Journal. 37(4), 35-40.
Popper, A.N., and Hastings, M.C. 2009. The effects of human-generated sound on fish. Integrative Zoology. 4(1), 43-52.
Putland, R.L., Merchant, N.D., Farcas, A., and Radford, C.A. 2018. Vessel noise cuts down communication space for vocalizing fish and marine mammals. Global change biology. 24(4), 1708-1721.
Radford, A.N., Kerridge, E. and Simpson, S.D. 2014. 'Acoustic communication in a noisy world: Can fish compete with anthropogenic noise?', Behavioral Ecology. 25(5), 1022–1030.
Radford, A.N., Purser, J., Bruintjes, R., Voellmy, I.K., Everley, K.A., Wale, M.A., ... and Simpson, S.D. 2016. Beyond a simple effect: variable and changing responses to anthropogenic noise. In The effects of noise on aquatic life II (pp. 901-907). Springer, New York, NY.
Rako-Gospić, N., and Picciulin, M. 2019. 'Underwater Noise: Sources and Effects on Marine Life', World Seas: an Environmental Evaluation. pp. 367–389.
Shafiei Sabet, S., Neo, Y.Y., and Slabbekoorn, H. 2016. 'Impact of Anthropogenic Noise on Aquatic Animals: From Single Species to Community-Level Effects', in The Effects of Noise on Aquatic Life II, pp. 957–961.
Shafiei Sabet, S., Neo, Y.Y., and Slabbekoorn, H. 2015. The effect of temporal variation in sound exposure on swimming and foraging behaviour of captive zebrafish. Animal Behaviour. 107, 49-60.
Shafiei Sabet, S. 2018. The impacts of anthropogenic sound on marine mammals in the Persian Gulf; current status and need for future research. Journal of the Persian Gulf. 9(32), 1-10.
Shafiei Sabet, S. 2021. The Caspian Sea and anthropogenic sound: a need for underwater sound assessment. In Каспий: прошлое, будущее, настоящее (pp. 71-74).
Simpson, S.D., Meekan, M., Montgomery, J., McCauley, R., and Jeffs, A. 2005. Homeward sound. Science. 308(5719), 221-221.
Slabbekoorn, H. 2016. 'Aiming for progress in understanding underwater noise impact on fish: Complementary need for indoor and outdoor studies', in Advances in Experimental Medicine and Biology.
Slabbekoorn, H., Bouton, N., Van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A.N. 2010. A noisy spring: The impact of globally rising underwater sound levels on fish, Trends in Ecology and Evolution.25(7), 419–427.
Slabbekoorn, H., Dooling, R.J., Popper, A.N., and Fay, R.R. (Eds.). 2018. Effects of anthropogenic noise on animals.
Smith, M.E., Kane, A.S., and Popper, A.N. 2004. Acoustical stress and hearing sensitivity in fishes: does the linear threshold shift hypothesis hold water?. Journal of Experimental Biology.

207(20), 3591-3602.
Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr, C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E. and Richardson, W.J. 2008. Marine mammal noise-exposure criteria: initial scientific recommendations. Bioacoustics.17(1-3), 273-275.
Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. and Tyack, P.L. 2019. Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. Aquatic Mammals, 45(2).
Urick, R.J. 1984. Ambient Noise in the Sea DTIC Document.
Vasconcelos, R.O., Amorim, M.C.P., and Ladich, F. 2007. Effects of ship noise on the detectability of communication signals in the Lusitanian toadfish. Journal of Experimental Biology. 210(12), 2104-2112.
Van Opzeeland, I., and Slabbekoorn, H. 2012. Importance of underwater sounds for migration of fish and aquatic mammals. Advances in Experimental Medicine and Biology. 730, 357–359.
Versluis, M., Schmitz, B., Von der Heydt, A., and Lohse, D. 2000. How snapping shrimp snap: through cavitating bubbles. Science. 289(5487), 2114-2117.
Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. Canadian journal of Zoology, 85(11), 1091-1116.Wenz, GM (1962), 'Acoustic Ambient Noise in the Ocean: Spectra and Sources', The Journal of the Acoustical Society of America. 34(12), 1936.
Williams, R., Wright, A.J., Ashe, E., Blight, L.K., Bruintjes, R., Canessa, R.,and Wale, M.A. 2015. Impacts of anthropogenic noise on marine life: Publication patterns, new discoveries, and future directions in research and management. Ocean & Coastal Management. 115, 17-24.
Wysocki, L.E., Amoser, S., and Ladich, F. 2007. 'Diversity in ambient noise in European freshwater habitats: noise levels, spectral profiles, and impact on fishes.', The Journal of the Acoustical Society of America. 121(5), 2559–2566.
Wysocki, L.E., and Ladich, F. 2005. Hearing in fishes under noise conditions. Journal of the Association for Research in Otolaryngology. 6(1), 28-36.
Wysocki, L.E., Dittami, J.P., and Ladich, F. 2006. Ship noise and cortisol secretion in European freshwater fishes. Biological Conservation. 128(4), 501-508.
Zonn, I.S. 2005. Environmental issues of the Caspian. In The Caspian Sea environment (pp. 223-242). Springer, Berlin, Heidelberg.