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Aftereffect of Anthropogenic Underwater Noise on Fish

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Abstract

This paper examines the sources, characteristics, and impacts of anthropogenic underwater noise on fish, drawing from existing literature. Sound is crucial for fish communication, navigation, and survival, but increasing industrialization and aquaculture practices introduce disruptive noise pollution. This noise, stemming from sources like electrical motors, seismic airguns, pile driving, aeration systems, and water pumps, interferes with natural acoustic environments. Fish hearing capabilities vary, with specialists able to detect wider frequencies compared to generalists. Anthropogenic noise can cause stress, leading to suppressed immunity, growth, and reproduction, and in severe cases, mortality. Studies reveal physical damages like ruptured swim bladders and hemorrhaging due to activities such as pile driving. The paper highlights the need to understand and mitigate underwater noise in aquaculture and marine environments to protect fish populations and ensure sustainable practices. Reducing noise at its source or eliminating it can benefit fish species and potentially enhance aquaculture productivity. Further research is needed to fully assess the long-term effects of noise pollution on fish behavior and physiology.

Keywords: aquaculture, noise, fish behavior, anthropogenic noise

Introduction

Sound is an important carrier of information for communication in an aquatic environment. Underwater generated sound is five times faster than in air and cannot be weakened quickly as compared to other signals (Gutscher, *et al.*, 2011) [10]. It can be assumed that fish may be listening to ambient sounds, from sound scattering objects, to interpret changes in their acoustic environment, and that these ambient noises may be as important to a fish as sounds used for communication (Scholik and Yan, 2001) [25]. Thus, fish is considered as dependent on sounds for a variety of functions that are critical for survival and reproduction (Fay, 2009) [7] and may therefore be negatively affected by noise pollution (Neo *et al.*, 2015) [18].

Based on observations, fish behavior from captivity is truly different to the same species' behavior in natural environment. There are many factors contributing to this difference. The shock of being new to the environment that leads to stress is the foremost reason. It is also believed that, aside from the initial shock of a new environment, the continuous noise level is another potential source of stress (O'Neal, 1998) [19]. In natural aquatic environment, fish exposed to sounds that are significantly above ambient levels can move away from the sound source. However, fish in aquaculture settings are typically confined to individual culture tanks where avoidance of less than optimal sound is not possible (Davidson *et al.*, 2007) [6].

Humans are not aware that fish is being exposed to high sound level generating equipment like water pumps, air bubbles, air pumps, chiller motors, pilling devices and the like (Anderson, 2009; Popper and Hastings, 2009) [2, 22]. Thus, reduction on the source causing high sound level on the environment or even eliminating it may benefit the species and potentially enhance the productivity of the industry (Davidson *et al.*, 2007) [6].

This paper aims to investigate the sources, characters of underwater noise and its impact to fish based on literatures.

Sound System Underwater

As industrialization approached the field of fisheries, anthropogenic sound increased and has been exploited the aquatic environment widely.

This man made disturbances in the water interfere the ability of the fish to detect and use sounds for biological purposes such as tracking prey, avoiding the predators, navigation and communication with other fish. Species that do not communicate by sound use the acoustic scene (or soundscape) to learn about and exploit their environment (Fay and Popper, 2000) [8].

Unwanted and unpleasant sound that could also affect negatively to the hearer is termed as noise. Underwater noise pollution is a growing problem in aquatic environments and as such may be a major source of stress for fish. According to Anderson (2009) [2], stress acquired from the environment may result to mortality, but even sublethal stress can compromise various physiological and behavioral functions, leading to suppressed disease resistance, growth rate, and fecundity. Therefore, as this stress' effect is being well studied, its source on the environment should be considered also

Hearing Capabilities of Fishes

Hearing thresholds among fish are highly variable. Teleost fishes are divided into two non-taxonomic groups based on hearing sensitivity, the hearing specialists and hearing generalists (some literatures term it as non-hearing specialists). Hearing specialists possess a gas- filled channel that connects the swimbladder to an ear structure containing dense otoliths (ear bones) that exhibit inertia when stimulated, allowing these species to sense sound over wider frequencies (Olesiuk, 2012) [20]. Fish with these specialize hearing systems include all the Otophysi and Clupeiformes, and some representatives in a wide range of other fish groups such as a few holocentrids, sciaenids, *etc.* The fish known to have the widest hearing frequency bandwidth are limited to the members of the clupeiform genus Alosa (Popper and Hastings, 2009) [22]. Hearing specialists can detect sounds to over 3 kHz; with best sensitivity between 300–1000 Hz and most hearing specialists can detect sound pressure levels as low as 50–75 dB re 1 mPa and in the frequency range of 100–2000 Hz (Davidson *et al.*, 2007) [6].

The majority of fishes do not have specializations to enhance hearing and are therefore called hearing generalists (Hastings and Popper, 2005) [13]. Hearing generalists lack specialized connections between the swim bladder and the inner ear and are therefore only able to detect low frequency sounds. Hearing generalists typically can only detect frequencies below 500– 1000 Hz and are not as sensitive to sound pressure levels as hearing specialists (Davidson *et al.*, 2007) [6]. Figure 1 demonstrates that species differ in the range of frequencies (bandwidth) and in the lowest SPL (threshold), that they are able to detect.

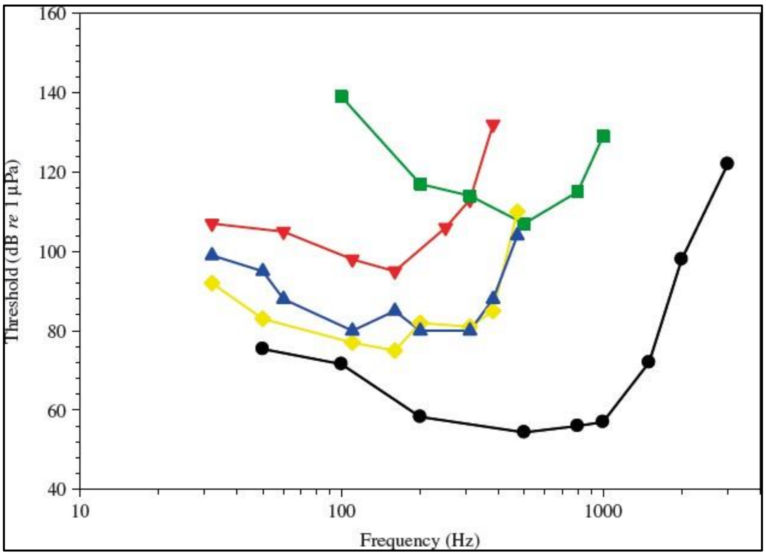

Fig 1: Hearing thresholds for a select group of fish species to illustrate fish hearing capabilities ● *Carassius auratus*; ▼ *Salmo salar* ; ■ *Euthynnus* sp.; ◆ *Gadus morhua*; ▲ *Melanogrammus aeglefinus*. *Carassius auratus* is considered a hearing specialist, whereas the other species would be considered hearing generalists. Davidson *et al.*, 2007 [6]

Causes of Anthropogenic Underwater Noise

The sources of anthropogenic sounds are extensive. Most maritime activity generates noise, and the aquaculture industry is no exception. Noise maybe generated by aquaculture facilities, and by the vessels and aircraft that service them. Aquaculture noise can be broadly categorized as 1) noise produced incidentally as a by-product of routine operations and maintenance; 2) sound produced intentionally to deter predators; and 3) sounds that might occasionally be produced during construction or demolition of infrastructure. Operational noise is produced at aquaculture sites by machinery, generators, aerators, feeders, harvesters, pressure washers, and by the vessel and aircraft traffic servicing these sites. Presence of predators uses seal bombs, cracker shells, and more recently powerful electronic Acoustic Harassment Devices (AHDs) deter seal and sea lion. Construction or demolition might occasionally involve more intense sounds, such as pile-driving or underwater explosives (Olesiuk *et al.*, 2012) [20]. Table 1 provides a general overview of the sources of noise, and the characteristics and prevalence of sounds associated with aquaculture in Canada by Olesiuk *et al.* (2012) [20]. Studies and ideas related to the sources of noise influenced by human will be presented.

Electrical motor, vibration, etc.

In the study conducted by Bart *et al.* (2001) [3], it was concluded the high frequency underwater noise was generated mostly by electrical motors, oscillating and collapsing air bubbles, aeration, and water pump action. Low frequency noise was generated by water flows, ground vibrations, tank wall vibrations and electrical pumps. To understand the effect of sound on cultured fish an ambient noise survey was conducted in enclosed recirculating raceways, fiberglass and concrete culture tanks, and in outdoor open ponds. Two distinct low and high frequency regions of sound were observed, above and below 315 Hz one-third octave band. Low frequency sounds were dominant in all systems measured. Overall noise levels were not significantly different between concrete or wooden frame raceways. However, the noise level in the low frequency range was higher by approximately 10 dB re:1 µPa in the concrete raceway. Low frequency noise was particularly high (130 dB re:1 µPa) in fiberglass tanks when compared with that in the concrete tanks (110 dB re: 1µPa).

Table 1: General overview of the sources, amplitude, characteristics and prevalence of noise associated with aquaculture in Canada. Olesiuk *et al.*, 2012 [20]

Noise Source	Intensity or Amplitude	Type	Frequency	Geographic Prevalence	Temporal Prevalence	References
Predator Deterrents						
Cracker shells	170-235 dB re: 1 µPa^{3}s	Single-Pulse	Broad 10-400 Hz	Formerly Common, Not Widely Used Currently	Intermittent	Awbrey and Thomas 1987
Sea lion bombs	160 dB re: 1 µPa^{3}s	Single-Pulse	200 Hz - 10 kHz	Rarely Used	Intermittent	Awbrey and Thomas 1987; Myrick *et al.* 1990b
Acoustic Harassment Devices	171-243 dB re: 1 µPa @ 1 m	Multi-Pulse Continuous	Narrow 10 kHz or 38 kHz	Potentially Widespread If Allowed	Continuous	Haller and Lemon (1994)
Pulsed Power Deterrents	240 dB re: 1 µPa @ 1 m at 1.8 kJ	Multi-Pulse	N/A	Under Development - Tests At Full Power or With Animals Have Not Been Approved	-	NMFS^{7}
Operational Noise						
Large Outboard Motor	175 dB re: 1 µPa @ 1 m ms	Non-Pulse	Broad 100 Hz - 20 kHz	Widespread	Routine	Richardson *et al*. 1995
Zodiac (5m 25hp)	152 dB re: 1 µPa @ 1 m ms	Non-Pulse	Broad Peak at 8 kHz	Widespread	Routine	Malme *et al*. 1989
Crew Boat (16m)	158 dB re: 1 µPa @ 1 m ms	Non-Pulse	Broad Peak at 90 Hz	Widespread	Routine	Greene 1985
Tugboat (Range of Loads and Speeds)	161 - 170 dB re: 1 µPa @ 1 m ms	Non-Pulse	1-5 kHz	Widespread	Occasional	Miles *et al*. 1987
Fishing Boat (12 m at 7 Knots)	161 - 170 dB re: 1 µPa @ 1 m ms	Non-Pulse	Broad 50 Hz - 1.5 kHz	Widespread	Routine	Miles *et al*. 1987
Whale-Watching Boats (Slow < 50 km hr^{-1})	145-168 dB re: 1 µPa @ 1 m ms	Non-Pulse	100-1.2 kHz	Widespread	Routine	Erbe 2002
Sonar (Fish-Finders)	210-250	Multi-Pulse (Very Brief)	50 & 200 kHz	Widespread	Continuous	Richardson *et al*. 1995; NRC 2003
Generators (125 kW to 2,000 kW)	90-118 dB; 20µPa @ 1 m ms	Non-Pulse	Broad 2 kHz - 2 kHz	Widespread	Continuous	ASHRAE 2002
Chain saws, pressure washers, etc.	90-110 dB re: 20µPa @ 1 m ms	Non-Pulse	630 Hz	Widespread	Routine	NICDC 2000
Construction and Demolition						
Pile-Driving	Up to 235 dB re: 1 µPa @ 1 m	Multi-Pulse	Peak at 160 Hz	Localized	Rare	Madsen *et al*. 2006; Tougaard *et al*. 2009
Explosives	Variable But High	Shock Wave	1-100 Hz	Localized	Rare	Richardson *et al*. 1995

Seismic guns

Seismic testing is an essential step in the exploration for oil and gas. It precedes the drilling, production, depletion and decommissioning phases. It seeks to identify precisely the character of prospective oil-bearing strata of the earth, deep below the ocean's bottom, so that the location of oil-bearing sediments can be pinpointed. Reservoirs can then be mapped accurately and drilling targets clearly established, even thousands of feet below the surface. Detailed seismic re-surveys may also take place if a reservoir is discovered during the drilling and production phases of a project (Peterson, 2004) [21].

In terms of decibels, seismic airgun arrays have maximum noise levels at source in the 200-250 decibel range. By comparison, open ocean ambient (normal) ocean noise ranges between 74-100 decibels. In the study conducted by Popper *et al* examining the effects of exposure to a single acoustic pulse from a seismic airgun array on caged endangered pallid sturgeon (*Scaphirhynchus albus*) and on paddlefish (*Polyodon spathula*) in Lake Sakakawea (North Dakota, USA), the experimental fish held in cages reached 231 dB re 1 µPa (205 dB re 1 µPa^{2} sound exposure level [SEL]). The experiment was designed to detect the onset of physiological responses including minor to mortal injuries.

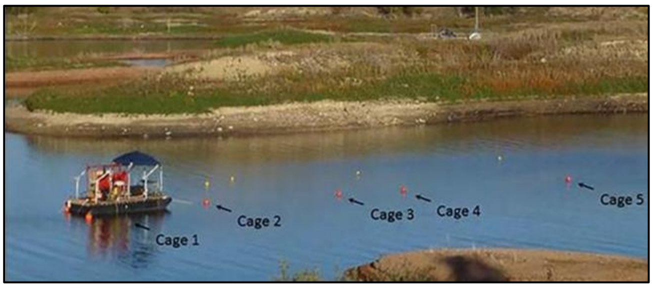

Fig 2: Airgun barge and fish exposure cage locations in Lake Sakakawea

Pile driving

Pile driving is commonly used for the construction of foundations for a large number of structures including bridges, buildings, retaining walls, harbor facilities, offshore wind turbines, and offshore structures for the oil and gas industry. It always involves multiple strikes over an extended period of time, with an average strike interval of 1.0 to 1.5 seconds (Popper *et al.*, 2014) [24]. The pile is a long tube, stake, or beam that is driven into the seabed, often by means of a hydraulic hammer. Sound is generated by direct contact of the pile with the water.

Such sound is much more likely to affect bottom-living fishes and invertebrates than those in the water column (Hawkins, *et al.*, 2015) [16].

Aeration/ blowers

Blowers are used to provide large volumes of air at low pressures (less than 4 psi) and are most commonly used in conjunction with air diffusers and air lifts. This combination adds oxygen and removes CO2 with low power consumption. Typical applications include recirculating fish systems, bait and lobster holding facilities, and shallow pond aeration. Despite the role of blower (aerator) is important in aquaculture, the noise it produces is alarming.

Noise Solutions Inc. conducted a Noise Impact Assessment (NIA) on an air injection vacuum blower unit to identify the prevalent noise sources. A Brüel & Kjær 2260 Investigator sound level meter was used to accurately quantify the noise produced by the sources which is significant in the NIA, which were: the blower casing; the blower exhaust outlet; and the blower air injection inlet. These noise sources were found to be extremely dominant during the blowers' operation, and were made the primary objective of the investigation. (Mose and Faszer, 2010) [17]. The measured sound pressure levels produced by the three sources stated above are presented in Table 2.

Table 2: Sound pressure levels

Source	Sound Level Contribution (dBC)	Sound Level Contribution (dBA)
Blower Air Injection Inlet	150.6	130.6
Blower Exhaust	150.5	130.5
Blower Casing	133.9	113.9
Sum	**153.6**	**133.6**

Ringing pipes and pumpset

Water flows in a pipe causing vibration at the pipe wall and generating broadband noise which may cause noise disturbance to the fish (Figure 3). When the water flow changes direction suddenly because of obstacles in the pipe such as sharp bends or valves, a loud noise is generated which becomes louder with increasing water flow rate and pipe size (www.info.gov.hk).

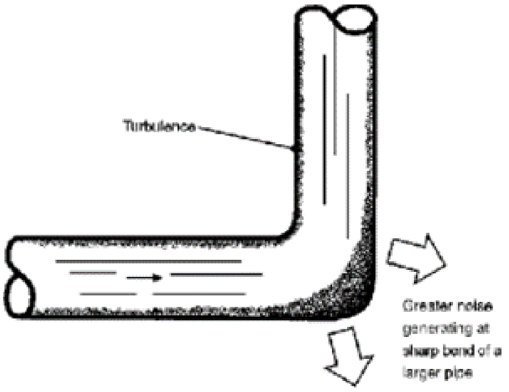

Fig 3: Noise from ringing pipes

Vibration from the water flow in pipes may be transmitted from the pipe runs to the wall of the tank where the pipes are mounted. It becomes more severe when the pipes are in direct contact with large planes such as walls or slabs (Figure 4). The vibration transmitted may activate the tank structure to generate noise which causes noise disturbance to cultured species inside the tank (www.info.gov.hk).

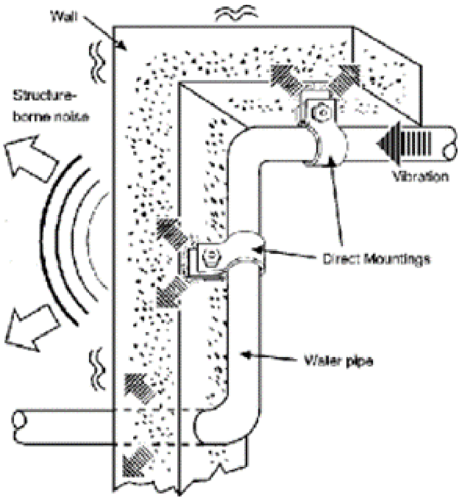

Fig 4: Noise from vibrating pipes

The major noise source of a pump is usually the bearing noise as a result of bearing worn-out. However, the noise contributed by the pump itself is small relative to that generated from its associated motor. The major noise source of a motor is usually the air movement induced by the cooling fan, which may cause noise disturbance to nearby residents (Figure 5) (www.info.gov.hk).

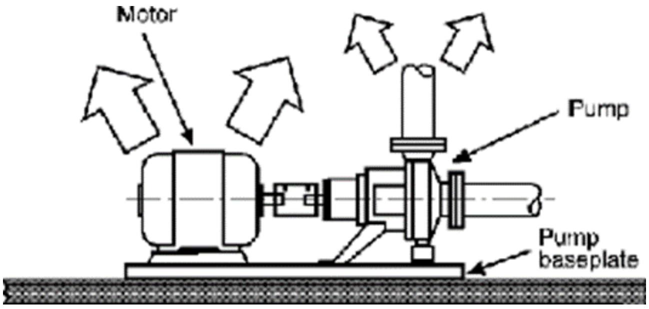

Fig 5: Noise from pumpsets

Effect of anthropogenic underwater noise on fish

Although the major concern is the effect of anthropogenic noise to the communication of the aquatic environment, other potential effects of these sounds has been considered also. To know the effect of higher or lower sound level (compared to the control) of the environment to the fish, several studies were conducted.

Recorded mortalities

Assessing the effect of exposure to pile-driving sounds to shiner surfperch (*Cymatogaster aggregate)*, results indicate that there was mortality caused by exposure to pile-driving sounds, with dead fish of several different species found within at least 50 m from the pile being driven.

According to Caltrans (2001) [4], numbers were relatively low, reflecting difficulty in retrieving dead or dying fish and the possibility that fish did not come to the surface at all, or not until they were away from the collecting operation.

Physical damages

Gross physical damages were observed to the cultured shiner surfperch (*Cymatogaster aggregate)* in cages at different distances from the pile driving source. Results showed that as cages get closer to the source of sound, the number of damages were greater than farther away (Caltrans, 2001) [4]. The same observation was found in the study of Abbott & Bing-Sawyer (2002) [1] as they look for the effects of pile driving on Sacramento blackfish (*Orthodon microlepidotus*). Abbott and Bing-Sawyer (2002) [1] added that substantial interanimal variation in damage may also occur even within the same cage. Figure (6) and Figure (7) shows the injured shiner surfperch (*Cymatogaster aggregate)* (Caltrans, 2001) [4]. Based on a review of existing information, Popper *et al*., (2014) [24] proposed injury criteria for fish exposed to single pile-drive pulses as 206 dB re 1 µPa and the maximum SEL cum was designated as 187 dB re 1 µPa^2·s for fish ≥2 grams and 183 dB re 1 µPa^2·s for fish <2 grams.

Fig 6: Ruptured swim bladder of a white surfperch

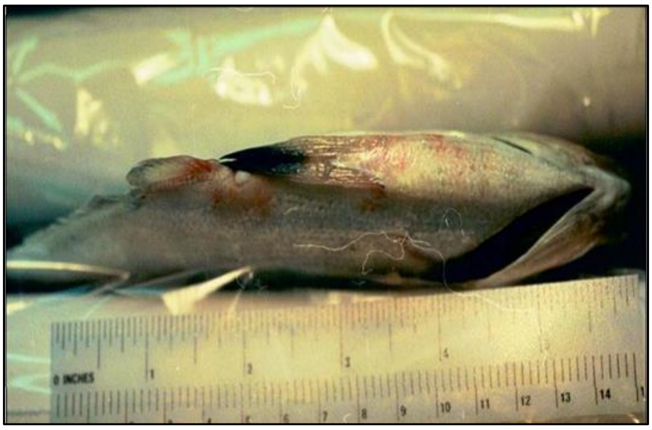

Fig 7: Ventral surface of a surfperch showing areas of redness where blood vessels were ruptured

Barotrauma is tissue injury that results from rapid pressure changes (e.g., forced change in depth, explosions, and intense sound) (Popper *et al*., 2014) [24]. In the study conducted by Halvorsen *et al*. (2012) [12], impulsive sounds generated by an impact hammer striking a steel shell pile was used. Neutrally buoyant juvenile Chinook salmon *(Oncorhynchus tshawytscha)* were exposed to impulsive sounds and subsequently evaluated for barotrauma injuries. Observed injuries ranged from mild hematomas (an abnormal collection of blood outside of a blood vessel that occurs because the wall of a blood vessel wall, artery, vein, or capillary, has been damaged and blood has leaked into tissues where it does not belong) at the lowest sound exposure levels to organ hemorrhage at the highest sound exposure levels. Fish were examined for barotrauma injuries both externally and internally then photographed to document injuries (Figure 8).

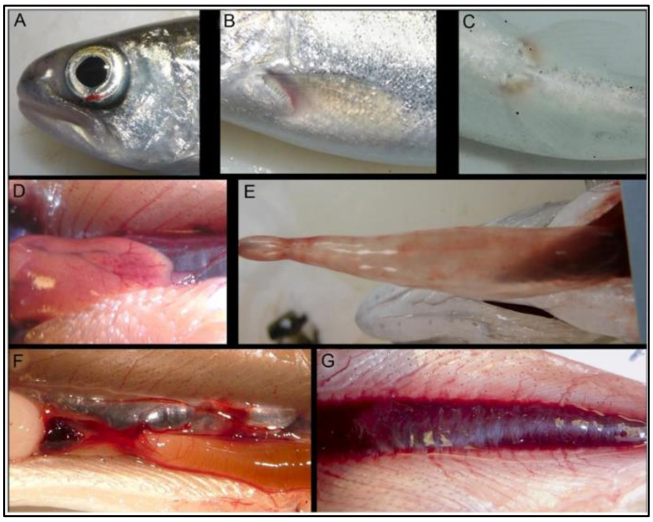

Fig 8: Injuries of Chinook salmon. A) eye hemorrhage, B) and C) fin hematoma, D) liver hemorrhage, E) bruised swim bladder, F) intestinal hemorrhage and G) kidney hemorrhage

Furthermore, Casper *et al*., (2013) [5] used High Intensity Controlled Impedance Fluid Filled wave Tube (HICI-FT) to investigate the effects of sounds produced by impulsive pile driving on two size groups of hybrid striped bass (white bass *Morone chrysops* x striped bass *Morone saxatilis*). The larger striped bass (mean size 17.2 g) had more severe injuries, as well as more total injuries, than the smaller fish (mean size 1.3 g). However, fish in each size group recovered from most injuries within 10 days of exposure. A comparison with different species from previously published studies show that current results support the observation that fishes with physoclistous swim bladders are more susceptible to injury from impulsive pile driving than are fishes with physostomous swim bladders. Figure 9 shows the injuries obtain by the larger hybrid striped bass. All presented photos are the ventral view of the fish with anterior to the left.

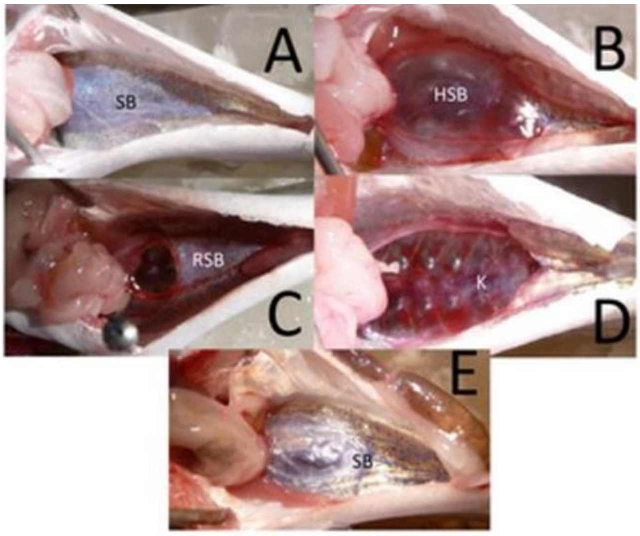

Fig 9: A. Control fish showing a healthy swim bladder (SB). B. Fish with herniated swim bladder (HSB). C. Fish with ruptured swim bladder (RSB). D. Fish with kidney hemorrhaging (K). E. Fish with fully healed swim bladder as evidenced by the white scar tissue on the swim bladder (SB)

To further understand the involvement of the swim bladder in tissue damage, Halvorsen *et al.*, (2012) [12] used to expose three species to pile-driving sounds. Species includes lake sturgeon (*Acipenser fulvescens*)—with an open (physostomous) swim bladder (Figure 10), Nile tilapia (*Oreochromis niloticus*)—with a closed (physoclistous) swim bladder (Figure 11) and the hogchoker (Trinectes *maculatus*)—a flatfish without a swim bladder (Figure 12). There were no visible injuries in any of the exposed hogchokers, whereas a variety of injuries were observed in the lake sturgeon and Nile tilapia.

Fig 10: Internal anatomy of the lake sturgeon in (a) control and (b,c) exposed fish. (a) shows a fully inflated, healthy swim bladder (Sb) and kidney (K; visualized by the grey strip of tissue above the swim bladder). (b) shows a partially deflated and bruised swim bladder. Photo (c) shows renal haematoma (K) (i.e. bruised kidney; visualized by the reddening of the grey strip of tissue above the swim bladder). Other organs pictured: intestine (In); liver (L); spleen (Sp); stomach (St). Halvorsen *et al.*, (2012) [12]

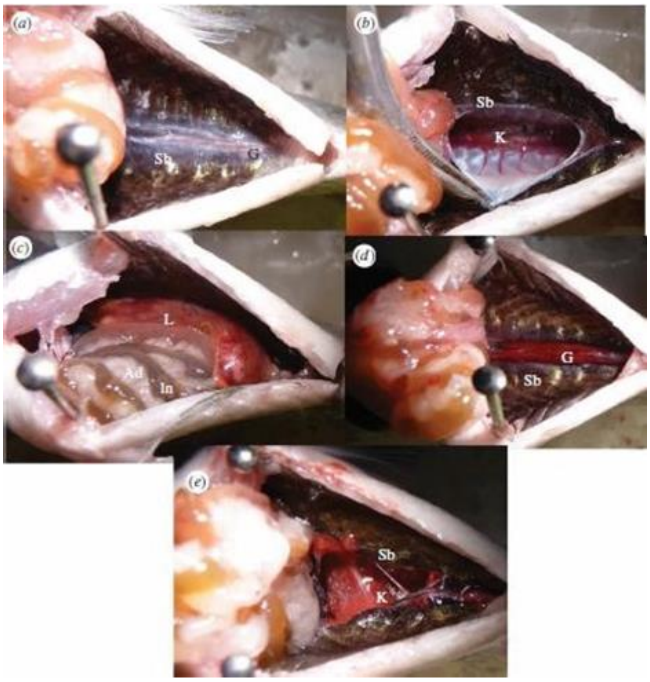

Fig 11: (a,b) Nile tilapia in control and (c,d,e) exposed fish. (a) healthy swim bladder (Sb) and gonads (G), which are visible as clear, thin structures along the midline of the swim bladder. (b) swim bladder has been cut open to show a healthy kidney (K). (c) hepatic haematoma (i.e. bruising of the liver, L). (d) internal organs have been pulled away to reveal bruising of the gonads. (e), the internal organs have been pulled away, and the swim bladder has been cut open to reveal renal haemorrhaging. All photos show ventral portion of body with anterior to the left. Other organs pictured: intestine (In); adipose tissue (Ad). Halvorsen *et al.*, (2012) [12]

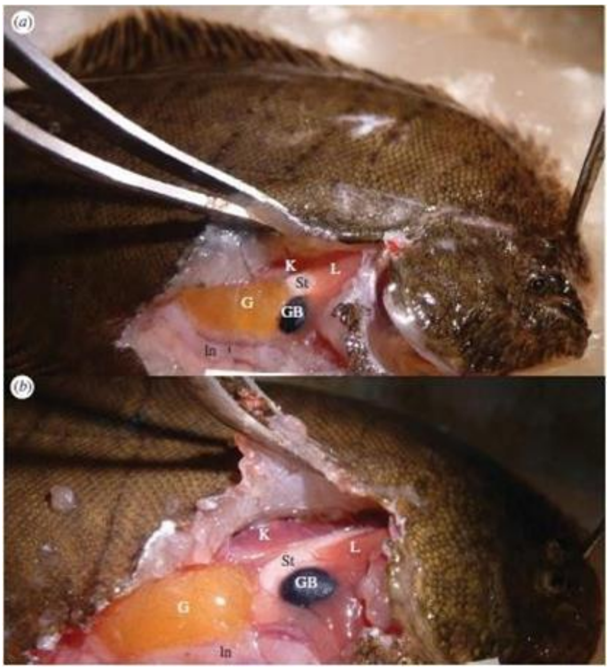

Fig 12: Examples of internal anatomy of the hogchoker in a (a) control and (b) exposed fish. There were no injuries observed in the organs for exposed or control fish. Organs visible within the pictures include liver (L), stomach (St), kidney (K), gall bladder (GB), intestine (In) and gonads (G). Both photos show the dorsal side of the fish, with anterior to the right. Halvorsen *et al.,* (2012) [12]

Behavioral response

In the study of Fewtrell and McCauley (2012) [9], captive marine fish were exposed to the noise from a single air gun. Noise levels received by the samples ranged between 120 and 184 dB re 1 µPa^{2}·s (SEL). Behavioral observations of the fish were made before, during and after air gun noise exposure. Results indicate that as air gun noise levels increase, fish respond by moving to the bottom of the water column and swimming faster in more tightly cohesive groups. Significant increases in alarm responses were observed in fish to air gun noise exceeding 147– 151 dB re 1 µPa SEL. An increase in the occurrence of alarm responses was also observed as noise level increased.

In the study of Hawkins *et al.* (2014) [14], schools of sprat *Sprattus sprattus* and mackerel *Scomber scombrus* (Figure 13) were examined at a quiet coastal location to understand the actual behavior of fish to impulsive sounds. The fish were exposed to a short sequence of repeated impulsive sounds, simulating the strikes from a pile driver, at different sound pressure levels.

Fig 13: Atlantic mackerel *Scomber scombrus* (left) and European sprat *Sprattus sprattus* (right). Hawkins *et al.* (2014) [14]

The incidence of behavioral responses increased with increasing sound level (Figure 14). Sprat schools were more likely to disperse and mackerel schools more likely to change depth. The sound pressure levels to which the fish schools responded on 50% of presentations were 163.2 and 163.3 dB re 1 μPa peak-to-peak, and the single strike sound exposure levels were 135.0 and 142.0 dB re 1 μPa^{2} s, for sprat and mackerel, respectively, estimated from dose response curves.

Temporary and Permanent hearing loss

There are two classes of effects of exposure to sound on the ear. Exposure to low levels of sound for a relatively long period of time or exposure to higher levels of sound for shorter periods of time may result in temporary hearing loss, referred to as temporary threshold shift or TTS. The level and duration of exposure that causes TTS varies widely and can be affected by factors such as repetition rate of the sound, pressure level, frequency, duration, health of the organisms, and many other factors. By definition, hearing recovers after TTS. The extent (how many dB of hearing loss) and duration of the TTS may continue from minutes to days after the end of exposure, and the extent of TTS depends on many variables.

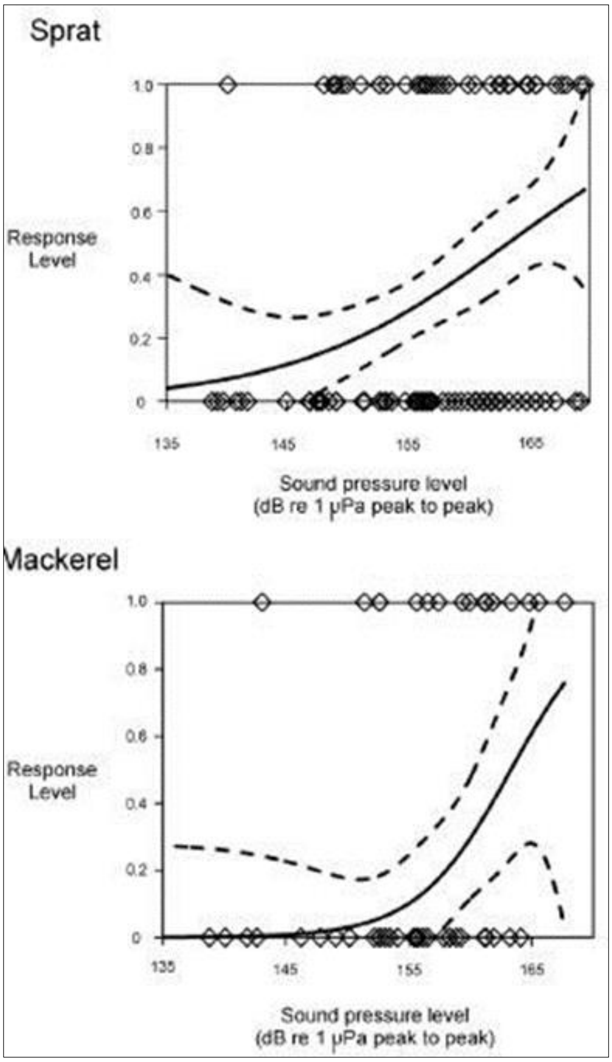

Fig 14: Responses of sprat schools (top) and mackerel schools (bottom) to sound exposure

The second possible effect is referred to in the literature as permanent threshold shift or PTS. PTS is a permanent loss of hearing and is generally accompanied by death of the sensory hair cells of the ear.

Smith *et al*. (2004a, b) [26, 27] tested hearing in goldfish and tilapia (*Oreochromis niloticus*) to determine more detailed parameters of hearing loss, including the effects of different exposure durations and recovery times. They demonstrated that goldfish had a 5-dB TTS after only 10 minutes of exposure to band-limited noise (0.1 to 10 kHz, approximately 170 dB re 1 µPa overall spectral sound pressure level), and with a three-week exposure to the same stimulus fish experienced a 28 dB threshold shift and took over two weeks to return to normal hearing

Laboratory studies have been used to determine whether there may be temporary or permanent changes in hearing ability in animals exposed for short or long periods of time to different types of sound (*e.g*. pure tones or white noise), and a few field studies have investigated the effects of sound from anthropogenic sources on hearing in fish. Hearing loss has been measured using behavioural or electrophysiological tests for several fish species, including Rafinesque, northern pike *Esox lucius* L., lake chub *Couesius plumbeus* (Agassiz) and *O. mykiss* (Popper and Hastings, 2009) [22].

Similarly, Scholik and Yan (2001) [25] demonstrated that fathead minnows did not recover to control thresholds even as long as 14 days after termination of a 24-hour exposure to white noise from 0.3 to 2.0 kHz with an overall spectral sound pressure level of 142 dB re 1 µPa.

Growth and reproduction

Data about effects of sound on developing eggs and larvae are very limited. There are a number of gray literature studied the effects of sound on developing eggs and larvae. The following studies that will be discussed are based from the article made by Hastings and Popper (2005) [13].

An increased mortality of eggs and embryos of *Cyprinodon variegates* was observed when it is exposed in 20-litre glass aquaria with a broadband noise (100-1,000 Hz) that was about 15 dB above ambient sound level. The sound did not affect hatched fry of C. *variegatus*, and neither eggs nor fry of *Fundulus similis* were affected. Larval growth was significantly less in the noise-exposed larvae of both species than in the larvae raised in ambient noise. While these results are of considerable interest, they were from only two species subject to relatively low noise levels and for a limited time period.

Conclusion

Exposure of fish to anthropogenic noise became a matter of serious concern. Sounds coming from the equipment that we usually use in or near the culture system may cause some effects and even be a silent killer. It is also evident that sound in different conditions can affect differently to the cultured species. Ways on how to minimize the level of sound of particular equipment should be study. Other potential sources of sound should undergo test and be assessed as well.

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