

Understanding and Mitigating the Underlying Acoustic Causes for Ship Collisions with Whales

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Abstract: Two prominent effects can render whales vulnerable to collisions, the Lloyd Mirror effect and acoustical shadowing when a ship's propellers are above keel level. The confluence of these effects, together with spherical spreading, and masking, pose significant ecological challenges for detecting and locating approaching ships. Underwater acoustic measurements of controlled ship passes at various distances and speeds were conducted with vertical hydrophone arrays to document these effects. The arrays were designed for simultaneous data acquisition at various depths as ships approached. Ship noise has been generally measured in deep water and at depths where whales are not hit by ships. These conditions do not measure complications arising from the Lloyd Mirror Effect and acoustical shadowing of propeller noise. Ideally, ship noise measurements for the purpose of whale studies and playback experiments should be made at depths and in environments where collisions can occur. Measurements for this study were made from a range of 1.5-m to 15-m hydrophone depths in water depths of 10 m to 1500 m. A series of empirical measurements support predictions that propeller noise directly ahead of large vessels can become indistinguishable from ambient noise and impossible for whales to detect in time to avoid collisions. Large acoustic nulls form ahead of vessels and lower frequencies are attenuated near the surface. Ironically, these nulls or shadows may attract whales seeking refuge from ship noise radiating from other areas. Directional acoustic solutions that "fill in" these shadows could be used to negate this dangerous ambiguity and alert whales of approaching ships. Careful projection techniques are necessary to selectively ensonify the near surface space

without attracting them to the surface. Alerting whales of imminent danger may prove to be the most effective method to mitigate ship strikes as it provides the animals with the sensory awareness to react at any point in time and space. Current visual surveillance systems are restricted to coastal areas and are inoperative during periods of reduced visibility. Speed reductions currently being proposed are also acoustically naive and can actually increase collision risks by reducing the audibility of approaching ships, while increasing the transect times and opportunities for collisions. Regulators may be unaware of Lighthill's theory of aerodynamic sound that predicts that ship noise intensity is proportional to the 5th power of propeller tip velocity. Empirical measurements support this relationship and demonstrate that faster ships are acoustically detectable at significantly greater distances. Since the ship's propeller is the only source that contributes substantially to ship noise, reducing tip rotation and cavitation results in lower acoustic levels and overall spectral output. For ships > 80 meters long (the length of ships implicated in most reported strikes) the spreading loss is > 38 dB at the bow. The lower spectral components are further attenuated by 20 to 50 dB by the Lloyd Mirror Effect. Detection of these quieter ship sounds is more precarious for whales with respect to near surface effects and complications from masking. In multiple ship environments masking challenges are the greatest, and sounds of slow vessels are masked by the sounds of distant faster moving vessels. An acoustic alerting system is being explored to provide whales with the enhanced sensory awareness of approaching ships and to reduce the ambiguity of acoustic shadows ahead of ships.