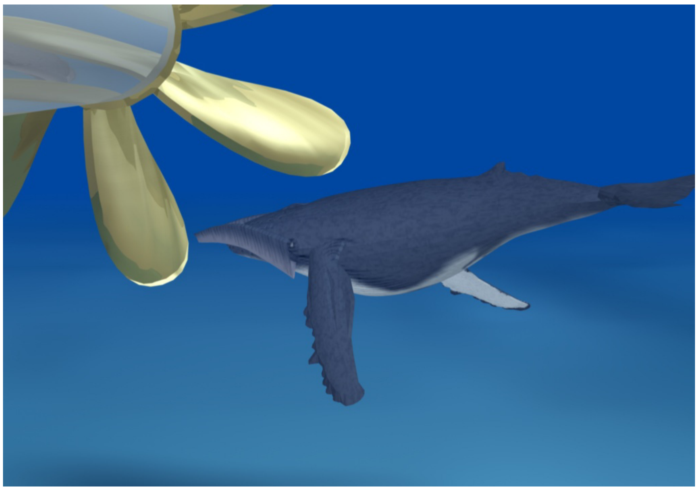
ACTIVE SONAR FOR MARINE MAMMAL RISK MITIGATION WITH HIGH SPEED VESSEL OPERATIONS



A TECHNOLOGY REVIEW AND DISCUSSION PAPER

XENTHOS
ABN-20020619392647

TABLE OF CONTENTS

COMMERCIAL IN CONFIDENCE

The information contained in this document shall remain the sole exclusive property of Xenthos (ABN-20020619392647) and shall not be disclosed by the recipient to any third parties without the written consent of the owner.

1 INTRODUCTION

Ensuring the safe passage of his vessel and crew has always been the primary consideration for any mariner throughout the ages. Unfortunately, with the onset of the industrialized age and the increased displacement and speed of maritime vessels, the consequences of collision have lead to some tragic milestones in the historical record. The collision between the Titanic and an iceberg off the coast of Newfoundland in 1912, claimed 1512 lives and is probably one of the best known. However, while less publicised, collisions between vessels have been far more serious in terms of loss of life. The collision between the heavily overloaded ferry, Dona Paz, and a merchant tanker in the Philippines in 1987 reportedly cost more than 4000 lives.

While collisions with icebergs, other vessels and running aground have been an enduring focus for maritime safety; considerations of collisions with submerged objects have certainly been of a secondary consideration to the commercial maritime industry. The only submerged objects of any serious danger to an underway vessel were mines (other than icebergs which are visible on the surface). Yachtsmen have regularly reported collisions with whales and, with their increasing usage over the last 40 years, shipping containers but the extent of the problem with respect to containers is not well understood. Reportedly, container ships lose 1800-2000 containers over the side each year but there is considerable debate as to how many of these then retain enough structural integrity to remain afloat[1]. Again, while of concern to yachtsmen it has certainly not been an important consideration for commercial maritime activities.

However, increasing concern is now focusing on the consequences of collisions between underway vessels and marine mammals (primarily whales), not from the perspective of the safety of the vessel but of the impact on the populations. Research has shown that ship-strike is now the leading cause of documented deaths[2] for the Northern Right Whale (*Eubalaena glacialis*). Concerns are motivated by a number of factors, an increasing awareness of environmental issues by the general public, increasing amount of income based on whale watching activities and the increased shipping activity in whale breeding grounds and passages.

The maritime industry should be aware that environmental groups and interests should not be disregarded. Public concern over the use of LFA (low frequency active sonars) by military vessels and their possible effects on whale populations is a recent issue of note. Despite the fact that air-guns used by the oil exploration industry are more common, have a much higher acoustic output level and are used around the world has not detracted from calls by environmental groups sufficient to restrict the use of LFA's. Thus, the concerns of the environmental groups cannot be easily dismissed, regardless of whether those concerns are justified or not. Needless to say, there is now a growing concern over the use of air-guns and noise pollution in the oceans.

---

[1] http://www.imia.co.nz/imiaweb/imiawebpublishing.nsf/Content/PhotoFeature0007

[2] "Active High Frequency Phased-Array Sonar for Whale Shipstrike Avoidance: Target Strength Measurements", James H. Miller, David C. Potter. Oceans Conference: An Ocean Odyssey, Nov. 5-8, Honolulu, HI. 2001.

For vessel constructors, the increase in demand and use of high-speed ferries and catamarans, simultaneous with an increasing environmental awareness and concerns for the safety of marine mammals, may be problematic. A number of strategies have already been proposed[3] to reduce the incidence of vessel collisions to the Northern Right Whales around the Eastern seaboard of the US. Those measures include

- Routing vessels around high-risk areas.
- Routing ships through a high-risk area to minimize travel distances of vessels and the risks of whale-vessel interactions through the area.
- Restricting vessel speed through high-risk areas.

Obviously any proposal to restrict vessel speed (<10 kts in vulnerable areas) is a major concern to operators and constructors of high-speed ferries. Whilst the referenced proposals apply only to specific areas of the US, they are generic and equally applicable to other regions. Hence, operators of high-speed vessels in sensitive areas should be aware that they might face legislative changes in the future that restrict or impact on the operations of their vessels. Similarly, vessel manufacturers should be cognisant that their clients may be demanding methods or systems that allow them to meet the environmental requirements and still operate their vessels efficiently.

Obviously a reliable method of collision avoidance would be of considerable benefit but, predictably, the problem is not an easy one to solve. Forward looking collision avoidance sonars (FLCAS) are regularly deployed on submarines and mine sweepers and it may be presumed that they could easily be modified to meet the described application. However, the nature of the threat to the vessel from a mine means that these systems are optimized, and always operated in, slow speed configurations. The high-speed environment of a 40 kt catamaran introduces onerous performance requirements in terms of the noise generated by the vessel. Furthermore, the obstacle detection distance required to successfully evade an identified target is also increased with the speed and displacement (momentum) of the vessel. Unfortunately, these issues compound to present a problem that is at the very edge of the theoretical performance achievable by any system.

Whilst noting that the performance requirements for a collision avoidance system suitable for the evasion of large cetaceans presents significant implementation problems; the successful provision of such a system could provide a valuable discriminator between vessel manufacturers, particularly if the clients operations were in an environmentally sensitive area.

This document presents a brief background to the technical issues associated with vessel strikes on cetaceans. It is provided in support of marketing activities for high-speed catamarans and is not intended to be a tutorial on acoustics or an outline for a potential system solution.

[3] "Ship Strike Committee Report on Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales", Report to National Marine Fisheries (US), Bruce A. Russell.
co-chair, Ship Strike Committee. August 2001.

2 WHALE STRIKE AND COLLISION AVOIDANCE

Before trying to formulate possible solutions to the problem of collisions between high-speed vessels and cetaceans it’s important to have a full understanding of the scope and requirements of the issue.

2.1 THE OBSTACLE

The obstacle is generally described as a large baleen whale, non-specific species. However, a better understanding of the problem and the design of a functional system can be gained by knowledge of both the nature and behaviour of the target species.

Marine mammals comprise three taxonomic orders, Cetacea (whales, dolphins and porpoises), Pinnipedia (seals and walruses) and Sirenia (dugongs and manatees). Seals and walruses can be disregarded in terms of their collision potential. There is a recognised concern of the effect of vessel collisions on the Manatee population in Florida but the vessels involved are primarily recreational vessels and the issue is considered outside the scope of this document.

The taxonomic order Cetacea, to which all whales belong, is further divided into two suborders, Odonticeti, the toothed whales and Mysticeti, the baleen whales.

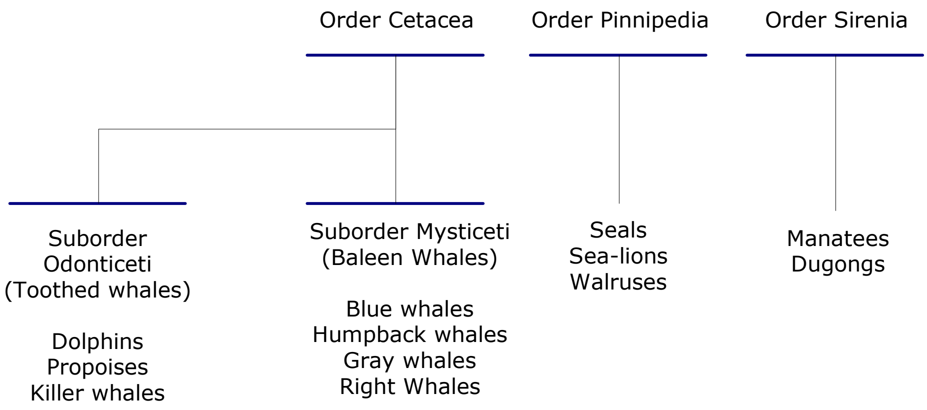


Figure 1 – Taxonomy of order cetacea

Of the cetacea suborders, Mysticeti or baleen whales present the greatest risk of collision. Research shows that Fin Whales (Balaenoptera physalus) are hit most frequently. The Sperm Whale (Physeter catodon), is the largest and only toothed whale to be involved in collisions between vessels. While the smaller size and greater agility of the toothed whales may be a factor, Baleen whales, by definition, are filter feeders and do not use echolocation to hunt their prey. While undoubtedly possessing sophisticated acoustic capabilities for long-range communications and possibly navigation, the feeding and hunting habits of the baleen whales do not require a sophisticated spatial awareness like that of the toothed whales. The brains of the baleen whales show significant development in the olfactory lobes suggesting that they may possess a well-developed sense of smell that may assist in their search for food in contrast to the complex echolocation capabilities of the toothed whales.

The behaviour of a baleen whale and the duration of its time on the surface is obviously a significant factor in its vulnerability to ship strike. Based on observations from tagged subjects, a northern right whale can be expected to spend approximately 45% of the time at the surface and approximately 55% below the surface on dives longer than 1 minute[4]. A Northern Right Whale will move at an average speed of 1 kt during its migration period.

The physiology of whales is of direct relevance. Whales are not involuntary breathers and therefore need to remain semi-conscious at all times to remain breathing. Hence, whales sleep on the surface with only one hemisphere of their brain in a sleeping state, the other hemisphere in a resting state, effectively lowering their general alertness but not entering a full sleep state.

The feeding habits of the toothed and baleen whales must also contribute to the collision hazard. Baleen whales will predominantly feed at or near the surface while toothed whales will feed throughout the water column. Interestingly, the Whale Shark and Basking shark, both filter feeders and endangered are also reported to be involved in vessel collisions. Whale and Basking sharks have a widespread distribution throughout both tropical and temperate waters.

While acknowledging some of the less common or infrequent hazards, the typical collision hazard is assumed to be a migrating right whale loitering at, or near, the surface. An adult whale will be some 12-16 meters in length and up to 63 tonnes in mass.

2.2 THE VESSEL

The relevant vessel is considered to be a high-speed catamaran or ferry. The vessel is assumed to be approximately 40 m or greater in length and capable of speeds up to 40 kts. Vessel propulsion is generally from water jets rather than propellers but not directly critical. Discussions with Austal Ships have nominated a minimum detection distance at 40 kts of 700 m in order to be able to successfully maneuver the vessel away from the detected target.

Little information is available in the literature on the specifics of the whale strike as it relates to the vessel. It is known that the probability of collision is directly related to the speed of the vessel but does the presence of water jets rather than propellers change the extent or likelihood of damage to either the whale or vessel?. Similarly, does the greater subsurface structure of a catamaran present more of a risk than a monohull? Fortunately, these questions do not have a direct impact on the consideration of a collision avoidance system.

[4] "VHF-Radio Tracking of a North Atlantic Right Whale (Eublaena glacialis) Female and Calf in the Calving Ground: Preliminary Results", Christopher K. Slay, Steven L. Swartz, Amy R. Knowlton, Robert D. Kenney. New England Aquarium. 1996.

3 THE COLLISION AVOIDANCE SYSTEM

The mechanics and arrangement of a potential collision between a high-speed vessel and baleen whale are relatively simple.

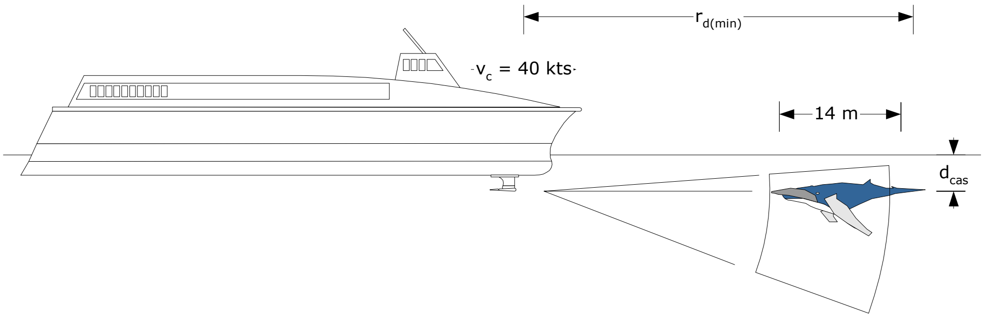


Figure 2 – Forward looking collision avoidance sonar

Figure 2 depicts a catamaran closing on a loitering baleen whale. As described earlier, the vessel speed is 40 kts and the minimum detection distance ($r_{d(min)}$) must be >700 m. The whale is approximately 14 m in length and an adult is estimated to weigh 60 tonnes.

The problem is to detect the presence of the whale at a distance of at least 700 m when the whale is loitering at, or near, the surface. At a vessel speed of 40 kts, the 700 m detection distance corresponds to a post-detection manoeuvring time of 35 s. The keel depth of a representative high-speed ferry is 4 m. The whale must be able to be detected at some distance from the surface. Given that the whale may be surfacing or diving, and that it can be expected to surface or dive the surface at less than 1 $m.s^{-1}$, in order to avoid collision the detection depth should be at least 39 m, (35 + 4).

It is often postulated as to whether an acoustic system could be used to alarm or encourage the animal to move away from an oncoming vessel. Unfortunately with the increasing amount of acoustic pollution in the ocean due to shipping traffic, whales are increasingly tolerant to noise. Moreover, if a whale is not alarmed by the noise of a fast-ferry, the noise from which can be detected for hundreds of kilometers, it is unlikely it will be discouraged by any other acoustic signals. Furthermore, unless the system operated continuously, which is unlikely to be environmentally acceptable, it would need to be triggered by the detection of an obstacle. If the obstacle (whale) can be reliably detected it would be significantly more effective to change the course of the vessel rather than relying on the startled whale to move.

An alternative and previously proposed method would be to detect the whales passively through their vocalizations. Unfortunately, the vocalizations are not predictable and the physical extent of a system required to provide the necessary tracking data would be prohibitively expensive and inherently unreliable.

Two active, rather than passive, methods of remotely detecting the presence of the loitering whale are usually nominated. An acoustic system based on active sonar principles or, less commonly, an optical system. While it is not intended to restrict possible solutions to an acoustic approach, it is generally considered in the literature that an acoustic solution is the most likely approach to be successful. Research and production of an optical system based on a laser line scanner has been reported and similar systems are employed for underwater conditions where simple illumination is problematic. While an optical system could offer considerable advantages in terms of its resolution and physical size, it is considered that it would likely be problematic in coastal areas due to the large amount of suspended material in the water from river runoffs etc. Given that ferries are operating largely in coastal areas because of their proximity to populations, it is therefore considered unlikely that an optical system would provide sufficient performance capability.

It should be noted that electromagnetic waves in the RF spectrum are not propagated in seawater and hence any form of radar is not viable in the underwater environment.

Submarines and mine hunters routinely deploy mine detection and collision avoidance sonars in a similar configuration to that described by Figure 2. In those situations the collision avoidance sonar (CAS) is deployed in a forward-looking mode and is denoted a FLCAS.

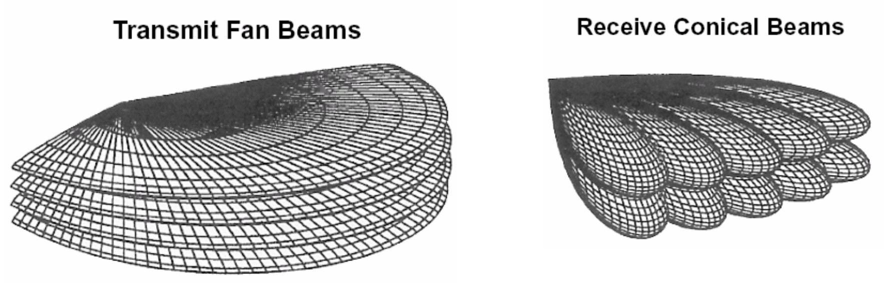


Figure 3 – Transmit and receive beams from a typical FLCAS

The acoustic array from a FLCAS is usually configured as separate transmit and receive sub-arrays. The beampattern from each sub-array is configured as vertical and horizontal arrays and the product of the two arrays then provides the composite two-dimensional beampattern. Figure 3 depicts the beampatterns from the two sub-arrays. The FLCAS, by virtue of its two-dimensional beampattern is denoted a two-dimensional sonar. If range gating of the received signal is also applied in the signal-processing unit, the sonar is then capable of discriminating range in addition to elevation and azimuth, and is described as a three-dimensional sonar.

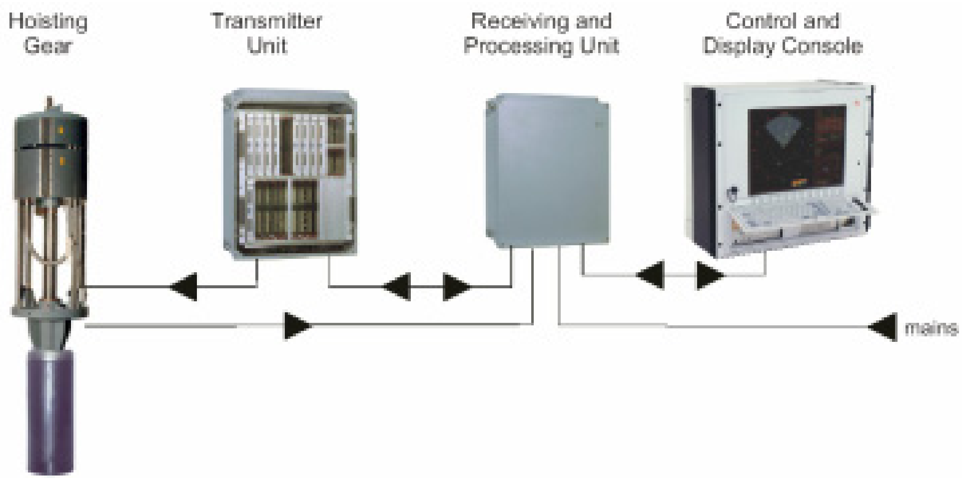


Figure 4 – Vanguard NDS 3070 FLCAS system from ELAC Nautik

Figure 4 shows the system composition of the Vanguard FLCAS, a representative three-dimensional sonar manufactured by ELAC Nautik. Note that depicting the Vanguard FLCAS in this document should not be construed as implying any assessment of its performance or capability. The in-water components are depicted on the far left with an acoustic array and its associated hoisting gear. This particular system is designed for deployment through a moon pool on a mine-hunter or similar vessel and can be withdrawn into the hull when not required. The two central cabinets house the acoustic transmitting and receiving units, while the control and display console, on the right, would usually be mounted on the bridge of the host vessel.

Operating Frequencies	30 kHz (LF) 70 kHz (HF)	
Measurement Ranges	100, 500, 1000, 2000, 4000 m	
Typical Detection Ranges	30 kHz	70 kHz
Mines	2000 m	880 m
Obstacles	3300 m	1200 m
Small Submarines	4000 m	1450 m
Bearing Accuracy	LF < 2° HF < 1°	

Table 1 – Vanguard FLCAS operating parameters

Table 1 lists the essential operating characteristics of the Vanguard system. A cursory examination of Table 1 would seem to imply that this system may be suitable for the described application however some important differences arise when comparing the operations of a system such as the Vanguard FLCAS and the requirements of a system for the avoidance of whale strikes on ferries. The primary difference relates to the difference in speed between a mine hunter and a high-speed ferry. In the former, the vessel will be progressing with caution at slow speed in an acoustically quiet configuration. In contrast a large ferry running at 42 kts will be generating very large amounts of ambient noise. In addition the target will present a totally different acoustic profile. Most mines are designed to present a minimal acoustic profile (reflection) and are physically small when compared to a 60-tonne, 14 m baleen whale.

3.1 SONAR SYSTEM PERFORMANCE

The operability of any active sonar system depends on a complex series of calculations associated with

- The amount of power transmitted by the sonar projector
- The distance of the target from the projector
- The acoustic reflectivity of the target
- The sensitivity of the receiver
- The level of ambient noise

The calculations are combined in a mathematical expression denoted the two-way active sonar equation. The equation uses a number of definitions based on the bulleted quantities

SYMBOL	DESCRIPTION
SL	Source level from the acoustic projector
DI_P	Directivity Index or spatial gain provided by the projector
TL	Transmission Loss of the acoustic path from the projector to target
TS	Target Strength of the target. Can be positive or negative depending on the physical dimensions and properties of the target
DI_R	Directivity Index or spatial gain provided by the acoustic receiver
FOM	Figure of Merit. An overall measure of the viability of the system
DT	Detection Threshold. The amount by which the echo must be greater than the ambient noise to provide reliable detection
NL	Noise Level. The level of ambient noise at the acoustic receiver.

Table 2 – Acoustic signal budget description

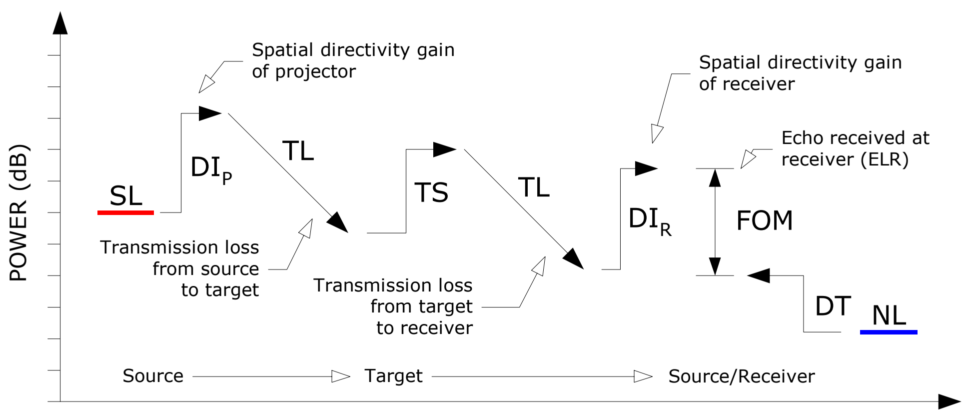


Figure 5 – Signal Budget Process for Active Sonar

Figure 5 depicts a conceptual view of the signal budget process. To aid in calculation, logarithmic values are used in all the calculations and are represented by the vertical axis. The signal budget progresses from left to right corresponding to the flow of the signal from the projector to the target and back to the receiver. Note that the acoustic transducer for transmit and receive paths may or may not be the same units depending on whether the system is in a monostatic or bistatic configuration. While separate projector and receiver arrays are often employed by FLCAS's, they are generally co-located and therefore considered to operate in a monostatic configuration.

The viability of an acoustic system is expressed in terms of the figure of merit (FOM) of the system. The two-way active sonar equation can be rearranged to define the FOM

$$\mathrm{FOM} = \left(\mathrm{SL} + \mathrm{DI_P} + \mathrm{TL} + \mathrm{TS} + \mathrm{TL} + \mathrm{DI_R}\right) - \left(\mathrm{NL} + \mathrm{DT}\right)$$

Equation 1

Ultimately, if the FOM is positive then the system is operable, if the FOM is negative, then the signal returned from the target is not detectable in the ambient noise and the system is inoperable.

It is not intended to provide a full analysis of a sonar system design in this document. However Equation 1 is provided as background to the important issues which impact on the performance of a sonar system relevant to the problem of whale ship-strikes. Those issues which are specific to the described problem and potentially problematic are the,

- Location and deployment of the transducer arrays on the vessel
- Level of backscattered energy from the whale
- Level of ambient noise generated by the platform

3.1.1 SYSTEM DEPLOYMENT

The deployment of an FLCAS such as that depicted in Figure 4 on a high-speed ferry or catamaran is routine with the exception of the in-water components. As described earlier, a high-speed ferry can be operate at speeds as high as 40 kts. Hence the mechanical construction of the array must be capable of sustaining the loads encountered. Additionally the acoustic array is often stabilized for vessel motion using integrated pitch and roll sensors and a mechanical orientation mechanism. The Petrel USM 5424 manufactured by Thales Underwater Systems Pty Ltd (Australia) is such a system. The azimuth and elevation control of the array must therefore be capable of orienting the array in the high flow speed and enduring the increased rate of change of vessel attitude. The cross sectional area of the acoustic array is important in considering the drag and forces on the system. While the performance of the vessel is unlikely to be affected, the mechanical forces imparted to the array by the induced drag may be substantial. Reducing the cross sectional area of the array will reduce drag but also has the effect of increasing the beam dimensions. Hence, there is an optimization consideration between the mechanical drag and the required beam dimensions.

3.1.2 ACOUSTIC TARGET STRENGTH OF A BALEEN WHALE

The ratios of the power of the incident and reflected acoustic energy on a sonar target is denoted the target strength (TS). Fortunately, a whale has large air-filled lungs that, by virtue of the acoustic impedance discontinuities relative to the whales surrounding organs, will generate strong acoustic reflections. It is the impedance discontinuities from the lungs that generate the bulk of the reflected acoustic energy; if they were not present, the large water content of a whale would mean that the animal would be practically transparent to active sonar. Similarly, the gas filled swim bladders of non-mammalian fish are primarily responsible for the reflection of incident acoustic energy from fish-finders etc.

Target strength calculations are notoriously difficult to predict from theoretical considerations, even for relatively regular and geometric objects such as torpedoes, submarines mines etc. Predicting the target strength of a whale would be, at best, based on very loosely defined assumptions and is best done empirically. Measurements have already been made by researchers on the target strength of whales, and while not comprehensive, are certainly useful. Researchers[5] found that, at 20 kHz, the target strength of an adult humpback, 15 m in length, varied between 7 dB broadside and −4 dB head on. These measurements were later repeated by Love[6] with a pod of Northern Right Whales but with an ensonification frequency of 86 kHz. The values obtained were some 5 dB lower on average but the results are encouraging and the differences in target strength are certainly within the ranges that could be anticipated, given the different species and ensonification frequency.

The field trials conducted by Love[6] successfully imaged a pod of right whales at a range of 80 m from the projector of forward-looking sonar. While the trials were obviously not subject to the onerous requirements of the high-speed catamaran, or achieve the nominated detection range, they do, at least, indicate the veracity of the concept. Furthermore the experiments were conducted with a very low level acoustic output (170 dB // 1 μPa @ 1 m) thereby indicating that improvements in performance could be obtained relatively easily.

3.1.3 AMBIENT NOISE

The ambient noise generated by a water jet catamaran at 40 kts will be very substantial. No literature is readily available on typical values. However, Ross[7] reports that the cumulative radiated noise for a vessel in the range of 500 Hz to 1 kHz increases as a function of U^5 to U^6 (where U is the speed of advance). The onset of cavitation represents a breakpoint in the radiated noise function and results in an even higher output. Hence a high-speed catamaran probably represents one of the most potentially troublesome platforms on which to deploy an acoustic detection system.

---

[5] "Active High Frequency Phased-Array Sonar for Whale Shipstrike; Avoidance: Target Strength Measurements", J. H. Miller D. C. Potter.

[6] "Target Strengths of Humpback Whales, (Megaptera Novaeangliae)", R. H. Love. J. Acoustical. Soc. Am. 54 (5), PP 1312.

[7] "Mechanics of Underwater Noise", D. Ross. Peninsula Publishing, Los Altos California 1987. ISBN 0-932146-16-3.

The radiated noise from a catamaran will be dominated by flow and machinery noise. The frequency characteristics of flow and machinery noise are largely predictable in that the frequency roll-off generally follows a 6 dB.octave^{-1} trend after a peak around 200-500 Hz. Given an operating frequency of 80 kHz, as used in the reference[6], the carrier frequency is some 7 octaves above the peak of the flow and mechanical noise, thereby representing an attenuation of the vessel noise by 42 dB.

The radiated noise from a high-speed catamaran will be predominantly generated at the rear of the vessel. The projector and receiver of the FLCAS will have a highly directional beampattern and the radiated signals will be directed away from the source of the radiated noise. It is therefore reasonable to assume that a high degree of noise rejection would be achieved by exploiting the directionality of the noise source and the in-water system components.

Flow noise, or hydrodynamic noise is generated by pressures impinging on the acoustic receiver from the turbulent flow in the boundary layer around the transducer. Flow noise is not strictly speaking an ambient noise since it is generated only in the vicinity of the acoustic receiver but, regardless of its origin it can be an important consideration in the assessment of system performance.

Flow noise is a complex phenomenon, the causative mechanism and behaviour of which, is outside the scope of this document. However, the primary strategy always employed in its minimisation is the placement of a streamlined housing or sonar dome around the relevant transducer. Such domes funtion to reduce the flow noise by minimising turbulent flow, delaying the onset of cavitation and transferring the flow noise region away from the vicinity of the transducer.

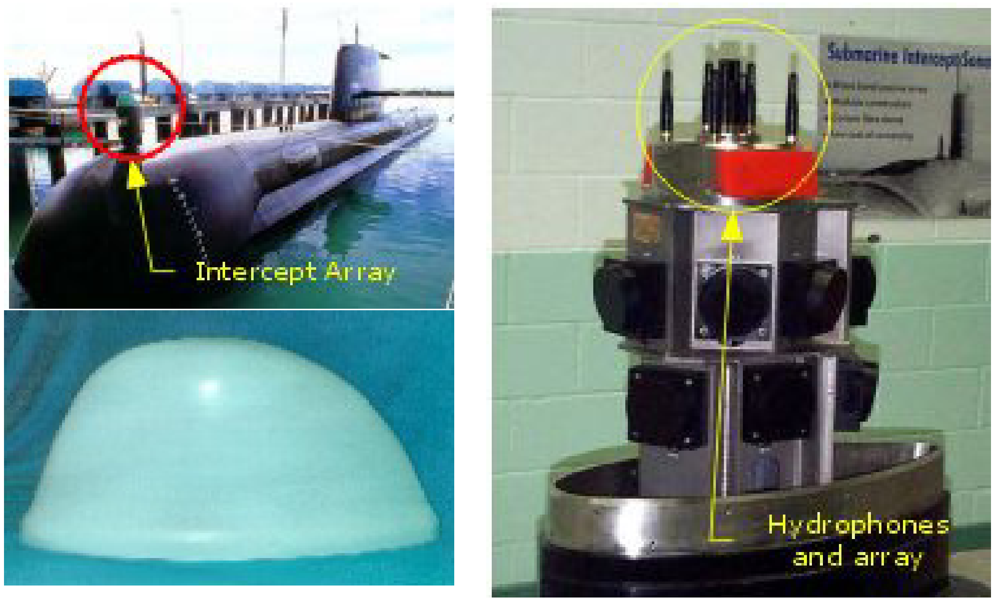


Figure 6 – Intercept Array and Sonar Dome

Figure 6 shows a disassembled view of an intercept array as would be deployed on a submarine (HMAS Collins - RAN) and the associated sonar dome fitted to reduce flow noise around the hydrophones in the array.

The high-speed of the vessel introduces some concerns about flow noise. However, it should be noted that the active intercept array on a modern torpedo functions adequately at speeds substantially greater than 40 kts. Hence given that the issue can be successfully addressed in that application, it is reasonable to assume that the same physical principles can be applied to the proposed application on a high-speed catamaran.

4 SUMMARY

Collisions with whales by maritime vessels is becoming an issue of concern to both environmental and conservation groups. In turn, those concerns are being translated into recommendations that include a restricted scope of maritime operations in vulnerable areas. While those proposals are currently limited in their geographic application, it is inevitable that the recommendations will become more widespread and that more nations and governments will eventually take on whale conservation measures.

Of the two sub-orders of whales, the baleen whales are the greatest contributor to the recorded occurrence of ship strike. Ship strike is now the greatest cause of mortality to the Northern Right Whale, an endangered species. Ship strike is also a commonly recorded cause of death for Fin, Humpback and Grey.

The speed of the vessel has been shown to be a direct contributor to the likelihood and consequences of whale strike, and owners and constructors of high-speed vessels should be aware that the conservation measures may impact directly on their operating parameters and revenues.

The detection and avoidance of whale strike by a high-speed vessel is problematic. A number of methods have been proposed and researched but an active sonar approach holds the greatest potential for success.

Intercept arrays on submarines and mine-hunters carry out similar tasks but at much lower vessel speeds. The large amount of radiated noise produced by a high-speed vessel put the operation of an active sonar at the very edge of the performance curve. In addition problems such as flow noise and deployment of the system on the host vessel add to the burden. However, research has shown that whales present relatively large acoustic targets due to the size and nature of their physiology.

The detection of whales at the ranges and speeds required for high-speed vessel operations cannot be demonstrated currently. However, neither can the realisation of a solution be ruled out. Several groups are currently researching possible solutions.

The provision of a system that allows the vessel owner to operate their vessel in vulnerable areas without risking collision with a whale or damage to the vessel will be readily accepted. The manufacturers of vessels equipped with those systems should therefore enjoy a commercial advantage over their competitors.

ANNEX - A COLLISIONS FROM SHIPS POSE RISK TO SOME WHALE POPULATIONS

This annex is reproduced from Ocean Update, May 2001

(http://www.seaweb.org/resources/48update/collisions.html)

Ship strikes can "significantly affect small populations of whales, such as northern right whales in the western North Atlantic," and in many cases a reduction in vessel speed is the best way to reduce such collisions drastically. So concludes a recent paper in the journal Marine Mammal Science.

The paper notes that although "collisions with motorized ships are a recognized source of whale mortality, little has been done to compile information on the frequency of their occurrence or contributing factors." The study's authors therefore "searched historical records and computerized stranding databases for evidence of ship strikes involving great whales (i.e. baleen whales and the sperm whale). Historical records suggest that ship strikes fatal to whales first occurred late in the 1800s as ships began to reach speeds of 13-15 [knots], remained infrequent until about 1950, and then increased during the 1950s-1970s as the number and speed of ships increased. Of 11 species known to be hit by ships, fin whales are struck most frequently; right whales, humpback whales, sperm whales, and gray whales are hit commonly."

The number of whales hit by ships is at times surprisingly high. For example, in some areas, "one-third of all fin and right whale strandings appear to involve ship strikes." Among the conclusions reached by the paper's authors:

- Although all types and sizes of vessels may hit whales, most lethal and serious injuries to whales are caused by relatively large vessels (e.g. 80 m or longer);
- A great majority of ship strikes seem to occur over or near the continental shelf;
- The behaviour of whales in the path of approaching ships is uncertain but, in some cases, last-second flight responses may occur;
- Most severe and lethal injuries caused by ship strikes appear to be caused by vessels travelling at 14 kt or faster;
- Ship collisions probably have a negligible effect on the status and trend of most whale populations, but for very small populations or discrete groups, they may have a significant effect.

The authors note that most whales hit by ships are apparently "not seen beforehand or seen only at the last moment. Collision avoidance strategies dependent on detecting and avoiding whales therefore may be ineffective for large ships with limited manoeuvrability … Collision accounts suggest that serious injuries to whales may occur infrequently at vessel speeds below 14 kt and rarely at speeds below 10 kn.

Therefore, there may be benefit in management actions designed to reduce vessel speed below at least 14 kt to reduce the impact of vessel collisions on large cetaceans."

As Ocean Update was going to press, management measures to reduce vessel-related deaths of right whales were scheduled to be examined at a workshop convened by the National Marine Fisheries Service (NMFS) and held in New London, Connecticut. Speed and routing measures were to be the main mitigation measures examined.

Source: Laist, D.W., et al. 2001. Collisions between ships and whales. Marine Mammal Science 17(1): 35-75, via www.seaweb.org

Contact: David W. Laist, Marine Mammal Commission, 4340 East-West Highway, Bethesda, MD 20814. Tel: (301) 504 0087. E-mail: dlaist@mmc.gov

ANNEX - B

MEDIA RELEASE FROM WWF

Ship Strikes And Entanglement Pose Greatest Threats To Whales - October 24, 2001[8]

> Earlier this year, we saw graphic evidence of the effect of shipping strikes after a whale was struck by a high-speed vessel in waters just off the coast near Sydney. Clearly what is needed are speed restrictions and propeller cowling for shipping in critical feeding, calving and migration areas," said Dr Butcher.

SYDNEY: A dead whale discovered recently in waters off Lakes Entrance in eastern Victoria, was more likely to have been killed as a result of a collision with shipping or entanglement in marine debris, according to WWF Australia.

"Entanglement in fishing gear kills more cetaceans worldwide each year than any other mortality factor," said Dr David Butcher, WWF Australia's CEO.

"It is estimated that 65,000 to 85,000 cetaceans die each year in gillnet, shark netting and similar gear. The true figure is likely to be much higher as many deaths are unreported. "

Dr Butcher said entangled whales frequently drowned as they were unable to surface, but even if they were able to break free of netting, they could continue to tow some of the fishing gear for long distances - this eventually resulted in debilitating injures and a slow death.

Dr Butcher said that although noise pollution from seismic surveys was "strongly suspected" of having severe effects, such as damaged ear structures, on whales and other cetaceans, the biggest threats facing whales were entanglements and by-catch in fisheries, ship strikes, chemical pollution and habitat degradation due to industrial effluents and ocean pipeline sewage disposal.

"The whale found off Lakes Entrance was reported to be badly decomposed. Seismic testing had only just started in the region, so if the reports of the whale's condition were accurate, then I think we can rule out the testing as a likely cause of death in this instance, " said Dr Butcher.

"However, this does not mean that noise pollution is not a problem - it is just one of a suite of problems impacting on the survival of the world's great whales and smaller cetaceans."

Dr Butcher said that a recent report by the Scientific Committee of the International Whaling Commission (IWC) stated that most incidents involving fatal collisions between ships and whales "go unreported and unnoticed" and raised the possibility of developing technology to reduce ship strike mortality. Ship strikes had been blamed for nearly 90 per cent of all North Atlantic right whale deaths, he said.

"Earlier this year, we saw graphic evidence of the effect of shipping strikes after a whale was struck by a high speed vessel in waters just off the coast near Sydney. Clearly what is needed are speed restrictions and propeller cowling for shipping in critical feeding, calving and migration areas," said Dr Butcher.

[8] http://www.wwf.org.au/content/release_whale_strike2410.htm.

ANNEX - C PRESS RELEASE – ASSOCIATED PRESS

Ships A Growing Cause Of Whale Deaths : By Randolph E. Schmid, Associated Press, Sunday, April 21, 2002.

WASHINGTON: Although only two nations continue to hunt whales, the giants of the oceans still face a threat from humans: being struck by ships.

Between 20 percent and 35 percent of whales found dead show signs of having been struck by ships, more in some species, recent studies found.

Right whales in the western North Atlantic appear to have been especially hard hit. Their population is estimated at 300 to 325.

"Nearly half of the known mortality of the species is due to ship collisions or net entanglement. Ship collisions probably account for 40 percent," said David W. Laist of the federal Marine Mammal Commission. "It's a very significant share. ... It's clearly preventing their recovery."

Scott Kraus, director of research at the New England Aquarium, estimated that ship collisions are killing off one to two right whales a year, "and probably more that we don't see the bodies of."

"In a population this small, that's a significant percent," he said.

Prized for their oil, right whales were heavily hunted in the past. They were named because they were considered the right whale to hunt.

After most hunting ended, the majority of whale deaths and strandings were written off to disease, old age or similar reasons, said James G. Mead, a whale specialist at the Smithsonian Institution's National Museum of Natural History.

As researchers began studying the animals, however, they discovered signs of bruising. "You can't bruise a carcass; an animal has to be alive to bruise," Mead said. The most likely cause of bruising, he said, was a collision with a ship.

Some whales also had rows of slash marks left by propellers, while others suffered massive internal injuries in collisions, researchers found.

"I would say (ship collisions) is at least comparable and probably exceeds hunting mortality," Mead said.

While the International Whaling Commission bans hunting whales, Japan and Norway still conduct hunts, ostensibly for research purposes. A Japanese whaling fleet that returned home recently killed 440 minke whales during a six-month hunt.

Among recent cases of whale deaths:

- A baby right whale was found dead off Long Island, N.Y., in June, the fourth calf of the endangered species to perish last year and the second believed killed in a collision with a ship.
- The following month, a 45-foot humpback whale died of a crushed skull near Glacier Bay National Park in Alaska. Park officials said the whale had been struck by a cruise ship.

Janice M. Straley, who teaches marine biology at the University of Alaska Southeast in Sitka, said park officials are urging cruise ships to reduce their speed to below 14 knots (16 mph) in Glacier Bay.

In 1999 the government launched a mandatory ship reporting_system for vessels over 300 tons entering designated areas known to be right whale habitats off Cape Cod, Mass., Florida and Georgia. The goal is to understand ship traffic patterns in the areas so efforts can be made to protect the whales.

In the first year of operation -- the most current data available -- there were 699 ship reports in the northern area and 279 in the southern district. Officials believe, however, that many vessels failed to report in and others filed inaccurate reports that had to be dropped from the analysis.

Among the proposals to help avoid collisions have been rerouting vessels around high-risk areas, restricting speed in those areas or changing routes to minimize the time in whale areas, though no official steps have been taken.

Avoiding ships seems to be learned behaviour, and in several species, particularly right and humpback whales, most of the animals are juveniles and may have less awareness of the danger, Laist of the Marine Mammal Commission said.

Calves also tend to be fatter, so they have more trouble diving and spend more time at the surface than adults.

Laist said there are "all sorts of behaviours" that keep whales on the surface. Right whales sometimes doze there, engage in sexual activities or nurse and may be less alert during those times. In a behaviour called "logging," right whales tend to laze at the surface and are often unaware of what is going on around them, he said.

Kraus of the New England Aquarium suspects there is so much noise in the oceans, especially off New England, that the whales simply do not hear the ships coming. And, he added, they sometimes form courtship groups that can number up to 30 or 40 whales for hours at a time, and they are oblivious to anything going on around them.

ANNEX - D TETHYS WORKSHOP

The Tethys Research Institute has organized a workshop on the problem of cetacean collisions in the Mediterranean Sea during the 15th Annual Conference of the European Cetacean Society (Rome, Italy, 6-10 May 2001).

ANNEX - D.1 BENEFITS AND LIMITATIONS OF ACTIVE SONAR FOR MARINE MAMMAL RISK MITIGATION

Joseph E. Bondaryk

SACLANT Undersea Research Centre, Viale S. Bartolomeo 400, 19138 La Spezia, Italy

As part of the Sound Oceanography and Living Marine Resources (SOLMAR) project, the NATO SACLANT Undersea Research Centre is investigating a low power, active sonar concept for the detection and localization of marine mammals to implement risk mitigation policies for underwater acoustic sound sources. Such a system could also have application as an early-warning, collision-avoidance sonar for shipping. During the Sirena sea trial, which was conducted in the Ligurian Sea in August 2000, data from a test system was collected to determine concept feasibility and assess system performance. The benefits of the system include wide area coverage, exact whale position and tracking capability. Limitations are imposed by the summer sound velocity profile, low and aspect-dependent Target Strength of animals, and interference from the whale's own vocalizations. An example of the success of this system is the in situ Target Strength measurement of striped dolphin, Stenella coeruleoalba, of -20.3 dB re 1 µPa @ 1 m with a standard deviation of 4.7 dB.

ANNEX - D.2 POTENTIAL MITIGATION OF FAST-FERRIES ACOUSTIC AND DIRECT PHYSICAL IMPACT ON CETACEANS: TOWARDS A SUSTAINABLE DEVELOPMENT OF MODERN SHIPPING

Michel André(1) & John R. Potter(2)

1) Marine Mammal Conservation Research Unit, Department of Morphology, Veterinary School, University of Las Palmas de Gran Canaria, Trasmontana, 35416 Arucas, Gran Canaria, Canary Islands, Spain, mandre@cicei.ulpgc.es

2) Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260. johnp@arl.nus.edu.sg http://www.arl.nus.edu.sg

Collisions between cetaceans and shipping are becoming a major threat to marine mammal conservation. The recent introduction of fast-ferries in areas of intense shipping and coincident cetacean occupation seems to have worsened the problem of unfortunate encounters. A case study in the Canary Islands is presented, providing evidence of the negative impact of fast-ferries via acoustic pollution, leading to a possible hearing loss and increased difficulty for cetaceans to avoid imminent collisions. The use of acoustic deterrents has been shown to be ineffective in the medium term on populations already highly tolerant to noise. An alternative solution, based on ship traffic and cetacean detection, classification and localisation by a wide-aperture distributed array of passive acoustic sensors, is discussed. Such a system would be an ambitious synthesis of many advanced acoustic technologies, and would certainly take considerable resources to implement. The benefit would be an efficient, benign system which could detect, classify and localise cetacean vocalisations, continuously transmitting (in real time) the estimated position, heading and speed of individuals crossing a "acoustic security corridor" established in areas of intense shipping. Once the system was operational, it could conceivably be extended to provide protection to non-vocalising cetaceans by imaging passive cetaceans using the radiated noise from shipping and vocalising marine mammals, a technique which is part of a new acoustic development known as "Ambient Noise Imaging". Although the system would be a challenging undertaking, no other passive solution has yet been found, and there remains little time to prevaricate.

ANNEX - E COLLISIONS BETWEEN SHIPS AND WHALES

(Marine Mammal Science: Vol. 17, No. 1, pp. 35-75.)

David W. Laist, Amy R. Knowlton, James G. Mead, Anne S. Collet, Michela Podesta.

Abstract--Although collisions with motorized ships are a recognized source of whale mortality, little has been done to compile information on the frequency of their occurrence or contributing factors. We searched historical records and computerized stranding databases for evidence of ship strikes involving great whales (i.e., baleen whales and the sperm whale). Historical records suggest that ship strikes fatal to whales first occurred late in the 1800s as ships began to reach speeds of 13-15 kt, remained infrequent until about 1950, and then increased during the 1950s-1970s as the number and speed of ships increased. Of 11 species known to be hit by ships, fin whales (Balaenoptera physalus) are struck most frequently; right whales (Eubalaena glacialis and Eubalaena. Australis), humpback whales (Megaptera novaeangliae), sperm whales (Physeter catodon), and gray whales (Eschrichtius robustus) are hit commonly. In some areas, one-third of all fin whale and right whale strandings appear to involve ship strikes. To assess contributing factors, we compiled descriptions of 58 collisions. They indicate that all sizes and types of vessels can hit whales; most lethal or severe injuries are caused by ships 80 m or longer; whales usually are not seen beforehand or are seen too late to be avoided; and most lethal or severe injuries involve ships traveling 14 kt or faster. Ship strikes can significantly affect small populations of whales, such as northern right whales in the western North Atlantic. In areas where special caution is needed to avoid such events, measures to reduce the vessel speed below 14 kr may be beneficial. Keywords--mortality, strandings, ship collisions, species conservation, right whales.

© Copyright by The Society for Marine Mammalogy 2001.