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Locating fish bomb blasts in real-time using a networked acoustic system

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ABSTRACT

Results are presented of a demonstration of real-time fish blast location in Sabah, Malaysia using a networked hydroacoustic array based on the ShotSpotter gunshot location system. A total of six acoustic sensors - some fixed and others mobile - were deployed at ranges from 1 to 9 km to detect signals from controlled test blasts. This allowed the blast locations to be determined to within 60 m accuracy, and for the calculated locations to be displayed on a map on designated internet-connected computers within 10 s. A smaller three-sensor system was then installed near Semporna in Eastern Sabah that determined the locations of uncontrolled blasts set off by local fishermen. The success of these demonstrations shows that existing technology can be used to protect reefs and permit more effective management of blast fishing activity through improved detection and enforcement measures and enhanced community engagement.

1. Introduction

Blast fishing (also known as dynamite fishing and fish bombing) is an illegal destructive fishing technique that uses underwater explosions to kill and stun fish so they can be more easily harvested. The use of explosives for fishing has been reported as far back as 1898 in Hong Kong (Cornish and McKellar, 1998). Today blast fishing and other destructive fishing techniques and overfishing are reported to be a medium to severe threat to nearly 60% of reefs globally (Burke et al., 2011), with the greatest prevalence occurring in countries in the coral triangle in Southeast Asia (Burke et al., 2012) and in Tanzania (Wells, 2009).

Fishers using explosives typically target schooling fishes such as Rabbitfish (siganids) and Fusiliers (caesionids), but reef fish are also targeted (Fox and Erdmann, 2000) resulting in structural damage that leads to a loss of fish diversity and abundance, and reduces the capacity of the reef to recover naturally. The effect is stark. Reefs in Indonesia that have been subjected to frequent and chronic dynamite fishing are reduced to fields of unstable rubble that showed zero natural recovery after five to seven years (Fox et al., 2003; Fox and Caldwell, 2006). This eliminates the benefits provided by reefs in the forms of protein and tourism, and threatens biodiversity. Additionally, the blasted reefs have a much-reduced capacity to regenerate and therefore their efficiency as physical buffer against wave action is impaired.

Recovery rates of blasted reefs vary according to the level of damage, the stability of the crater or rubble field, and the potential of surrounding reef to produce larvae. Working in the Philippines, Alcala and Gomez (1979) estimated that reestablishing 50% of initial coral cover would take 40 years. Riegl and Luke (1998) estimated recovery of damaged reefs in Egypt would take 'several hundred years', while Raymundo et al. (2007) reported no recovery on a blasted reef in the Philippines after 20–30 years, which is consistent with Fox and Caldwell's (2006) findings.

The impact and risk to coral reefs caused by destructive fishing is so immediate and so severe that the elimination of destructive fishing practices is a key element of Goal 14 of the Sustainable Development Goals that set out a framework for global sustainable development from 2015 to 2030 (UN, 2016).

A study of the yield and economics of dynamite fishing by Fox and Erdmann (2000) indicates why dynamite fishing is common: fishermen collected several kilograms of fish from each blast, which was collectively worth five times the average daily labouring wage in the area (Fox and Erdmann, 2000). The high economic return arising from this catch per unit effort (CPUE) provides sufficient motivation to make the practice widespread, even at the expense of losing future fish production potential. Other key factors are the general lack of effective monitoring, surveillance and control (MSC) by government agencies, links with organized crime, and ineffective laws regulating illegal fishing that together result in low detection, detention, and prosecution rates (Sebastian, 2016).

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In principle, strategies for managing blast fishing activities will require a combination of community development including increased awareness and education i.e. soft measures, and enforcement i.e. hard measures. To optimize a management plan's effectiveness, the balance of soft and hard measures must be matched to the root causes and social structure of the blast fishing activity. Dealing with criminal syndicates will require greater emphasis on enforcement while addressing blast fishing carried out in response to severe overfishing and poverty will require a more community-development orientated approach. Certainly, economic analysis of strategies of enforcement (as compared to rehabilitation of dynamited reefs) by Haisfield et al. (2010) in Indonesia indicated that enforcement was between 5 and 70 times more cost effective. This supports the principle that prevention is more effective than cure, even when cost-effective and low technology approaches are used, such as that of Raymundo et al. (2007). Evidence from COREMAP, a coral reef management program conducted in Indonesia for over 15 years, indicates that the reduction of blast fishing is most effective when the local community and enforcement agencies are sufficiently empowered in the enforcement process (IUCN, 2002). A paper by (Braulik et al., 2017) presents results of acoustic monitoring of blast fishing hotspots in Tanzania and confirms heavy activity near Dar Es Salaam.

The aims of this paper are to show that an underwater acoustic location system based on a mature technology used to locate gunshots can readily locate fish blasting and that there is significant scope to develop t affordable systems that can detect blast fishing over large areas. We describe testing in Sabah, Malaysia, where a technology first developed for locating gunshots in US cities for law enforcement, was adapted for determining the locations of underwater explosions. The testing was successful in detecting both controlled blasts and ongoing community blast fishing activity. The testing also identified performance enhancements to pursue for future deployments, such as improved discrimination algorithms to reduce the effects of background noise, for example snapping shrimp clicks, and lapping sounds at piers or boats.

In parallel with an integrated approach to the management of marine resources by governments, this technology provides the means to better utilize enforcement resources and improve the chances of obtaining successful convictions against blast fishermen. Such an approach should have a deterrent effect on blast fishing and allow societal measures to curb this practice.

2. Background

2.1. History of acoustic blast monitoring in Sabah

The practicality of acoustic detection and location of blasts from fish bombs was investigated by two of the authors in the early 2000s (Woodman et al., 2003, 2004). This work indicated that the acoustic signal from a blast should be readily detectable at ranges up to 30 km in open water, and that the angle to the blasts could be determined to within a degree. It was found that islands blocked acoustic signals, and confounding noise sources such as nearby snapping shrimp (alpheids) would need to be filtered out.

Using similar angular detection techniques, Marine Conservation Society and St Andrews Instrumentation Limited have been working with Sabah Parks Authority over the last few years to monitor blasting in Tun Sakaran Marine Park on the east coast of Sabah (Wood and Ng, 2014). Their work has measured the rate of blasting near several islands, thus bringing much-needed attention to the prevalence of blast fishing and the potential for technology to locate individual blasts.

This paper is the third in a series in the Marine Pollution Bulletin begun by Woodman et al., (2003 and 2004), and validates their supposition that measurements with a networked acoustic array would allow accurate and precise locations of blasts.

2.2. The ShotSpotter system for gunshot location

The company that created ShotSpotter was founded in 1996 in California to develop acoustic detection and location technology for gunshots (Showen, 1997) and (Showen et al., 2008). Based on the similarities of their respective work, two of the authors (Showen and Woodman) began to discuss the possibility of using ShotSpotter's technology as a means to detect fish bombs in 2012. The premise was that adaptation of a successful system for gunshot location would be significantly cheaper than development of a new system designed for real-time location of blast fishing.

The impetus to install an acoustic gunshot location system is the unfortunate occurrence of significant urban gunfire in many cities. The systems have been shown to aid police in suppressing gunfire by indicating the precise locations and the number of gunshots in a particular shooting event in real time.

The ShotSpotter System uses a combination of the measured 'time of arrival' (ToA) and 'angle of arrival' (AoA) at the distributed sensors to determine blast locations. (Showen et al., 2009). Many navigation systems, including LORAN and GPS, use the ToA method that is colloquially known as triangulation but is more properly called multilateration. (https://en.wikipedia.org/wiki/Multilateration). See also (Hamann, 2007) for a straight-forward mathematical explanation at http://w3.uwyo.edu/~hamann/TrilatShow.pdf.

When a set of sensors at known positions receive impulses at different arrival times, it is readily possible to compute the location of the gunshot or blast. The difference in arrival time between a pair of sensors defines a locus of possible blast locations along a hyperbola, and the intersection of multiple hyperbolae provides a location.

Fig. 1, adapted from (Showen et al., 2009) illustrates how blast locations can be calculated using a combination of ToA and AoA methods. Using them both together reduces the number of sensors required for many geometries. Using both can also guard against being fooled by an echo instead of a directly propagated path, or lift an ambiguity when only two independent hyperbolae are available and they intersect at two locations.

The simplest case of using ToA and AoA together is illustrated here using only two sensors. The cross-hatched area is a potential blast location, the size of which is determined by the accuracy of the two angle measurements – possibly enlarged by orientation errors at each sensor. The hyperbola is given by the ToA measurement between the two sensors, and further constrains the blast location to a small segment around the hyperbola. If there were a third sensor detecting the blast, then the resulting intersecting hyperbolae would even more constrain the blast location to a very small region. In that case, the accuracy of the location would be determined by the relatively small changes in the speed of propagation between the paths or in the small uncertainties in the sensor positions.

ShotSpotter has created a National Gunfire Index for several years, documenting and analyzing the incidence of gunfire and describing many aspects of data usage and collection (http://www.ShotSpotter.com/2016NGI). The system is demonstrably a mature technology, which presents a real opportunity to combat the blast fishing problem. Such data can be used to determine 'hot spots' where the prevalence and timing of gunfire can be quantified to enable planning for future interdiction (Watkins et al., 2002). One of the notable findings is that typically less than 20% of the gunfire detected by ShotSpotter is reported to the police through an emergency '911' call. (Carr and Doleac, 2016). Such methods applied to the blast fishing problem, have great potential to better understand the extent of the blast fishing culture.

According to the US Department of Justice, 'The certainty of being caught is a vastly more powerful deterrent than the punishment' (DOJ, 2016). In the case of blast fishing this dictum may also prove true.

Our relatively short-range impulsive location method can be contrasted with the detection or tracking of quasi-continuous marine mammal sounds (Møhl et al., 2001). Additionally, we are not using the