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Fishing for common ground: Investigations of the impact of trawling on ancient shipwreck sites uncovers a potential for management synergy

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ABSTRACT

Maximizing social and economic benefits from fisheries and protecting culturally significant archaeological sites are management goals often viewed to be at odds with eachother. However, a potential for management synergy arises if fisheries related benefits can be associated with the protection of shipwreck sites. This study reviews fish abundance and community assemblage on several ancient shipwreck sites in the Aegean Sea. In this region, the presence or absence of fishing has been correlated to shipwreck condition. The results indicate that, on average, wrecks in worse condition (heavily fished) had 55% lower species richness, 57% lower abundance, and 41% lower diversity than wrecks in pristine condition, though only the patterns for abundance and species richness were statistically significant. No statistically significant change in fish community composition between fished and unfished wrecks was observed, though community composition between shallow water and deep water wrecks was statistically different. This research highlights the potential benefit of marine protected areas around areas of high density of shipwrecks that can both protect these sites and increase local fisheries by preserving these artificial reefs.

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1. Introduction

Marine usage conflicts are common with issues of marine policy where multiple parties seek to exploit the same areas. As populations in coastal areas grow, and demands on marine resources struggle to keep pace, the frequency and severity of these conflicts between user groups only continue to increase. This conflict is especially acute between the fishing industry and the conservation community. Bottom trawl fishing operations have long been challenged by benthic ecologists and fisheries biologists for their destructive effects on the seabed and non-selective capture of species [2,26,13]. Increasingly, however, the use of marine protected areas (MPAs) has been proposed as a potential management synergy where the exclusion of fishing within a protected area generates increased landings in adjacent fishing grounds by means of "spillover" [11,12,21]. Here we investigate preliminary field data that suggest the possibility of using MPAs to protect shipwreck sites in order to enhance the fisheries value of the MPA, based on the improved ability of protected cultural heritage sites to function as artificial reefs, potentially supporting higher abundance and/or diversity of fish than unprotected sites.

The use of MPAs and artificial reefs for fisheries benefits dates back several hundred years [18,9,14], however, their widespread use as a modern management tool dates back only a few decades. Fisheries benefits from MPAs center around the concept of spillover, wherein the fish population within the protected area grows rapidly. This can lead to fisheries benefits when adults migrate out of the reserve and into fishable waters to alleviate density dependence, or when the high density of spawners within the protected area create additional larval recruits which may advect or swim into fishable waters [23,28]. The fisheries benefit of artificial reefs on the other hand, is somewhat less clear. While artificial substrate has been clearly documented to attract fish [36,20], whether these structures can supplement regional fisheries production is the subject of some scientific debate, and is likely dependent on regional and species specific factors such as population size, availability of suitable habitat, and fishing intensity [22,24].

Suitable artificial reef habitats often include the architecture of a shipwreck. Whether an accidental or intentional sinking [35], the

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structure and cargo of a shipwreck provide a range of habitats highly suitable for colonization. Particularly in amphora pile or ballast stone wrecks where the cargo provides a range of mesoscale and microscale habitats, these artificial reefs can closely resemble the habitat assemblages found on natural reefs [29,3,8].

There is a strong interest within the marine archaeology community to protect known shipwreck sites, especially those in coastal deep waters that are below the reach of divers and the impact of storms, but within reach of fishing activities. In addition, the UNESCO Convention on the Protection of the Underwater Cultural Heritage calls for in situ preservation of underwater cultural heritage sites as the first option for site management [32]. However, when it comes to justifying their protection in these areas at the expense of other extractive uses, it becomes a difficult proposition to suggest restricting or eliminating these known productive uses to protect resources that are hidden from the public eye. However, there is an increasing body of literature publicizing the amount of damage that trawling can do to shipwrecks [5,7,10,16,25], not only damaging and scattering artifacts, but also destroying the integrity and context of the sites. Some areas are so heavily trawled that locating shipwreck sites there may no longer be possible [5]. This opens up the legitimate possibility that continued unrestricted trawling in nearshore regions will reduce remaining undiscovered shipwrecks to indistinguishable rubble very rapidly. This is particularly true for ancient wrecks, as all that usually remains from shipwrecks more than a few centuries old is non-biodegradable cargo such as ceramics and ballast stones.

This call for shipwreck site preservation at first seems in direct opposition to increased pressure on the fishing industry to meet increasing demand for seafood, and to remain profitable despite rising fuel costs, depleted stocks, and falling quotas. However, in coastal marine areas, there may be a possibility for a synergistic and mutually beneficial relationship if both interest groups can be aided by the same management action. There are copious data on the ability of marine reserves to augment fisheries through adult fish spillover [11,12,21]. There is also precedent for protecting shipwreck sites with MPAs, although they differ in their effectiveness. For example, Thunder Bay National Marine Sanctuary was established to specifically protect maritime heritage sites, whereas Stellwagen Bank National Marine Sanctuary in Massachusetts Bay does not prohibit trawling operations, leaving "protected" shipwreck sites entangled in and damaged by fishing nets [33,34]. However, little effort has been put into determining the potential for additional nested fisheries benefits associated with protecting artificial reefs, which are also cultural heritage sites. This research demonstrates a potential for synergy to call for the protection of areas with high densities of shipwreck sites, based on data from the Aegean coast of Turkey and ancient shipwrecks located there. Additionally, this work emphasizes the importance of continued ocean exploration to determine other areas where this approach can be beneficial.

In order to demonstrate the potential for management synergy, the following argument must be established. Some of the steps are relatively well accepted in the literature, but others have been more difficult to support with data:

1. Fishing damages shipwreck sites [5,7,10,16].
2. The exclusion of fishing protects these sites, making them better refugia.
3. Artificial reefs (including shipwrecks) aggregate commercially important fish in higher than ambient quantities [30,31,36].
4. Protection of important fisheries habitats using MPAs increases overall fisheries production and ecosystem services in the region [1,14].

Most of the steps in this argument have been well studied in the literature, and been shown to be true in most cases. However, data showing that the exclusion of fishing protects shipwreck sites and improves their ability to enhance the fishery remains limited. To address this gap, this study examines a series of 49 ancient shipwrecks located in the Aegean Sea off the coast of Turkey by Exploration Vessel (E/V) *Nautilus* from 2009–2012 in waters ranging from 50–600 m. These wrecks also lie in areas of heavy bottom trawl activity, as shown by [5], though some areas within this region have never been fished due to submarine cables or topography which prevents the use of bottom trawling equipment. When these wrecks are viewed as topographic features of the modern submarine landscape, the conditions of the sites illustrate the environmental effects of trawled and undamaged sites on fish populations. Analysis of 18 of these sites shows that shipwrecks in areas historically excluded from fishing are in better condition and support larger and more diverse fish communities than wrecks which have been damaged by trawling.

In addition, these results indicate that fishing pressure does not change the species assemblage, but wreck sites in better condition and not in the path of bottom trawls are positively correlated with both abundance and, to a lesser degree, species richness. While a relatively small sample size, this is the first time such an effort can be attempted statistically because this is one of the largest concentrations of ancient shipwrecks found in deep water. The results of this analysis suggest that protection of an area with a high density of archaeological sites, such as off Knidos, Turkey, can help to increase the south Aegean fishery through spillover into fishable areas. No protected areas have been established in these waters off Turkey to date, although some studies have indicated the southeastern Aegean by Rhodes, Datça, Bodrum, and Kos to be an ecologically important area and important for conservation [15,19]. This research illustrates a potential for management synergy between benthic ecology, marine archaeology, and the fishing industry in an already overburdened fishery that, upon the establishment of MPAs, would simultaneously protect maritime heritage sites in these waters.

2. Study area

E/V *Nautilus* conducted exploration operations along the Black, Aegean, and Mediterranean coasts of Turkey from 2009–2012. During these expeditions, a large number of shipwrecks were found in deep water ranging from 50–600 m and ranging in time from Archaic Greek to the 1950s [4,5,7]. One wreck was found in the northern Aegean off the Gallipoli peninsula during a survey of the World War I battlefield [6]. Ancient wrecks were also located during surveys off the Bodrum peninsula near the modern town of Yalıkavak, and in the northeastern Mediterranean south of Marmaris, Turkey. However, the largest concentration of shipwrecks was found south of the ancient site of Knidos at the end of the Datça peninsula in the southeast Aegean Sea. Twenty six ancient wrecks were located here and provide the best case for a theoretical protected area. These approaches to Knidos were hazardous to mariners looking to round the point in ancient times, and today the flat area of seabed south of this peninsula is heavily trawled [5]. Bottom trawling is prohibited in certain areas, including within 2.5 km of the Turkish coast and within 100 m of any submarine cable [17]. However, the majority of the wrecks found in this area are just outside the 2.5 km zone and exhibit evidence of trawl damage.

3. Methods

Shipwrecks were located with a side-scan sonar towfish from

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