IMPACTS OF BOTTOM TRAWLING

ON UNDERWATER CULTURAL HERITAGE

A Thesis

by

CHRISTOPHER MICHAEL ATKINSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

May 2012

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Shelley Wachsmann
Committee Members,	Luis Filipe Monteiro de Castro
	William Bryant
Head of Department,	Cynthia Werner

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ABSTRACT

Impacts of Bottom Trawling on Underwater Cultural Heritage.

(May 2012)

Christopher Michael Atkinson, B.A. Drexel University

Chair of Advisory Committee: Dr. Shelley Wachsmann

The fishing method of trawling, or dragging, has long been shown to be harmful to a plethora of sea life inhabiting the world's oceans and inland waterways. Fishing nets scour the seabed, disturbing everything in their path, while usually in search of only one type of bottom-dwelling species. Impacts to the seafloor include a removal of topographic features, disturbance of the upper sediment layers, including deep furrows, as well as physical and chemical changes to sediment morphology. While biological organisms and communities can potentially recover from this destruction, archaeological data cannot. Fishermen have been raising important artifacts in their nets for over a century. These finds have helped archaeologists locate significant sites, but they also have the adverse effect of irreparably damaging these sites. This thesis explores the impacts of bottom trawling on underwater cultural heritage. The methods and gear used by trawlers and their documented effects upon the sea floor are identified. Examples of the types of damage shipwreck sites receive after being impacted by trawling are presented. Instances where fishermen have raised prehistoric artifacts from inundated land sites are also introduced. The fishing and archaeological communities must cooperate to limit further damage to underwater cultural heritage around the globe.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Over the last half-century, interest in the effects of fishing on the underwater environment has increased based on concerns surrounding biodiversity and resource scarcity. Trawling, also known as dragging, is the most destructive fishing practice because it destroys benthic habitats and overharvests certain populations (Collie et al. 2000; National Research Council 2002). Fishing nets scour the seabed, disturbing everything in their path while in search of their target species. While biological organisms and communities can recover from this destruction, archaeological data cannot. While some damage is inevitable, fishermen have greatly contributed to our knowledge of the past by reporting artifacts found in nets and snag locations. This thesis provides a comprehensive understanding of the relationship between underwater cultural heritage (UCH) and the commercial fishing industry and aims at an understanding of the many facets of the relationship, both positive and negative.

Despite the prevalence of commercial fishing impacts on archaeological sites, published information about this issue is scant.

This thesis follows the style of *Historical Archaeology.*

Major post depositional events like fishing gear impacts deserve more attention. However, in many cases, only a single sentence of a site report describing an affected site is dedicated to the topic. Unfortunately, it is not possible to fully quantify the occurrence of fishing impacts on global UCH. Factors contributing to the deficiency of information include lack of publication, fishermen's delinquency in reporting damage, loss of sites due to repeated impacts, and lack of discovery. However, it is possible to draw broader conclusions based on regional studies and individual known cases. For example, 11 of the 18 historic shipwrecks located in the Stellwagen Bank National Marine Sanctuary exhibit damage from fishing gear (National Oceanic and Atmospheric Administration 2008a:125). A recent study of 52 Mid-Atlantic shipwrecks showed a 69% occurrence rate of trawling impacts (Steinmetz 2010). In the Aegean Sea, 16 wrecks were observed near the Turkish coast in an effort to quantify trawl damage within this limited geographical area (Brennan et al. 2011). In the waters off New South Wales (NSW), Australia, roughly 260 shipwrecks have been located out of roughly 1700 known losses. Nearly every one of the 260 wrecks was impacted by bottom trawling at some point in their history (Tim Smith 2009, elec. comm.).

Conversely, fishermen have played a key role in locating important submerged archaeological sites. Having raised and reported hundreds of artifacts and thousands of fossils, fishermen have helped to reveal the submerged landscape under the North Sea. Numerous individual shipwrecks have been discovered by fishermen snagging their nets and investigating the cause. These events come at a cost to both the fishing and archaeological communities.

Fishermen risk losing valuable gear when encountering a shipwreck or other culturally significant submerged resources (Olsgard et al. 2008:124; Marx 2009:8). Gear may become irretrievably snagged and must be cut away to avoid risk to the vessel, or nets can be torn resulting in a loss of the catch and delay of further fishing. In Great Britain between 1976 and 2005, 16 vessels capsized after gear was snagged on shipwrecks or similar obstructions, resulting in 33 deaths (Roberts 2004: 18; Roberts 2010:45). A specific example is the 1985 loss of the fishing vessel *Sea Hunter*. While trawl fishing 1.5 mi. (2.4km) east of St. Abbs Head, Scotland, the wreck of another fishing vessel was snagged resulting in the 51ft. (15.5 m) vessel taking on water and sinking (Baird 2009:30).

Snagging UCH can lead to challenges for fisherman and archaeologists. Archaeologists benefit from instances when an encounter is reported and the site can be investigated; however, a great deal of damage to the site may have already occurred. There exists the need for further cooperation between archaeologists and the commercial fishing industry. It is essential that the archaeological community understand the methods, needs, and implications of the commercial fishing industry in order to communicate effectively.

LITERATURE REVIEW

When towed fishing gear comes in contact with a shipwreck or other UCH, the remains can be severely damaged or disarticulated. As marine archaeologists continue to locate, document, and excavate underwater sites, the impact of bottom trawling on archaeological resources has become increasingly apparent. Regional archaeologists may be very familiar with these impacts; however, the wider archaeological community as well as the general public is not. A significant amount of information has been gathered regarding biological impacts of this practice (Johnson 2002). Yet, despite the significance, very little has been published on the effects of trawling to our UCH and several authors have noted the need for further research on the topic (Firth and Ferrari 1992:69; Robertson 2007:85; NOAA 2008a; Evans et al. 2009:46).

A review of the available literature on the subject reveals that while a few regional areas have been observed, there is a lack of context and background that would be beneficial for further research. The following studies demonstrate the ways in which commercial fishing has impacted UCH in specific areas of the world. Dag Nœvestad (2006) reviews the impacts of bottom trawling to submerged cultural resources in the Arctic region. He relates a number of incidences in which trawlers raised artifacts in their nets and dredges including anchors, pottery, large ship timbers, and stone tools from submerged prehistoric settlements. Within his review, Nœvestad briefly describes the gear used in the region. He also describes the nature and importance of the region in terms of its cultural heritage, as well the artifact-preserving qualities of the Arctic waters. Michael Brennan (2011) presents a case study of 16 ancient shipwrecks in Turkish waters that may have been subject to bottom trawling. The wrecks and associated landscape were located and imaged using video and acoustics over the course of three years. Trawl scars were recorded on the seabed, which indicate active bottom trawling activity. Two wrecks, Knidos C and Knidos J, exhibited trawl scars running directly through the sites. The damage to the sites was quantified based on amphora breakage rates and compared to wrecks in areas of little or no trawling, such as marine protected areas and areas with obstructions like underwater cables. Brennan et al.'s (2011) study found breakage rates of 25% to 40% on observed sites with known trawling impacts. In addition, breakage rates of 5% to 10% were found on other regional wrecks that may have been impacted, and less than1% on sites unaffected by bottom trawling or near coastal environmental processes (Brennan et al. 2011). The authors also note a 62.5% breakage rate on the Marmaris B site, outside of the study region. This is the most comprehensive study to date. The data from Joyce Stenimetz's (2010) master's thesis has yet to be published. Her 52-case sample study of Mid-Atlantic wrecksites found a high rate of trawling disturbance as well as a significant financial impact to fishermen due to lost gear. One to five large trawling gear systems were found on 69% of the wrecks studied (Joyce Steinmetz 2011, elec. comm.). Future regional studies, such as these, will help to produce a more accurate depiction of how trawling differentially affects shipwrecks of various ages and types. I am unaware of any studies detailing trawling impacts on inundated land sites. This is an area requiring further research.

Marine scientists from a variety of fields have gathered data and conducted studies on how trawling affects the seafloor (Johnson 2002). Research has been conducted for the purpose of managing fish stocks and habitats, as well as understanding the overall impacts to the benthic ecosystem. This information can be applied by archaeologists to help understand how UCH sites are impacted by trawling. Studies have focused on the depth of penetration from trawl gear (Smith et al. 2007), sediment re-suspension (Palanques et al. 2001), chemical changes to the sediments (Duplisea et al. 2001), reduction of macro- and mega-faunal species (Freese et al. 1999), and ecosystem recovery (Frid et al. 2000). These studies have been carried out in a variety of ways. Comparing trawled to un-trawled seabeds in local regions allows researchers to observe long-term changes in habitat and seafloor structure using controls. Research trawling in areas closed to commercial fishing has proven valuable to our understanding of the immediate effects that single and repeated trawl passes have on the benthic environment. By doing the research in an area that is not currently fished and at depths beyond natural coastal processes, a clear picture of the damage caused by a single trawl pass is shown. Most commercial trawlers will tow their gear through the same lanes multiple times per year. If a shipwreck or other submerged site is within an area of heavy fishing, it is likely to suffer repeated impacts if it does not cause snags. Many of the world's bottom trawling grounds have been active for well over 50 years. It is only possible to imagine how much damage has already occurred to UCH in these regions.

Using the available literature on previous studies conducted on trawl impacts allows for a more thorough and holistic understanding of the impacts on UCH. Combined with the data available on affected shipwreck sites, archaeologists can begin to develop a broader understanding of how the commercial fishing industry is affecting UCH. Conservationists and marine scientists have increased public awareness to the destructive process of bottom trawling. Unfortunately, archaeological remains have not been a factor within the movement to further regulate bottom trawling. Blake (1996:821) notes "…the low status of archaeology in the context of discussions relating to economic, ecological and strategic considerations." In other words, underwater cultural heritage is not a motivating factor within the legislature although a great deal has been achieved in limiting bottom trawling in many biologically sensitive areas. The possibility then exists to limit this practice in culturally significant regions of the sea.

In the following chapters I will provide an overview of the bottom trawling industry and how it relates to UCH. This includes a brief history of trawling in order to introduce the evolution of the practice. I also summarize the different mobile fishing gear types used in the bottom trawling industry to provide an understanding of the variety and scale of the equipment. Next, I discuss the scientific research regarding how bottom trawling affects the seafloor and benthic environment. This demonstrates the different manners in which bottom trawling is currently being studied and highlights specific impacts that have been discussed. Underwater archaeological site formation provides context as to how bottom trawling can affect the archaeological record. Specific examples of fishing impacts to shipwrecks sites and inundated landscapes show the types of damage that can occur, but also highlights the contributions and discoveries fishermen have made. Finally, will follow an examination of current legislation regarding bottom trawling with management and mitigation options.

CHAPTER II

OVERVIEW OF TRAWLING

HISTORY AND DESCRIPTION OF TRAWLING

The act of towing a net behind a vessel is not a recent idea. Models of reed rafts towing fishing nets have been found in Egyptian tombs, such as the XI Dynasty Tomb of Meketre (Brewer and Friedman 1989:46). More relevant to this discussion is the first reference of destructive trawling presented to the English parliament in 1376 (March 1953:33). The report petitioned that the use of the wondyrchoun or "wondrous machine," a net of 18 ft. (5.48m) in length and 10ft. (3m) across, which corresponds to a small beam trawl, be banned based on its destruction of small fish and seafloor damage. The mesh size of the gear did not allow juvenile fish through, thus wreaking havoc on the fishing grounds. Further, multiple references to trawl-net mesh size also appear in 17th century government documents, and a sketch on the back of one state paper from 1635 depicts a beam trawl in tow (Graham 1956:14; Gabriel et al. 2005:385) (Figure 1).

A trawl can generally be described as a net of which the mouth is held open by a beam or other method, towed behind one or multiple vessels at various depths depending on the intended catch species, be they demersal or pelagic. In general, nets are conically shaped; the small end is referred to as the cod-end, and the mouth of the net is characterized by a groundrope on the bottom and a headline with floats or a solid beam

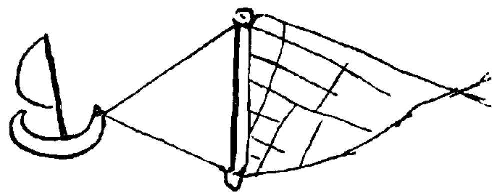

Figure 1. A Sketch of a beam trawl being towed by a sailing vessel on the back of a state paper from 1635. (Graham 1956:14)

across the top. There are many variations and designs of mobile fishing gear. Often, fisherman will create custom rigs suited to local seabed conditions and intended catch species.

The size and development of trawls closely corresponds to vessel and engine technologies and will offer a good starting point for the discussion of gear types. Traditionally, trawls were towed by sailing vessels designed for this explicit purpose. Beam trawls were towed from the stern of the vessel or from outriggers placed amidships: They are limited by the length of the beam needed to hold the mouth of the net open (Figure 2).

An early solution for creating a larger net involved dragging a frameless net from the broadside of the vessel with the lines, or warps, attached to the bow and stern to hold the mouth of the net open. This method could only be used on a sailing vessel, as the wind and current were used to push the vessel abeam with the net in tow (Gabriel et al. 2005:392).

Figure 2. A beam trawl being set. (Photo courtesy of The Institute for Agriculture and Fisheries Research).

Steam power was integrated into trawl fishing only in the late 19th century. The first documented use of steam for trawling was in France in 1865 and later in Italy and the United Kingdom (U.K.) in 1872 and 1877 respectively (March 1953:41; Robinson 1996:86). The use of steamships was significant; new areas, previously inaccessible, could be trawled, and larger gear could be used as a result of increased vessel power (Sainsbury 1996:45). Early steam tugs developed only 25 to 50 horsepower; today modern vessels can employ thousands of horsepower (March 1953:42; Lindeboom and de Groot 1998:72).

The early steam trawlers towed beam trawls directly behind the vessel, and the catch was hauled up alongside. Since steamers could not tow a net broadside, another method was needed to hold the net open even wider to increase the effective area for fish to enter. In 1894, an engineer named James Robert Scott successfully implemented the first otter boards, though an Irishman named Musgrave came up with the initial concept between 1860 and 1870 (Gabriel et al. 2005:394). Otter boards, also known as trawl doors, are generally flat, rectangular pieces of wood or metal attached to the warp on either side of the mouth of the net (Figure 3). The doors effectively force the mouth of the net open as they turn obliquely to the water during the tow. As a result, net size is no longer limited by the length of the beam or ship, but rather by the power of the tow vessel.

The types of bottom trawlers can be categorized into two main groups based on where they fish. The coastal, or inshore, trawlers remain within the 200-mile Exclusive Economic Zone (EEZ) of either their home state or a neighboring state with which they have an agreement (Kaczynski 1989:3). Conversely, the high seas bottom trawling fleet operates outside of all maritime countries' EEZs. Most archaeologists will be concerned with the coastal fleet. Reasons for this include shallower depths, higher rates of shipwrecks near the coast and the occurrence of submerged landscapes on the continental shelf. However, the high seas trawling fleet poses an increasing threat to

Figure 3. Injector Scorpion bottom trawl doors. (Photo by Jan Egil Kristiansen).

UCH. In the past, due to technological limitations, archaeologists were concerned primarily with wrecksites in coastal waters, at depths of less than 100 m. Modern equipment has allowed the emergence of deep-submergence archaeology (DSA), and this approach offers archaeologists the chance to search for, and to document, sites that are hundreds and even thousands of meters below the surface of the ocean. Trawlers, however, are also moving into deeper waters, as fish stocks are depleted near shore and tighter restrictions force trawlers to operate far from coastal nations' EEZs (Morgan et al., 2005:2).

Thus, trawling even poses a significant threat to possibly well-preserved wrecksites not impacted by near coastal ocean processes or past anthropogenic disturbances, and recently, archaeologists have discovered the potential information associated with deep water wrecks (Wachsmann, 2007/8:134). Scholars once believed ancient mariners traveled within sight of land, hugging coasts and mooring or beaching overnight. However, ancient sea routes have been found to exist over deep, open water in the Mediterranean (Wachsmann 1998:298; Ballard et al. 2000:1591; Davis 2001:52). To study this, archaeologists have moved into the deep sea to search for wrecks that could help identify certain routes (Wachsmann 2007/8:130B; Ballard 2008:132). Seamounts are potentially promising areas to search for shipwrecks along possible trade routes for two reasons. First, seamounts are generally topographically flat (guyots), making them ideal for high-resolution sonar and acoustics. Second, their increased height from the surrounding seabed offers easier working conditions for survey equipment while still in areas of deep water. Lastly, sedimentation rates are typically lower on seamounts thus shipwrecks may remain visible on the seafloor longer. Many marine species spawn and feed on seamounts, making them attractive to fishermen and bottom trawlers actively operate in these areas, thus increasing the possibility of damage to UCH (Sumaila et al. 2010:495; Clark et al. 2011:19). Ninety-five percent of the high seas bottom trawling catch was taken by only 13 countries, including Japan, Russia, Spain, South Korea, Australia, Ukraine, Faeroe Islands/Denmark, Estonia, Iceland, Lithuania, Latvia, France, and New Zealand (Sumaila et al. 2010:496). It is apparent that bottom trawling is occurring throughout the world and can affect UCH in a variety of regions.

MOBILE FISHING GEAR

A variety of gear types and components are commonly used within the commercial fishing industry today. Custom variations of specific gear types as well as adjustments in tow speed and warp and bridle length will alter the effects of the gear on the seabed and, in turn, their impact on archaeological materials (Rose et al. 2000:1). For this reason, only a general description of the gear is possible. It is important that archaeologists working in specific regions consult with local maritime heritage officers or local fisheries agencies to better understand the gear being used and areas most commonly trawled.

OTTER TRAWL

Otter trawls are the largest bottom trawling gears in use today. By using otter boards, more commonly known as doors, the net can be stretched open without the constraints of a solid beam or frame. The few size-limiting factors include depth, bottom terrain, and the power and size of the tow vessel. Smaller otter trawls are also commonly used in coastal fisheries. Otter trawls have various impacts on the seafloor. Elements of the rig-the doors, groundrope, cod-end, bridles, and tickler chains (when in use)-all make contact with the bottom to some degree. The size of the rig and the immense vessel power can cause the destruction or removal of large archaeological remains, such as canons and bronze statues, and the breakage and/or displacement of large swaths of smaller remains, including amphorae.

DOORS

Doors vary in size and configuration, but larger doors can be measured in square meters and sometimes weigh several tons (Morgan et al. 2005:5). The trawl doors scrape along the seabed effectively scouring the bottom while also creating large furrows and spoil heaps and stirring up sediments. Depending on the style, large sediment plumes are created behind the door, which serve to confuse fish into entering the net. Door size and style is chosen based on the size of the tow vessel, bottom conditions, and desired catch species.

FOOTROPE, BOBBINS, AND ROCKHOPPERS

Footropes are generally a length of chain or cable which may be then wrapped in rope and forms the bottom of the net opening. Traditionally, trawlers worked only on relatively flat areas of the sea floor. In the last quarter-century, the development of new gear has allowed bottom trawlers to work in a variety of topographic conditions including rougher areas of the seafloor that would have previously destroyed their nets (Gabriel et al. 2005:404, 405). Large and heavy discs or balls known as rockhoppers, or bobbins, are now made from old tires or commercially produced plastic or steel models (Figure 4). Rockhoppers can range up to 1 m in diameter and can weigh hundreds of kilos each on dry land, making them extremely destructive when moving over the sea bed. Rockhoppers are strung along the footrope, also termed groundrope, of an otter trawl to keep the net from snagging on the terrain. Rockhoppers do not roll but rather fold under the groundrope when an obstacle is encountered (Recht 2003:14). This allows the net to ride safely over the obstacle without getting snagged. Rockhoppers can easily crush fragile artifacts when they come into contact with them. Bobbins roll over the seabed keeping the groundrope protected. These range in size depending upon the fishery and regulations from 14 to 24 in. (35.6 to 61 cm) in diameter (Recht 2003:13).

Figure 4. Rockhopper gear on the dock in Gloucester, Massachusetts. (Photo by Matthew Lawrence, NOAA)

NET AND TICKLER CHAINS

Contributing to the destructive impacts of otter trawls are the large net and, in some cases, tickler chains, which are located in front of the groundrope and serve to stir up sediments to attract and confuse fish.

The nets used for large otter trawls have mouths up to 100 m across, weigh upwards of 15 tons, and require a stern ramp trawler to haul in the massive catch (NRC 2002:12). As the name implies, stern ramp trawlers are purpose-built vessels that allow the nets to be winched over a ramp located at the stern of the vessel thereby reducing the labor involved (Gabriel et. al. 2005:406) (Figure 5).

Simple otter trawl nets consist of a top and bottom panel brought together at seams and are known as a "two seam" net. Variations for larger nets include adding side panels making it a "four seam" net. Regardless of the number of panels, the net remains funnel-shaped. Modern trawl nets are made of polyethylene (PE) or high-tensile polyethylene (HTPE). The fibers are 3 to 6 mm thick depending on the size of the trawl and bottom conditions, with thicker netting being used on the underside of the net to resist wear (Recht 2003:8). Trawl net mesh sizes vary depending upon the target species, but 4 to 5 in. (10.2 to12.7 cm) square can be considered average. While the gear is in tow, the mesh size will narrow in one direction and elongate in the other. Mesh size can be directly related to the types of artifacts that will remain in the net after an impact. Small artifacts such as beads, buttons, and fishing weights will be sifted through the net unless concreted into larger formations. The catch itself can weigh upwards of 100 tons

Figure 5. Stern ramp of the NOAA fisheries research vessel *Oscar Dyson*. (Courtesy of NOAA).

in a large trawl, and a full cod-end can be as destructive as any other part of the gear (Enticknap 2002:3) (Figure 6). Trawls generally last a few hours, covering several kilometers while towing at speeds of approximately 1to 4 knots (Sainsbury 1996:36, FAO 2008) depending on gear and target species.

Figure 6. Full cod-end of an otter trawl after a research trawl. (Courtesy of NMFS/NOAA fisheries)

BEAM TRAWLS

Beam trawls lack trawl doors and employ a solid beam to keep the net open. These trawls are commonly used throughout the world and can be towed with smaller vessels in both shallow and deep waters. A typical beam trawl is 4 to10 m across and can be towed in multiple configurations by a single vessel (Gabriel et al. 2005:385). Often, the trawls are towed in pairs using outriggers (Figure 7). Common target species include shrimp and flatfish such as sole.

TRAWL HEAD

The solid beam used to hold the beam trawl net open and the wheels or shoes used to hold the beam up are known as the trawl head. Shoes are most often employed and are solid steel. The shoes slide over the seabed and, on a larger trawl, keep the beam supported roughly 1 m off of the surface (Sainsbury 1996:111). An alternative to the shoe is to use wheels which allow the trawl to roll over the seabed. While not generally effective, wheeled beam trawls have proven useful in specific fisheries including Turkish sponges and Far East shrimp (Gabriel et al. 2005:385).

The beam itself was traditionally made of wood but is now hollow steel. The size of these trawls is limited by the length of the beam, which can become unwieldy when recovering and stowing the trawl. However, smaller beam trawls are well suited for use on smaller vessels in shallower waters, making them quite popular among fishermen. Beam trawls are also excellent for deep sea research and have been used to recover sample species at over 2,000 m (Gabriel et al. 2005:389).

Figure 7. Double-rigged beam trawl vessel *SR2*. (Photo by Lodewijk van Walraven).

NET AND CHAINS

The netting used for a beam trawl is the same as that of an otter trawl. The shape is also similar, with the top of the net protruding past the lower section and the body of the net being slightly cone shaped.

Tickler chains are also frequently employed in front of the net to stir up flatfish and cause confusion (Figure 8). Anywhere from 4 to14 rows of chains are used, depending on the target species (Sainsbury 1996:112). On a large beam trawl, the chains can weigh more than 2 tons and are considered destructive to the seabed (Gabriel et al. 2005:389). In some cases, chain mats are also used on beam trawls in front of the net. Chains are laid out in a grid-like pattern between the footrope and the shoes across the entire front of the net (Figure 9). These mats are used to allow the net to ride over rocks and debris when used on rougher terrain. The heavy weight and surface area of the chain mats make them destructive as they move over the seafloor.

DREDGES

Oysters, clams, and scallops are among the types of organisms collected by fishermen using a variety of dredges and can be found in both inshore and offshore waters. The principle function of a dredge is to dig out, or scrape from the surface, and collect the shells into a bag. A dredge consists of a metal frame, with a blade along the lower leading edge, attached to a mesh of wire or metal rings making up the bag (Figure10).

Figure 8. A beam trawl with tickler chains. (Photo courtesy of The Institute for Agriculture and Fisheries Research).

Figure 9. A beam trawl with chain mat. (Photo courtesy of The Institute for Agriculture and Fisheries Research).

The size of the mesh is regulated and varies in local regions and fisheries. In the case of a box dredge, there is no bag but rather a long box made of iron rods. Teeth can be attached to the blade of a dredge to dig out bivalves from beneath the sediment. These teeth typically range from 5 to10 cm in length (Sainsbury 1996:154). The overall size of a dredge varies between type and fishery. Widths can range from less than 1 m up to 5 m, and lengths are typically 2 times the width. As an example of scale, a 3.3 m-wide

Figure 10. A scallop dredge with pieces of old tires to protect the ring mesh on the dock in Viking Village, Barnegat Light, NJ. (Photo by Rodd Halstead).

scallop dredge can weigh roughly 640 kg empty on land and 1800kg when full (Sainsbury 1996:164). A single 2.5 cm wire cable is used to tow these larger dredges. The gear can be towed in numerous configurations including singles and pairs, up to eighteen individual dredges connected to a bar when used in offshore operations. These dredges are towed at slow speeds (2 to 4 knots) depending on the target species (NRC, 2002:13). The tow-vessels range in size from less than14 m for inshore dredging and up to greater than 50 m for offshore fisheries. The most significant variation of the standard dredge is the hydraulic dredge. Small water jets are placed along the frame which liquefy the sediment in front of the dredge and lift the shells out of the seabed (Figures 11, 12). This greatly disturbs the sediments and can easily displace small artifacts.

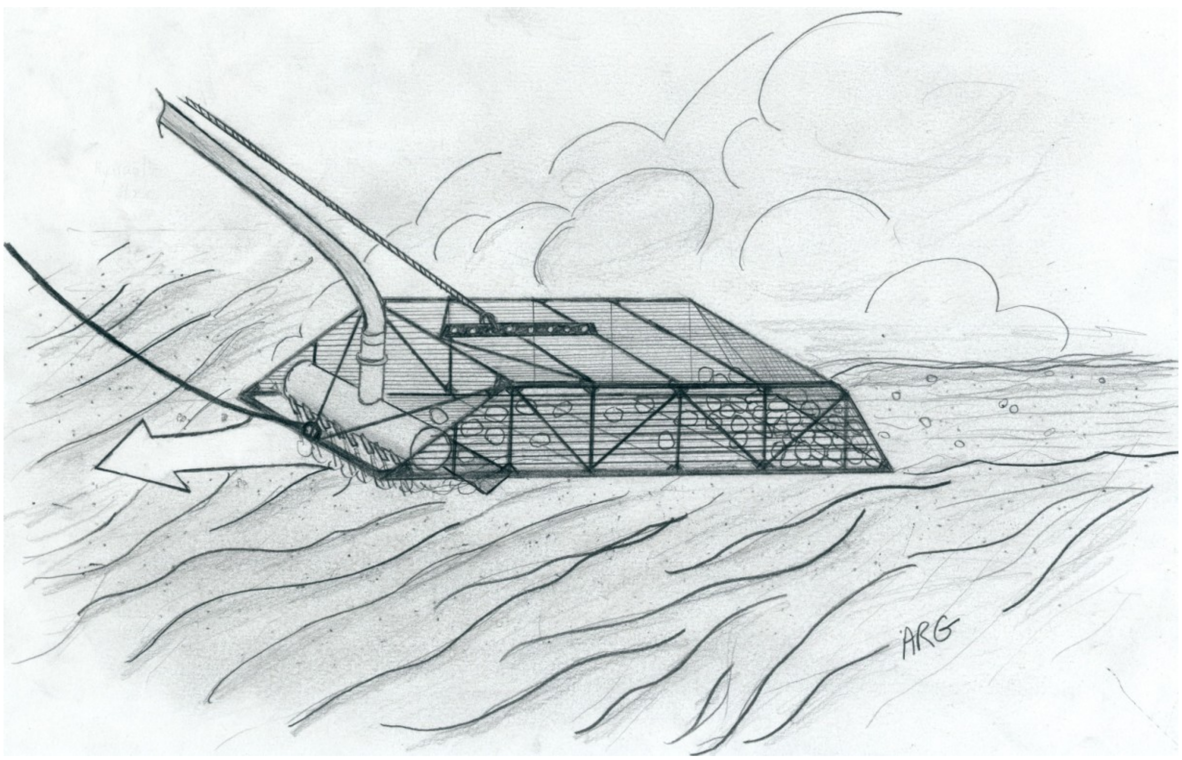

Figure 11. Drawing of a hydraulic clam dredge. (Drawing by Rich Galiano).

Figure 12. A large hydraulic oyster dredge on the *Sherri Ann* leaving Point Pleasant, NJ. (Photo by Rich Galiano).

CHAPTER III

SEAFLOOR IMPACTS

What does a trawl do when moving over the seafloor, and what destruction occurs as a result of it? The seafloor is not homogenous in its composition worldwide; therefore, the trawling gear has varying impacts on different regions. One of the more significant geologic distinctions concerns sediment composition. Obviously, fishing gear penetrates softer sediments to a greater degree than harder terrain. It has been observed that trawl doors can penetrate softer sediments 20 cm or more, with scarring 1 to 3 m wide in some cases (Dounas 2006:256; Morais et al. 2007:116; Sakellariou et al. 2007:377; Smith et al. 2007:1696). These areas are characterized by furrows and related sediment accumulations known as "spoil heaps" (Smith et al. 2003:480). Visible scarring from trawl gear is not permanent and is very dependent upon the nature of the sediments present. In harder sediment, scars may be seen for multiple years whereas in softer sediments tracks can begin to disappear in a matter of hours (Palanques et al. 2001:1102; Smith et al. 2007:1696-7). Side-scan sonar can often reveal scarring from trawls and dredges when present (Wachsmann, 1999; Sakellariou et al., 2007:377) (Figure 13, 14).

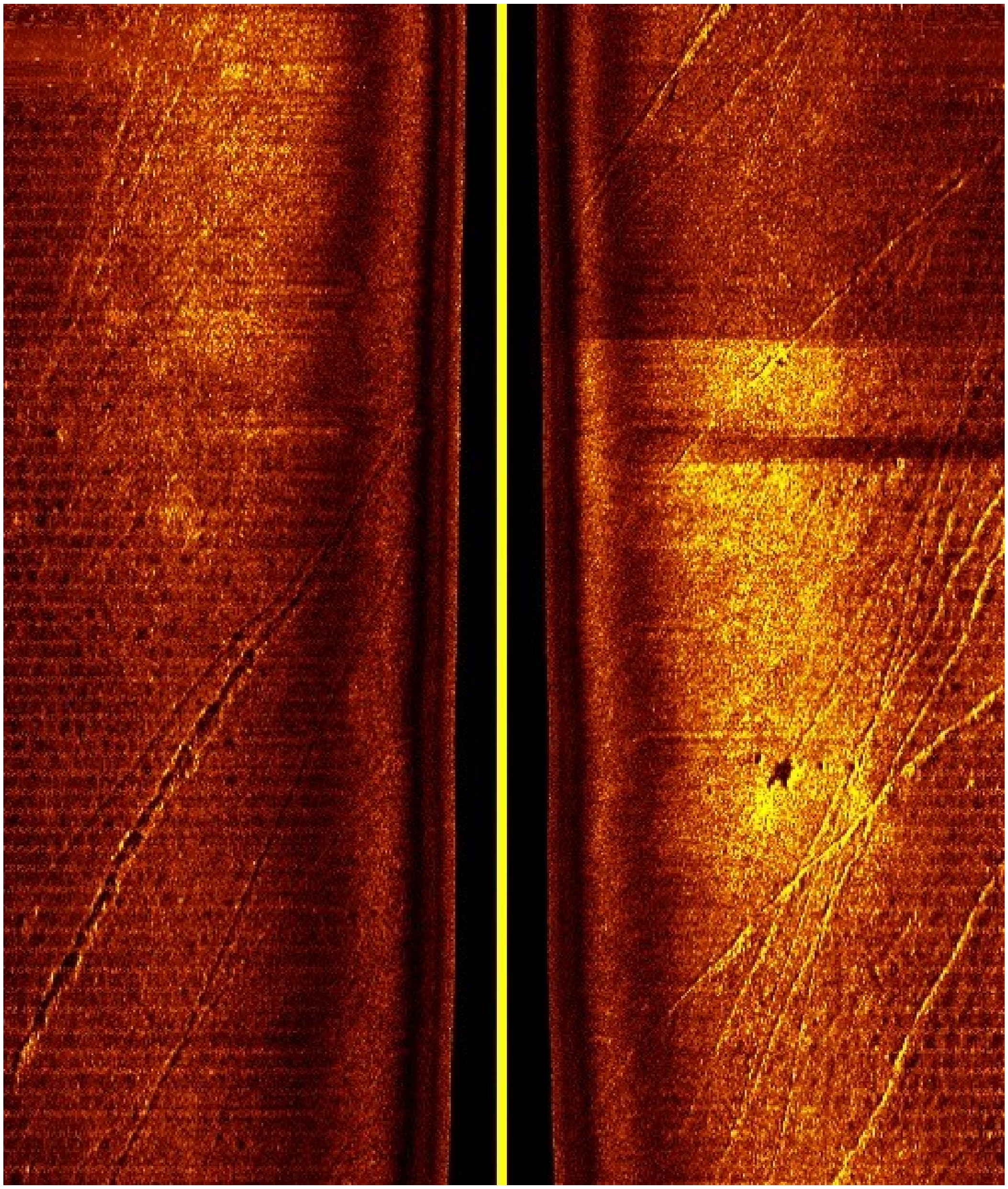

Figure 13. Trawl marks imaged on the Mediterranean seabed off Tantura, Israel with side-scan sonar. (Courtesy of Shelley Wachsmann, INA)

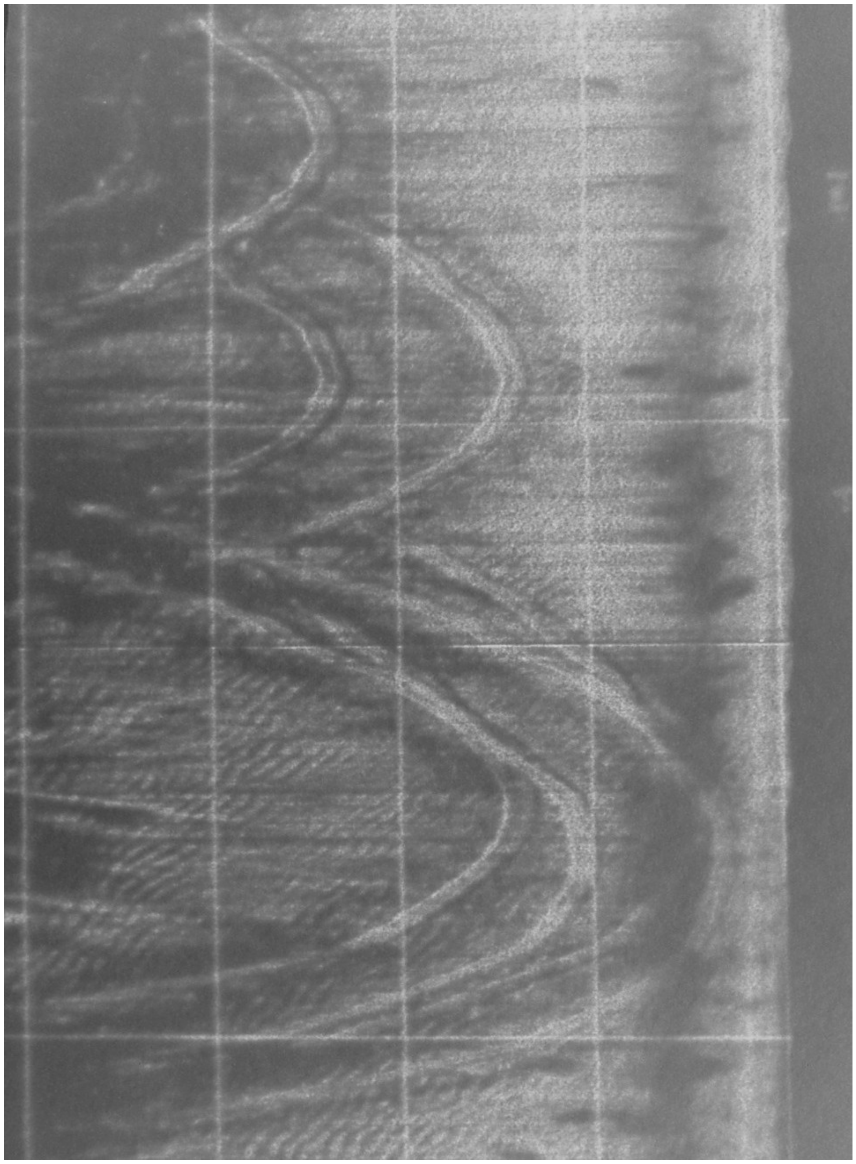

Figure 14. Hydraulic clam dredge marks imaged on the seabed with side-scan sonar. (Courtesy of Rich Galiano)

Even though harder sediments experience less depth penetration by the gear, removal of topographical seafloor features, including epifauna and boulders, occurs. The footrope of an otter trawl towed by a large stern trawler has the power to move boulders weighing several tons. The fact that trawls can impact heavy boulders demonstrates their potentially destructive threat to submerged cultural resources. Risk et al. (1998:13) calculate the weight of disturbed boulders reported in a Behnken (1993). The largest boulders were 3 m in height, and the authors assume the boulders were granite, thus calculating them to weigh upwards of 25 tons on land and 16 tons in seawater. If we assume the boulders were round and we use the specific gravity of granite given correctly by the authors as 2.7, then the boulders would actually weigh up to 38.15 tons on dry land or 31.57 tons submerged. This clearly demonstrates how a trawl can shift and even recover large artifacts such as canons and entire keel sections of ships, for instance.

During another study of hard bottom trawling impacts, 19% of the boulders observed were displaced after a single research trawl in an un-fished region at depths of 206 to 270 m in the Gulf of Alaska (Freese et al. 1999:122). The boulders were on average 0.75 m in height but ranged from 0.25 to greater than 5 m. While it is unknown what type of material the boulders were, if we assume they were basalt (given the volcanic nature of the region), which has a specific gravity of 3.01, a 0.75 m round boulder will weigh 1,457 lbs. on land or the equivalent of 657 lbs. in seawater when adjusted for buoyancy. In Freese et al.'s (1999) study, the research trawl used a combination of 0.6 m rubber tires, 0.45 m rockhopper discs, and steel bobbins strung along the footrope and wings. It was towed by a 42.5 m-long vessel aptly named *Dominator*. After the trawl, the site was investigated by a manned submersible to document the impacts. Aside from the disturbed boulders, 67% of erect sponges (greater than 6.5 cm) were damaged or missing. These results can be compared to the impact on smaller artifacts in a similar situation.

CHEMICAL IMPACTS

A complex series of chemical reactions occur as a shipwreck degrades on the seafloor (Florian 1987:1). As a trawl is towed over the seafloor, sediments are churned up resulting in sediment re-suspension and the mixing of layers. This suspended sediment contains nutrients and toxins which may alter the chemical composition of the benthic habitat and can, in turn, affect artifact preservation (Duplisea et al. 2001:1; Enticknap 2002:4; Johnson 2002:4). For example, the dissolved oxygen content, CO_2 levels, pH, Eh, and biota can be affected by trawling activities. These changes influence which organisms inhabit a site, resulting in varied preservation characteristics (Jordan 2001:50; Leino et al. 2011:139). This disturbance will affect the way artifacts interact with the marine environment, generally resulting in a sharp increase in the rate of metal corrosion and deterioration of organic material.

Another significant process resulting from trawling is bioturbation. Simply stated, bioturbation is the burrowing of organisms into the sediment. This is a diagenetic process in that it affects the physical and chemical nature of the sediment and is often seen associated with the spoil heaps left by trawl doors. Bioturbation is also responsible for the gradual roughening of the sediment after the gear has smoothed the surface. As the organisms burrow, they leave small spoil heaps and depressions behind, which also act to erase the trawl scarring over time. (Morais et al. 2007:116). Bioturbators aerate the sediments as they burrow which introduces oxygen to the anaerobic environment of buried artifacts (Bascom 1976:107; Ferrari and Adams 1990:145). Both sediment re-suspension and bioturbation are noted for the possibility of their effects on the chemical breakdown of artifacts after deposition (Stewart 1999:580, Ward et al.1999a:52). Future studies directly measuring chemical changes to wrecks in areas of intense trawling would be beneficial to understanding the possible effects.

CHAPTER IV

ARCHAEOLOGICAL IMPACTS

UNDERSTANDING SITE FORMATION OF SHIPWRECK SITES

A shipwreck is a single event in time that becomes part of a dynamic environment (Muckelroy 1978:157). Shipwreck site-formation was first discussed in the context of Mediterranean amphora wrecks and the regional underwater landscape (Dumas 1972:31-34). The principals discussed were not applicable across the broad range of shipwreck sites throughout the world. Keith Muckelroy's early work laid the foundations for understanding site-formation in marine environments universally. In *Maritime Archaeology* (1978), Muckelroy argues that certain consistencies can be found among all shipwrecks, and once these are understood, they can be applied to the interpretation of shipwreck sites. His models focus on the wrecking process, extracting filters (losses of material), and scattering devices. In *Archaeology Under Water* (1980: 179), Muckelroy recognizes disturbances of the seabed caused by trawls. More recently, David J. Stewart (1999) elaborated on Muckelroy's work and integrated Michael Schiffer's (1987) categories of cultural and environmental post-depositional processes to provide a holistic view of site formation in the marine environment. Stewart includes bottom trawling as a cultural formation process. Stewart (1999) expands on Muckelroy's (1978) previous model by adding new insights gained with twenty additional years of nautical archaeology. Stewart provides a specific look at pre and post depositional formation processes, and although he mentions deep-water, he is primarily concerned with shallow sites.

Researchers generally employ three approaches for understanding site formation processes: the analysis of individual processes, the holistic analysis of the processes as a system, and GIS-based mapping analysis of site formation. Individual processes have been explored most recently by a number of authors to better understand how each can affect a wrecksite. Both Ward et al. (1999a) and Wheeler (2002) identify the environmental factors affecting wreck disintegration. Ward et al. (1999a) evaluate the affects of sedimentary processes as the major factors of wreck preservation by measuring sediment accumulation and removal over time. They then describe a model of wreck disintegration based upon their findings (Ward et al. 1999a:43). In another article, Ward et al. (1999b) present a model of site formation based on a range of environmental factors: physical, biological, chemical, etc. Their model allows for a more predictive approach to site formation. Wheeler (2002) also evaluates artifact preservation based on types of individual processes; he assesses how physical, biological, and chemical forces affect a wreck. Wheeler (2002:1152, 1155) uses two case studies of underwater wrecksites, both located at depths less than 35m to demonstrate how these individual forces uniquely impacted site preservation. Gibbs (2006) takes a more anthropological approach to understanding site formation. Rather than concentrating on the physical environment, he employs behavioral theory to focus on the cultural processes involved in the formation of a wrecksite. Using his own model based on Muckelroy's (1978), as well as models produced within disaster studies, Gibbs offers a unique perspective on how both pre- and post depositional human interaction produces the archaeological context of a wrecksite. Richard Gould (2000) takes a holistic view of site formation by presenting the different approaches to studying shipwrecks and which factors may be more influential as a result.

Another approach to site formation has been through the use of Geographic Information Systems (GIS). Jun Kimura (2007) uses spatial analysis to understand individual sites, as well as GIS mapping to look at a large geographical area containing shipwrecks. This approach is especially interesting as it invokes anthropological questions as to the reasoning for distribution patterns of shipwrecks in concentrated regions and applies a methodological approach to understanding site formation. Wachsmann (2007/8) has recently produced a descriptive account of the formation of a deep-water shipwreck site. Deep-water sites are distinct in that they are not exposed to near coastal ocean processes and the anthropogenic disturbances of divers. However, these sites are subject to other processes such as offshore construction and drilling, different types of sedimentation, and wider artifact dispersion as a result of the depth.

These studies demonstrate the importance of understanding site formation when analyzing a shipwreck site. The potential impacts of bottom trawling are a cultural formation process and can have a major impact of how a site presents itself.

IMPACTS OF TRAWLING ON SHIPWRECK SITES

Shipwrecks act as artificial reefs and are havens for large numbers of fish. Fishermen, fully aware of this, intentionally trawl very close to known wrecks (NOAA, 2008b:126). While it is not always their intention to hit the wrecks, nets often get snagged (Firth and Ferrari 1992:69; Hall et al. 1993:202). Bottom trawling occurs throughout the world's oceans and understanding and managing the issue of trawling in relation to archaeology is critical to the survival of shipwrecks. Vessels operate anywhere from just off the coast to thousands of kilometers offshore (Morgan et al. 2005:5; Morais et al. 2007:113). Beyond the 200 nautical mile EEZ, few regulations exist. Operational depths vary considerably from only a few meters to as deep as 2000 m for large commercial trawlers (Sainsbury 1996:150; FAO 2008).

It may be difficult to tell if a site has been hit by a bottom trawl. For instance, an encounter that may have happened over 30 years ago would have no visible, fresh trace remaining. Therefore, it is important for archaeologists to determine if a possible site is within an area of past or present trawling prior to surveys and excavations. When observing a site that appears to have been disturbed, certain features may indicate whether or not it was caused by mobile fishing gear. At a disturbed site, the remains of the gear itself are often found in the form of dredge frames, doors, warps, nets, and/or chains snagged on the wrecksite. This is especially true of larger sites where the fisherman have to cut away their gear after the snag. However, damaged and discarded nets can also travel with currents until they eventually catch on a wreck (MacMullen

2011:3). This may not indicate an actual impact. Wrecks often collect debris while resting on the seafloor. To determine if a shipwreck was directly impacted by mobile fishing gear, researchers must make a close examination of the fouled gear for evidence as to how it became fouled on the wreck. It is also important to determine the type of gear present at the site. Fishing gear that is not associated with bottom trawling can easily catch on a site after drifting along the seabed. Environmental factors must also be taken into account including currents, biological organisms such as octopuses displacing artifacts, and other anthropomorphic disturbances such as offshore construction, cable laying, and anchor drag (Bass 1980: 46; Evans et al. 2009).

There are a number of different ways in which trawl gear can impact a shipwreck site. Factors affecting the type of impact include the gear type, power of the tow vessel, state of preservation of the shipwreck, hull composition and vessel type, seabed topography, amount of relief the shipwreck provides off the seafloor, and the type and size of artifacts present.

Under the right conditions, a wreck can be better preserved due to the covering of the wreck by sediment (Ward et. al.1999a:51 Wachsmann 2007/8:134). Sedimentation rates vary by site depending on factors such as currents, wave action, tidal activity, proximity to depositional rivers and tributaries, and depth. However, if a wreck is disturbed by trawling, one of the likely results will be the uncovering of artifacts, which will, in turn, be exposed to elements affecting preservation. For instance, marine borers will have access to uncovered fresh wood which will be rapidly consumed (Piechota and Giangrande 2008:85). For example, when the Knidos J wreck was observed, the trawl scar running through the site removed sediment and uncovered well-preserved wood (Brennan et. al. 2011).

In the case of steel or iron-hulled ships, a trawl encounter may cause twisting, bending, or shearing which will accelerate the corrosion processes. Stress corrosion will occur at the point of bending, and new areas will be exposed to corrosion after shearing. An example of this type damage is the Japanese M24 midget submarine sunk in 1942 just north of Sydney harbor, Australia. The 24 m long steel hull was found covered with trawl nets in 54 m of water (Figure 15). Significant corrosion was most noticeable in the areas of missing external structures, and it is postulated that the cause of the initial damage was bottom trawling (Smith 2008:86). Further, the conning tower, and numerous smaller components, had been torn from the hull.

A similarly impacted submarine is the Royal Australian Navy *AE2*, lost in 1915 in the Sea of Marmara. The submarine is a British E-Class, 176 ft. (54 m) in length, with a hull of riveted iron plating. While participating in the Gallipoli campaign during WWI, the sub was hit by a torpedo and scuttled by the crew. The vessel now lies at a depth of 73 m, east of Gallipoli Peninsula, Turkey. The submarine has been subjected to repeated trawl impacts (Smith 2000:12). Nets were fouled on the bow, conning tower, and stern when it was initially located and observed. The hull has been dented, resulting in the removal of protective marine growth causing accelerated corrosion. Numerous iron plates have been sprung, and some were removed by the trawl impacts (Smith 2000:14). Also in the Sea of Marmara, an iron paddle steamer was reported to have been so fouled in trawl nets that it took 2 tug boats to remove them (Smith 2000:12).

Figure 15. A trawl net and floats on the bow of the M24 Submarine. (Photo courtesy of NSW Heritage Branch, Office of Environment and Heritage).

Signs of fresh corrosion in damaged areas may be a good indicator of a recent trawling impact. A trawl may also shift metal artifacts causing new galvanic cells to form between metals with different Ecorr (corrosion potential) values resulting in increased corrosion rates (North and MacLeod 1987:72). On smaller or more fragile sites, indicators include trawl marks in the seabed and/or sheared-off artifacts and timbers level with the seafloor or nearest topographic high. Displaced artifacts are also an indicator of a disturbance, however not as easily identifiable. Analyzing a site plan may offer insight as to whether or not the spread of artifacts could be a result of the wrecking process, natural disturbances including biological organisms, or anthropomorphic interference. For example, a linear debris trail may be interrupted by a perpendicular dispersal of artifacts after a trawl passes through the site. Near Bodrum, Turkey, a line of broken and scattered amphoras was found between sites TK06-AD and TK06-AE, at a depth of 83m, in an area of heavy trawling (Royal 2008:95). In the same area, the surface of site TK06-AC was found littered with broken amphoras of varying date, overlaid with loose rocks at a depth of 91m. The site is located near a rocky outcrop, and it is postulated that "net dump" from trawl nets is responsible for the intrusive artifacts and debris (Royal 2008:90). Net dump is the result of a trawl coming in contact with a higher topographic area of the seafloor and losing some of the contents of the net.

In many cases, it is already known that the site was impacted because a fisherman reported the snag or recovered an artifact. Many shipwrecks are discovered when fisherman find pieces of hull, amphoras, or other artifacts, such as statues, in their nets after a trawl. For example, *El Nuevo Constante*, wrecked off the Louisiana coast in 1766, was rediscovered in 1979 by Curtis Blume when he snagged his shrimp trawl net and recovered three 20-inch diameter copper discs, weighing roughly 70 to 80 lbs. (31.8 to 36.4 kg) each (Pearson and Hoffman 1995:4) (Figure 16). After diving on the location and finding a wreck, Blume and his associates began removing artifacts and later employed a floating dredge to expedite the salvage. Blume then sought legal advice and reported the wreck to the State Department. This resulted in the first underwater excavation carried out within the state of Louisiana's waters. Blume entered into a contract with the State to salvage the wreck alongside archaeologists in return for 75% of the value of the precious metals recovered (Pearson and Hoffman 1995:6).

There have been numerous other wrecks impacted by trawling in the Gulf of Mexico and the southern Atlantic region. In 2004, the Deep Wrecks Project analyzed 6 WWII-era shipwrecks in the Gulf of Mexico that had been previously reported by the oil and gas industry to the Minerals Management Service (MMS). MMS was reorganized to

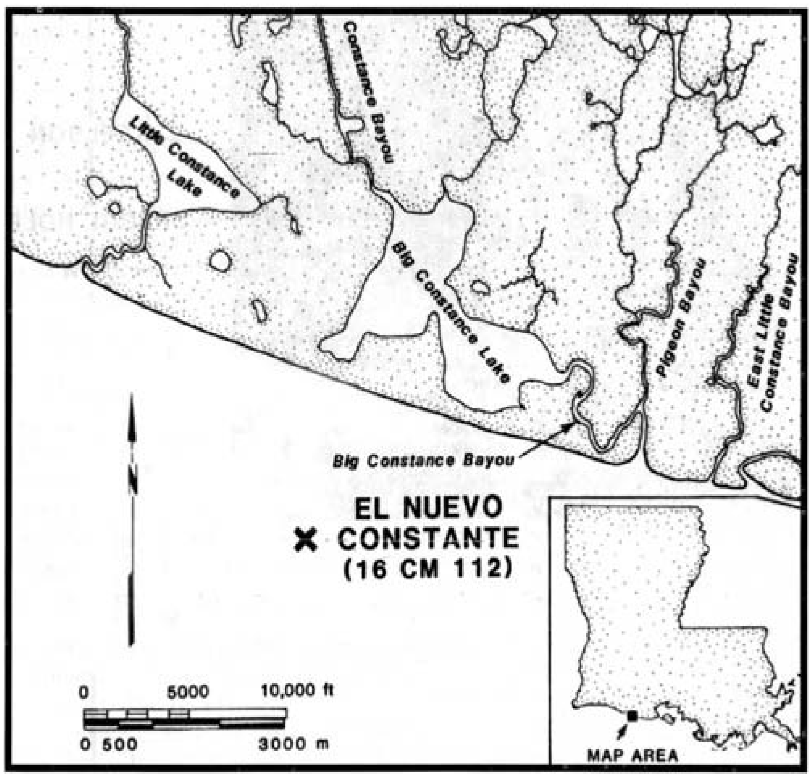

Figure 16. Map showing the location of the wreck of *El Nuevo Constante*. (Courtesy of the Louisiana Division of Archaeology).

form the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) in May 2010 after the Deepwater Horizon oil spill. BOEMRE is responsible for managing the cultural heritage impacts of offshore commercial industries. During the

Deep Wrecks Project, 2 of the 6 wrecks investigated had been impacted by trawling. The 501 ft. (153 m) long tanker *Virginia* (1941) was observed at a depth of 87 m. The ship was hit by 2 torpedoes in 1942 by the German *U-507*, and its cargo of 180,000 barrels of gasoline caused a massive explosion. The wreck was badly damaged but some of the superstructure still remains intact on the seafloor. Trawl nets were found to be covering much of what was left of the aft deckhouse making further investigation difficult. The tanker *Halo* (1920) was struck by German torpedoes in 1942 by *U-506.* The 436 ft. (133 m) vessel sunk to a depth of 143m and was found to have several trawl nets fouled on the stern (Church et. al. 2009:53).

BOEMRE has sponsored numerous shipwreck surveys in the Gulf of Mexico and the staff archaeologists have seen first-hand the interaction between commercial fishing and UCH. The gulf region is the heart of the U.S. shrimp fishing industry. Every wreck they have observed on the continental shelf in less than 330 ft. (100 m) of water had a trawl net fouled on it (Jack B. Irion 2011, elec. comm.). During one study, the S.S. *Castine* (1892) was found to have multiple trawl nets fouled on the bow section. The 204 ft. (62 m) ship is the first steel hulled vessel to have been built in Maine. It is also the first steel hull built by Bath Iron Works, who would go on to build one-quarter of the U.S. Navy's destroyer fleet during WWII (Enright et al. 2006:62). While investigating the site, researchers observed intrusive debris on the main deck including an engine block and electrical junction boxes. The report describes this as a common occurrence where fishermen dump snagged debris on a known hang site in order to prevent the debris from being caught in the net in the future (Enright et al. 2006:78). During the same survey, U.S.S *Hatteras* (1861) was observed as having part of a shrimp trawl net snagged on the site. U.S.S. *Hatteras* is listed on the National Record of Historic Places and is a Texas State Archaeological Landmark. The 201 ft. (61 m) vessel is a sidewheel steamer and was sunk by C.S.S. *Alabama* in 1863. Discovered by treasure hunters in the 1970s, the wreck lies in 17.7 ft. (5.5 m) off the Texas coast. It is a known hang site for shrimpers, who aided in locating the wreck for the latest survey. Aside from the net found on the site, engine components that were standing upright when first found have since been knocked over, presumably by shrimp trawls (Arnold and Anuskiewicz 1995:85). Also listed on the National Record of Historic Places is the wreck of *Josephine* (1867) which lies off the Mississippi coast. *Josephine,* like U.S.S. *Hatteras,* was built for the Charles Morgan Line (Irion and Ball 2001:48). The 235 ft. (72 m) vessel has a trawl net fouled on the port-side paddlewheel (Figure 17).

In an article entitled *Trawling for Treasure* (1997), Captain Sterling Vorus describes numerous wrecks and artifacts found by trawl fishermen in the Gulf and south-Atlantic region. The Spanish brig *El Cazador*, lost in 1784, was located when Captain Jerry Murphy of the fishing vessel *Mistake* snagged his net on the site about 50 miles south of Grand Isle, Louisiana. When the torn net was recovered, a number of silver coins were also raised in the debris, leading to an eventual salvage operation.

Captain Woody Moore located an early 19th century wreck roughly 100 miles east of Jacksonville, Florida. The site is known as Woody's Wreck and was later excavated by archaeologists. The Marquesas Wreck in the Florida Keys was eventually located and salvaged in 1993 after shrimp trawler Captain Clyde Jones recovered numerous artifacts in his nets including cannonballs, olive jars, timbers, and a small figurine. In 1954, the National Marine Fisheries Service (NMFS) was

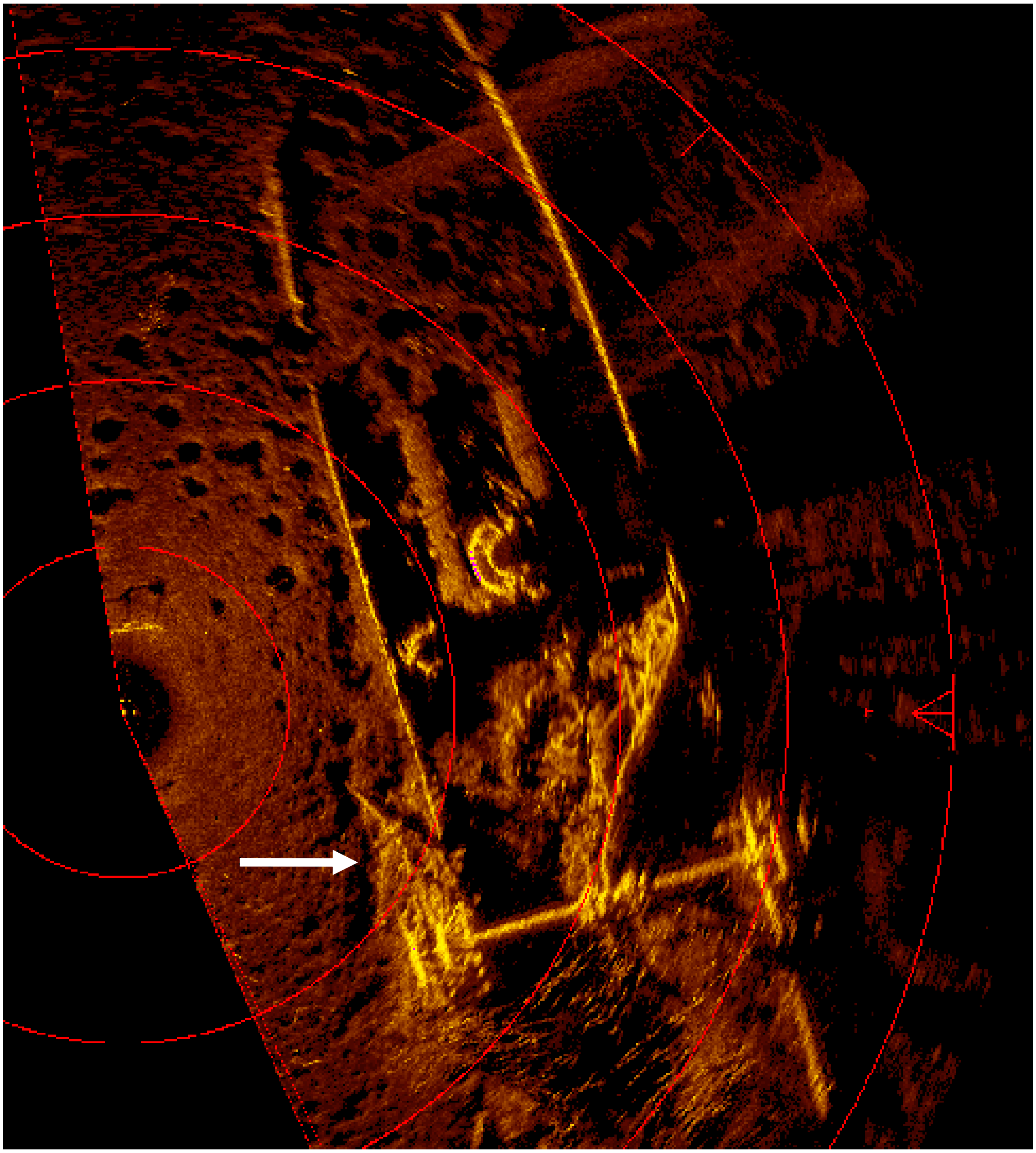

Figure 17. Sector scan of *Josephine* showing a net snagged on the port-side paddlewheel. (Courtesy of the Bureau of Ocean Energy Management, Regulation, and Enforcement).

conducting shrimp trawling for research when roughly 1,000 lbs. (454 kg) of wreckage was recovered including cannonballs, ballast, and metals. A salvage company located the wrecksite and recovered 18th -century artifacts. These instances highlight the importance of working with the fishing community to provide artifact knowledge and reporting procedures.

It is not unknown how many artifacts have been recovered by fishermen around the world and remain unreported. Vorus (1997) also relates an instance in which a fisherman raised a cannon in his net and decided to return it to the seabed, seeing no value in keeping it. On another occasion a shrimp trawler raised an olive jar from over 1,000 ft. (304 m) of water off the coast of Florida. The shrimper gave the jar to his mother who then placed it in her garden. The jar was later identified and dated as 18th century Spanish colonial. However, many fishing families keep collections of their finds, and some have been documented and analyzed by archaeologists. The occurrence is so widespread in the eastern Mediterranean region that there is an entire literature devoted to the subject (Safrai 1960; Barag 1963:13-19; Zemer 1978). In other cases, the artifacts are never recovered after a trawl but, rather, become displaced and subject to currents, resulting in their archaeological context being lost (Stewart 1999:577; Negueruela 2000:180; Wachsmann 2008:97) (Figure 18).

Seafloor geology is an important determinant when discussing how a trawl may impact a site. In the case of the 4th century CE Levanzo I, located near Sicily, soft sand only exists at the top 20 cm of the seafloor, which left the wreck sitting exposed. As trawlers have moved over this site, as much as 90% of the remains have been removed, and a number of artifacts have been re-deposited in a nearby rocky area (Jeffrey Royal 2009, elec. comm.).

Another impact of trawling over a wrecksite is destruction of artifacts and hull timbers. The weight of trawl gear has the power to crush artifacts on the sea floor. For example, the location of the 19th century Desaru ship off the Malaysian coast was identified by a fisherman who snagged his net twice on the wreck, bringing up pottery and a ship timber. After investigation, the excavators noted that the site appeared "shaved flat," while also observing a plethora of pottery sherds surrounding the area (Sjostrand, 2003). The 15th century Longquam and 16th century Singtai wrecks off the coast of Malaysia were also identified by Sten Sjostrand. Upon returning subsequently to the sites, he found that both wrecks had been hit by trawlers. The Longquam wreck once rose 1.8 m off the seabed and was sheared flat with the remains widely dispersed (Flecker 2002:14). Roughly 3 km west of Ko Si Chang, Thailand, the 16th century Ko Si Chang I wreck lies at a depth of 31 m. The site is located in an area of heavy trawling, and trawl nets were found to be fouled on the wreck during a survey. A significant amount of broken pottery litters the site. Likely removed by trawl gear, survey markers left on the wreck in 1983 were missing when the wreck was revisited in 1985 (Green et al. 1986:108).

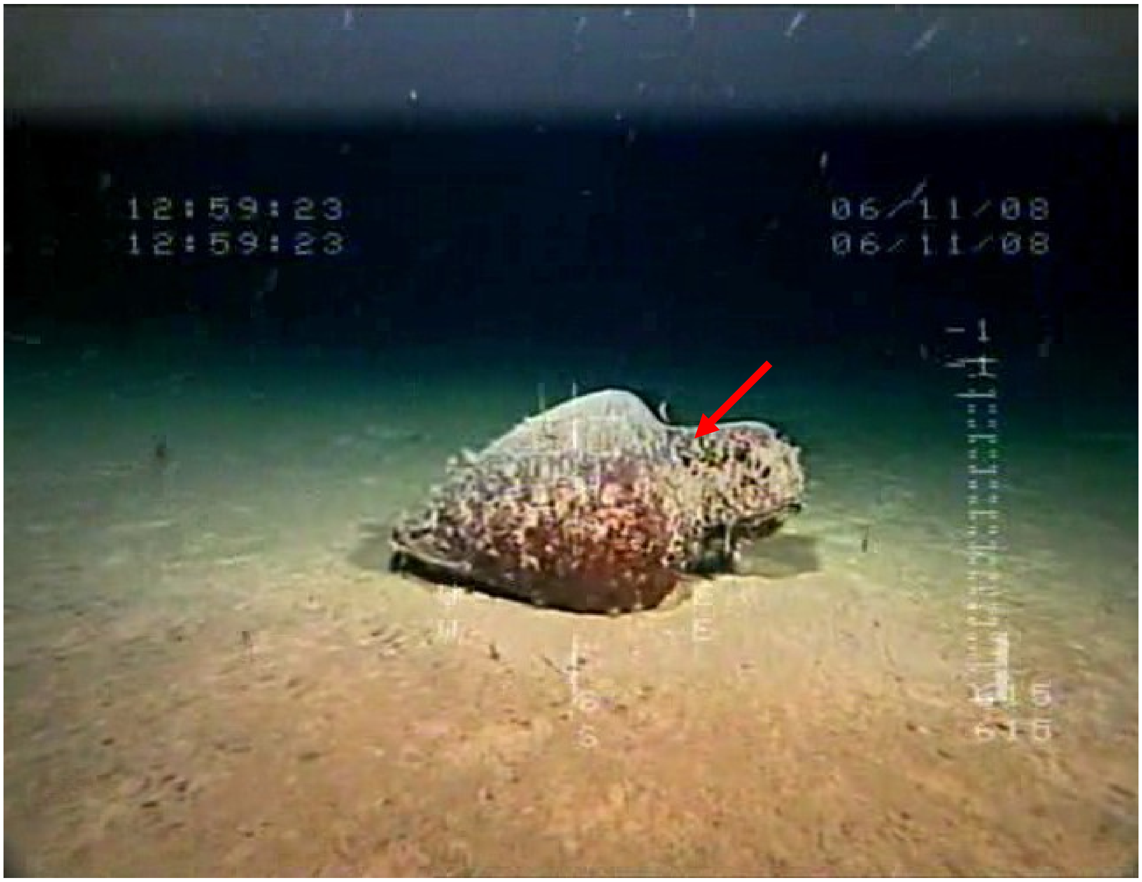

Figure 18. A lone Rhodian amphora on the seabed south of Crete at 615 m. Note the delineation between where the amphora was once buried and has no marine growth which indicates recent disturbance. (Courtesy of Shelley Wachsmann).

The Mongol invasions of Japan by Kublai Khan resulted in the loss of hundreds of ships after typhoons hit the fleet in both 1274 and 1281. Near the Island of Takashima, Japan, trawlers have been raising artifacts from the wrecks in their nets for decades. A bronze statue of Buddha dating to the 1281 invasion was raised and is now in a small shrine on the island. Also recovered in a net was a bronze seal once owned by a Mongol leader of 100 to 1,000 horsemen. The seal has been designated as a Japanese national treasure (Green 1987:167).

In some cases, ancient wrecks are characterized by their amphora piles or other cargo rather than the actual hull (Stewart 1999:570; Sakellariou et al. 2007:366; Brennan 2009:48). Therefore, destruction or dispersal of this fragile cargo is a likely result if encountered by a bottom trawl. However, a capsized ship could also leave a debris field of damaged goods due to the impact of the seafloor during the wrecking process (Stewart 1999:569). An ancient ship sinking to the bottom upright, in deep water, will most likely have its cargo still partially stacked as opposed to heavily spread around the region (Wachsmann 2007/8:133). Thus an ancient wreck with a widely dispersed field of artifacts, where hull remains, or evidence thereof, is still present below the level of the seabed, could indicate a major disturbance such as a bottom trawl.

Commercial Fishing is permitted in certain areas of the NOAA sanctuaries, but trawlers working in the areas have created challenges for divers and crews documenting wrecksites. In both 1997 and 2004, divers observed trawl fishing gear tangled on the *U.S.S. Monitor*, which lies in a protected marine sanctuary (NOAA 2008b). Similarly, the wreck of the *Paul Palmer*, which sank in 1913, has been struck at least twice by trawlers and is also located within a sanctuary (Foley 2008) (Figure 19). Eleven of the 18 documented wrecks in the Stellwagen Bank marine sanctuary have been impacted by trawling (NOAA 2008a:125). The impacts are mostly in the form of nets and cables found snagged on the vessels, and in the case of the *Paul Palmer,* a cable has cut into the bow and nets have enshrouded deck gear. The steamship *Portland* has an entire otter trawl rig, including net and doors, wrapped around its bow. These impacts have both damaged the wrecks and prevented NOAA divers and ROV crews from fully

Figure 19. A trawl net entangled on the windlass of the *Paul Palmer*. (Photo by Tane Casserly; courtesy of NOAA/ONMS Maritime Heritage Program).

documenting the remains. Off the coast of Maryland, the steel-hulled WWII era *U.S.S. Moonstone* had a deck gun ripped off by a trawler, which demonstrates the powerful force of a commercial trawler with large engines (Barnette 2008). During a survey of the Sound of Mull in Scotland, damage to the wreck of the *SS Hispania* (1912) was observed in the form of a recently downed mast and multiple hull scrapes showing signs of fresh corrosion; this damage was caused when a scallop dredger caught his gear on the wreck. There are also signs of trawling and scallop dredging near other wrecks in the immediate area (Robertson et al. 2007:85).

Within *Shipwrecks of the Forth and Tay* (2009), eight shipwrecks and one aircraft were identified as having trawl impacts in this region of Scotland. The impacts are in the form of nets fouled on the wrecks, and in the case of the *U-714* WWII German submarine, an entire trawl rig, including doors, is wrapped around the conning tower. Bob Baird (2009) also reports other impacted wrecks, including *Phineas Beard, Denmore, Merlin, Pathfinder, Sabbia, Magme,* "CHRIS", and a German Ju-88 aircraft.

In NSW, Australia, a significant amount of WWII plane wreckage has been raised in trawl nets over the last half-century. In addition to accidental crash sites, the region is home to a number of mass dumping grounds of surplus and non-operational aircraft that were discarded after the war. Trawlers have unintentionally encountered these sites and have either snagged and lost their nets or raised pieces of the aircraft at the end of their trawl. Some of the more notable finds include a radial engine, multiple sections of Corsair wings, and a Beaufort propeller (Smith 2004). In the same region, ROV surveyors, at a 400 m depth, observed trawl nets covering the stern of the HMAS *Australia* (1911) (Tim Smith 2010, elec. comm.). Also in NSW, the *Lady Darling* (1864) was located in 30 m of water when a trawl fisherman snagged his net and raised riveted iron plating. The snag location was reported, and GPS coordinates guided archaeologists to trawl scars on the seabed that led to the wreck. The *Lady Darling* is an early example of the transition to screw propulsion and offers a glimpse into early steam engine technology with its "simple" engine and "cylindrical" boiler, neither of which is well represented in NSW waters. The fishermen responsible for locating the wreck were awarded engraved finder's plaques during a ceremony. This recognition by the NSW Heritage Council is an excellent example of one of the many ways that fishermen can be acknowledged for their contributions in locating UCH (Smith and Nutley 1998:38). South of Melbourne, Victoria, Australia, the wreck of the *Isis* (1892) is mostly buried in sand at a depth of 10 m. The site has been repeatedly impacted by scallop dredgers, which are very active in the region. A deck winch and bollard were pulled free and moved, and the boiler was shifted. Other wrecks in the region reported impacted by scallop dredging include the *City of Launceston, Euralba,* and *Eleutheria* (Derksen and Venturoni 2011).

The wreck of *Mercure* (1806) off the northeast coast of Italy was identified when a 165 cm carronade was raised in a trawl net (Beltrame and Gaddi 2002:60). Further research showed the wreck was covered in snagged nets and cables and that artifacts were dispersed as far as 100 m from the site. Multiple artifacts have been raised in trawl nets at this site, including a sabre hilt, a blade, a copper cauldron, and various-sized cannon balls. Furrows were present surrounding the site and were visible on side-scan sonar (Beltrame and Gaddi 2002:62). This wreck is located in an area heavily trawled by fishermen using a gear type known as a "rapido" trawl. Rapido trawls are modified beam trawls with a rigid mouth and 7 to 10 cm metal teeth fixed along the lower edge of the opening. The trawl measures 4 m across and multiple gears are towed by a single vessel at a relatively high rate of speed averaging 12 km/hr (Scarcella et al. 2007:591). A number of teeth from the rapido trawls were found at the site of *Mercure*. Unfortunately, the soft, sandy nature of the northern Adriatic Sea is ideal for fishing with rapido trawls, and this industry has led to distinctive damage of UCH that makes efforts in archaeological survey and site preservation challenging. In Sweden, the paddle steamer *Eric Nordevall* (1837) lies at 45m on the bottom of Lake Vättern. The wreck was part of the European monitoring and visualization program "MoSS" from 2002 to 2004. The *Eric Nordevall* is an important example of ship technology due to its excellent state of relatively intact preservation, and the vessel is also a unique example of early European steam ship technology. When located in 1980, the wreck was covered in trawl fishing nets and cables. In 1986, the wreck was cleared of the debris, but when researchers revisited the site more nets had fouled on it (Cederlund 2004:60). Furthermore, various components of the ship had been removed or disturbed by trawlers. The wreck is now protected by the Swedish Ancient Monuments Act and diving and fishing are prohibited on the site. While the shipwreck itself has suffered some damage, a full-scale replica of the ship was built and named *Eric Nordevall II* to honor the significance of this UCH.

These examples show the wide range of impacts bottom trawling can have on shipwreck sites. From a site formation perspective, it is possible to conclude that bottom trawling scrambles, removes, or destroys the archaeological record. Intrusive objects including modern debris, rocks, and even other artifacts can be deposited by commercial fishing activities.

INUNDATED LAND SITES

At the time of the Last Glacial Maximum (LGM) roughly 24,500 to 18,000 B.C., glaciers had reached the end of their southern advance and covered nearly one-third of the Earth's surface (Coleman 2008:183; Clark et al. 2009:710). Water held in glaciers resulted in sea levels up to 130 m lower than they are today, exposing 3% more dry land worldwide (Coleman 2008:178; Clark et. al. 2009:710). During this time, human populations could migrate between landmasses over land bridges or shallow water crossings. Studying inundated land sites can reveal the patterns of these migrations and may help answer questions such as who the first Americans were and where they arrived from. As a result of deglaciation and isostatic uplift, these sites are now covered by meters of water, sometimes many kilometers offshore. By roughly 3,000 B.C., glaciers had retreated, raising the sea to its current level (Ward and Larcombe 2008:61). Developments in technology now allow researchers to image the seabed and the sub-seabed to create a picture of the ancient, now submerged, landscape. Settlement patterns taken from terrestrial archaeological and anthropological research have been overlaid on this landscape in an attempt to locate potential sites. However, fishermen are a key resource for locating possible inundated land sites. This chapter highlights some of the instances where artifacts have been raised by fishermen over the last century. Artifacts raised in trawl nets have confirmed the potential for archaeological exploration of the continental shelf.

Numerous artifacts from submerged land sites have been recovered and reported by fishermen off the coast of North America. In the fall of 1983, scallop fisherman George Roach recovered an 18 cm ground-slate semi-lunar knife from 19 to 28 fathoms (114 to 168 ft.; 35 to 51 m) of water while working 1 mile off North Lake, Prince Edward Island, Canada (Keenlyside, 1984: 26). Sometimes referred to as an "ulu", the knife, dated to the Middle Archaic period, and was still sharp when found indicating that it had likely not been transported after deposition and was found at, or near, its primary context. A similar knife was recovered in deep water off Digby, Nova Scotia, Canada (Keenlyside, 1984: 26).

Near White Horse Island, New Brunswick, Canada, Mr. Carroll Cook recovered a ground-slate semi-lunar knife while scallop dragging in the 1980s (Black and Turnbull 1988) (Figure 20). Also in Canadian waters, marine biologists employed by the Department of Fisheries and Oceans at the Federal Biological Laboratory (St. Andrews, New Brunswick) found a stone gouge while scallop dragging for research samples in the summer of 1995 (Figure 21). The scientists were working in 38 m of water east of Indian Island, New Brunswick. The gouge is 16.5 cm long, 3.8 cm wide, 2.9 cm thick and it is full-channeled; a feature that is consistent with other gouges dated to the Middle Archaic period (Black 1997:5).

Another stone gouge was found by scallop dragger David Farley along with a stone adze during a single haul (Figure 22). While fishing in the same area another day, he also recovered a slate point (Figure 23). Farley was working close inshore to Bass

Harbor, Maine, in 52 to 58 ft. (15.8 to 17.6 m) of water. Rising sea levels inundated this region of the seabed between 7,000 and 5,000 B.C., which is consistent with the 3 artifact types. The gouge is 16 cm long, 3.5 cm wide, and 3 cm thick, with a shallow channel along 80% of its length. The adze is 24 cm long, 8 cm wide, and 3.5 cm thick. The slate point is missing the tip and is 15 cm long. The point is lenticular in both plan and cross-section views, with slight shoulders for hafting (Price and Spiess 2007:27). Marine archaeologist Franklin Price, a former fisherman himself, gathered the information on the Farley artifacts during a survey of local fishermen and divers, highlighting once again the importance of a positive working relationship between archaeologists and the fishing community. The survey resulted in 121 possible sites, including 49 known shipwreck locations, 2 submerged aircraft wrecks, and 20 snag sites indicating potential wrecks.

Figure 20. A ground-slate semi-lunar knife recovered by a scallop dragger. (Photo by Scott Finley, Archaeological Services, New Brunswick, Canada)

Figure 21. The Indian Island slate gouge recovered by research scientists while dragging for scallop samples. (Photo by David W. Black, University of New Brunswick, Fredericton).

Figure 22. The Farley stone gouge. (Price and Spiess 2007:29).

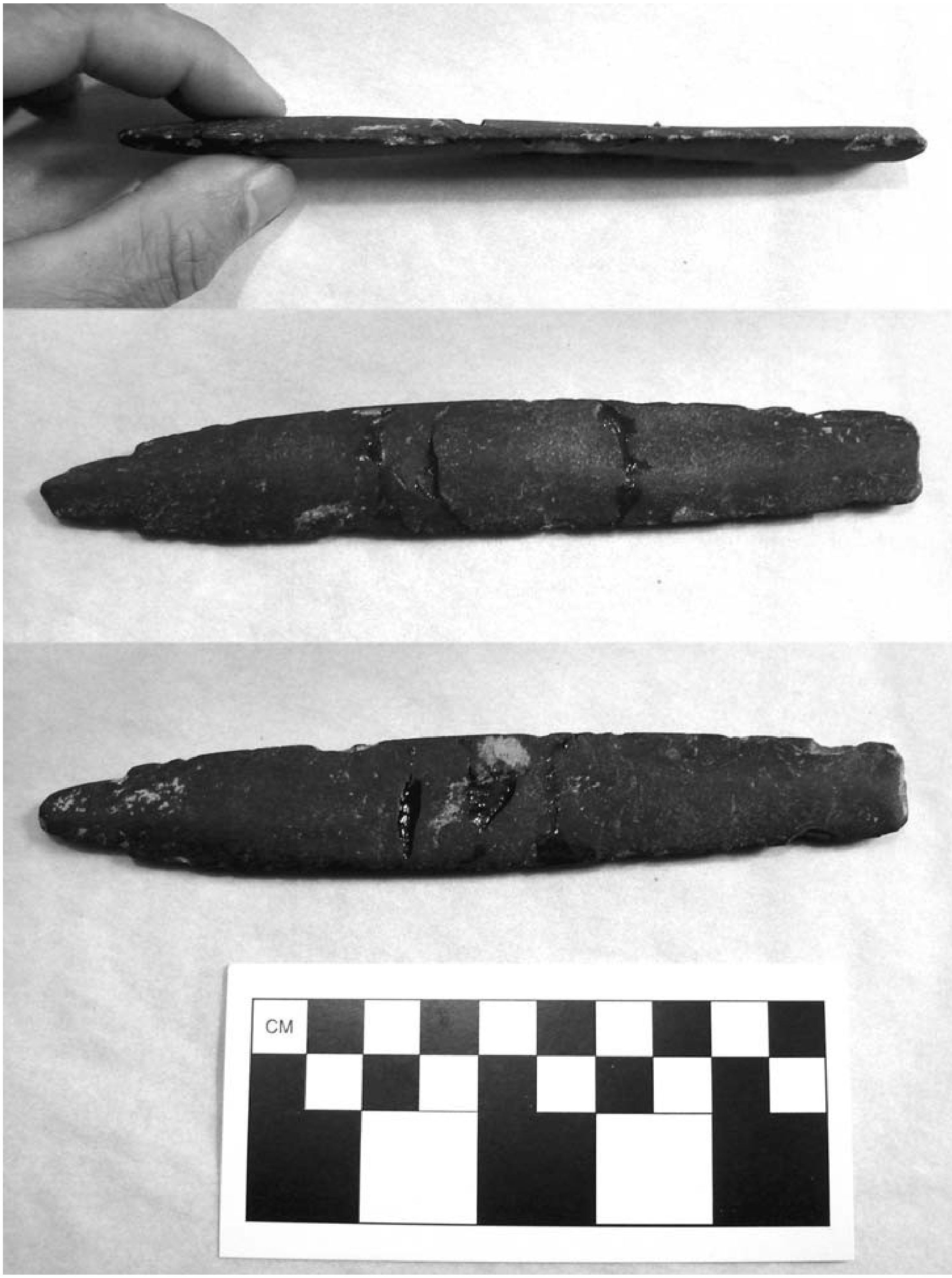

Figure 23. The Farley ground-slate point. (Price and Spiess 2007:28).

Nearby in the Green Islands region of eastern Blue Hill Bay, Maine, scallop fisherman Ross Anderson and his crew recovered a lanceolate biface from 43 to 46 m of water (Crock et. al. 1993:179). These depths would have been inundated between roughly 8,000 and 6,000 B.C., and the biface has been dated to the Early to Middle Archaic period based on similar finds. The biface is 17.75 cm long, 7.19 cm wide, 0.88 cm thick, and is made of rhyolite. The authors note that marine growth exists on only one side, indicating that it has been lying undisturbed on the seabed surface for some time; however, "waterwear" was also noted as a possible sign of post depositional transport (Crock et. al. 1993:184). According to the authors, when sea levels rise and inundate a region of dry land, artifacts can be eroded out of a bank and become part of a high energy inter-tidal system. As sea levels rise further, artifacts will enter a lower energy environment allowing marine growth to form on the exposed surface. An artifact found with marine growth on both sides indicates a recent disturbance. Two other bifaces have also been recovered in the same region at depths of 40 to 44 m and 60 m (Crock et. al. 1993:179). The first biface is 25.87 cm long and 6.75 cm wide; the other is 20.70 cm long and 5.63 cm wide. Anderson also recovered a perforated greenstone plummet from 15 m depth in Seal Harbor, Maine, northeast of Sutton Island. The plummet is 17.92 cm long, 7.41 cm wide, 6.82 cm thick, and weighs 977.8 kg. It has been generally dated to the Archaic period. Unfortunately, plummets are not diagnostic enough for a more precise date, and the likelihood of them having been lost overboard throughout antiquity while in use as fishing implements voids the recovery depths as an aid in relative dating.

The types of artifacts recovered by fishermen can be directly related to the size of the gear mesh, which is not consistent throughout the world, between different fisheries, nor throughout history. As an example, the minimum ring mesh size for scallop drags in Maine has increased over time. Many of these finds were reported when the minimum mesh size was 3 in. (7.6 cm) (Crock et al. 1993:183; Price and Spiess 2007:27). At the time of this research, scallop fisheries regulations required 4 in. (10.2 cm) rings to be used (Maine 2010). Increasing ring sizes will have an impact on the types of artifacts recovered by scallop fishermen in this region. None of the stone tools discussed here were smaller than 5 in. (12.7 cm) in length. It is important to note that these larger finds made by fishermen are providing a biased picture of the submerged landscape in the region. This size bias can directly be seen at a site in Penobscot Bay, Maine; at this site, scallop fishermen raised Middle to Late Archaic period artifacts including a semi-lunar ground-slate knife, biface preforms and adzes from a depth of 7.6 m (Stright 1990:439). Divers investigated the area and recovered numerous biface fragments, flakes, and flake cores, artifacts that would be too small to remain in a scallop dragnet. Stright (1990) also reports an articulated bone and projectile point found in the 1970s by clam dredgers. The fishermen were working in 9 m of water, 90 km offshore from Narragansett Bay, Rhode Island. The projectile point is described as an eastern lanceolate late Paleoindian point made of flint, and the point was found to correspond to the hole in the immature bison femur also recovered in the clam dredge.

In the Gulf of Mexico, a large 25.1 cm chert blade was found by shrimper Jack Cain in May 2010 (Figure 24). The blade was recovered while trawling in the Calcasieu

Ship Channel south of Lake Charles, Louisiana. The find was reported to the regional archaeologists who identified it as some variety of Benton Stemmed (ca. Late Archaic) (David Palmer, elec. comm.). There is an oyster shell encrusted on one side, a barnacle on the other, and some additional calcium carbonate deposits, which indicates disturbance prior to the artifact having been recovered during the trawl.

Roughly 40 years ago, the crew of the trawler *Cinmar* was scallop dredging about 100 km east of the Virginia coast. In a single haul, a mastodon skull and a large stone biface were recovered from around 70 m of water. The captain kept the biface, a tooth, and a section of tusk; these items were put on display at the Gwynn's Island Museum in 1974. Recently, Smithsonian archaeologist Dennis Stanford and his colleagues recognized the possible significance of the finds and initiated a thorough study of the material and its context. The mastodon remains were dated to 22,760+/-90 B.P.. The biface is made of rhyolite, and a possible source for the material was identified roughly 200 mi. (322 km) from the find. The laurel-leaf shape and the flake removal pattern make the blade morphologically and technologically unique in the Mid-Atlantic region. A use wear study of the biface suggests it was hafted and used as a knife.

Figure 24. A projectile point recovered by a shrimp trawler in Louisiana. (Photo by David Palmer, University of Louisiana at Lafayette, Southwest Louisiana Regional Archaeologist).

The still sharp edges and crisp flake scars suggest that the biface was not transported nor greatly disturbed by post-depositional processes, except the fresh damage received from the fishing gear during recovery. The seabed surface where the finds were recovered was exposed around 12,400 B.C. (Dennis Stanford 2011, elec. Comm.). This indicates that even if the mastodon remains and the biface are not contextually related, the biface would still predate Clovis culture by almost 1,000 years unless it was deposited in an already submerged marine environment. This challenges the traditionally accepted understanding of the peopling of the Americas. Only future evidence can answer the questions raised by these artifacts, and it is likely that trawlers will continue to make important discoveries on the continental shelf of North America.

In Europe, off the coast of the Isle of Wight, U.K., two Neolithic-age features have suffered trawl damage. The first is the remains of a wooden structure off Yarmouth consisting of a post alignment radiocarbon dated between 2,930 and 2,610 cal B.C. The site is designated as a submerged monument (GU-5260). Evidence of trawling damage was noted during a brief survey in 1997, but the site was never fully surveyed and its current condition has not been assessed (Isle of Wight County Archaeology and Historic Environment Service [IWCAHES] 2011). A Saxon period longshore post alignment (K16) with damage from oyster dredging was also observed during low tide in 2002. Because the oystermen are permitted to operate inshore of the low tide mark, several posts were pulled out of position, and the scour marks from the dredges can easily be seen during low tide (IWCAHES 2008) (Figure 25). Fragile structures like these are unlikely to survive any sustained trawling activity.

In 1997, a fisherman trawled up an entire 5 m long dugout canoe off Dunwich Bank, near Suffolk, England (Flatman and Blue 1999:198). The canoe was radiocarbon dated to the Anglo-Saxon period, ca. AD 775 to 892, and is the oldest vessel ever found off the coast of the U.K.. In the same region, an 8.4 m long ship timber was trawled up which was dated ca. 18th to 19th century. Similarly, the dive vessel *Seaway Kingfisher* was in the North Sea doing maintenance to the H-4 wellhead oil platform Troll B in 1999 when the crew discovered an 11 m long, 40 cm broad, and 2 ton keel section entangled in a trawl net hung up on the installation.

Figure 25. Oyster dredge marks seen during low tide at Quarr Beach, Isle of Wight. (Photo courtesy of Isle of Wight County Archaeology and Historic Environment Service).

It was later identified as most likely belonging to a ship of 300 to 400 tonnes burden (Nœvestad 2006:290). The size of this timber, once again, demonstrates the scale and power of some trawl gear.

There have been hundreds of other cases where bottom trawlers have raised artifacts from the North Sea. Many fishermen keep the artifacts for their own collections (e.g., Michael White Collection), while others offer them for sale to private collectors (Wessex Archaeology 2004). However, a growing number are reporting the finds to local archaeologists who generally document and return the artifact to the finder.

The southern portion of the North Sea was an alluvial plain from roughly 98,000 B.C. until the LGM (Ward and Larcombe 2008:59). This region, termed “Doggerland” by Bryony Coles (1998:47), once formed a land bridge between Britain and Europe, and during this time, it was an inhabited landscape. Evidence shows that a thriving community was living in the area during the upper Paleolithic and into the Mesolithic. Rising sea levels submerged the area by approximately 4,500 B.C., leaving what is now known as Dogger Bank to become an island and eventually a submerged landform around 3,000 B.C. (Louwe Kooijmans 1971:30 Ward and Larcombe 2008:76). Artifacts and fossils were recovered by fishing vessels in the southern North Sea as early as the 1870's (Mol et al. 2006:179). In 1931, the trawler *Colinda* raised a section of peat, known as "moorlog" to the fishermen, from 36 m depth, roughly 25 mi. (40 km) northeast of Norfolk, U.K.. Once removed from the net, a barbed point made of antler or bone fell free. Known as the Leman and Ower Banks barbed point, it was originally dated to 6,500 B.C. based on a pollen analysis of the peat and later C^{14} dating of moorlog raised from the same depth and region (Louwe Kooijmans 1971:32). More recently the point was dated by AMS to 13,600 B.P. (Ward and Larcombe 2008:78). This find is credited with raising early interest in the archaeological potential of the southern North Sea.

Louwe Kooijmans (1971) reports that Dutch fishermen have raised numerous artifacts from the Brown Bank region of the southern North Sea. Aside from the Leman and Ower Banks barbed point, 9 other worked bone implements are discussed. Based on their location at similar depths and in the same region of the Brown Bank, the artifacts were all dated to the Boreal-Late Preboreal (roughlyØ 7,200 to 6,000 B.C.).

In 1970, near Colijnsplaat, Netherlands, trawl fishermen raised two altar stones dedicated to the Roman goddess Nehalennia (Louwe Kooijmans 1971:46). Subsequent trawling and diving operations recovered an additional 122 similar altar stones from the site (Hassell 1978:43)

Further demonstrating the archaeological potential of the submerged landscape under the North Sea, a Neanderthal skull fragment was found among the sieving debris of a marine aggregates company (Hublin et al. 2009). Shell-rich material was dredged from roughly 15 km off the coast of the Netherlands, in the Zeeland Ridges area. In this type of dredging operation, material is brought ashore and sieved to extract the shell or target material, leaving behind a debris mound. The debris is often scoured by amateur fossil and artifact hunters. In this case, one such amateur recovered the skull fragment which was morphologically identified as being a brow ridge of a *Homo neanderthalensis*. Consistent with this identification, other lithic artifacts from the Middle Palaeolithic were found among the same dredge debris. This is the first Pleistocene fossil hominin found in the Netherlands and the first ever recovered from the seabed worldwide. It is important to note that while such a small fragment would likely fall through the mesh of a trawl net, a find this size could still be recovered entangled in other debris such as peat (e.g., the Leman and Ower Banks barbed point).

Marine aggregate dredging is only discussed here to show the archaeological potential of submerged landscapes. Fishing trawlers are likely to encounter and recover similar material, and thus, significant new finds are possible. In 2002, the U.K. government effected legislation that imposed a levy on all primary aggregate extraction known as the Aggregate Levy Sustainability Fund (ALSF). This fund is used to offset and research the environmental impacts of aggregate extraction, and a portion of the fund is dedicated to marine impacts (MALSF). As a result of the fund, significant research, including geophysical mapping, artifact analyses, strategy assessment, and outreach and education, has been possible in submerged landscapes off the coast of Britain. Seventy-five Paleolithic stone tools were raised at site 240 by a dredger. These artifacts were reported and studied, and dredging operations moved as a result (Bicket 2011:38). Cooperation such as this may loosely serve as a model for future interactions between the fishing community and archaeologists.

These examples raise important details regarding the interaction between the commercial fishing industry and UCH preservation. Submerged prehistoric land sites do not present the same topographically high profiles on the seabed as that of shipwreck sites. Therefore, the current sonar-based technologies cannot effectively locate these sites, nor relocate them after a find is reported (Michel et al. 2004:11; Faught and Flemming 2008:38). Bottom trawlers have become an essential tool for helping locate promising areas for investigation. However, relocating a site based on GPS coordinates reported by a fishing vessel can prove extremely difficult. A number of factors must be taken into account, and it is important to know how different types of bottom trawling can affect reported coordinates. In the case of otter trawling, the gear may be towed for hours, over distances measured in tens of kilometers. Once the gear is raised with an artifact, there will be no way to tell where exactly it was located. Conversely, a scallop dredger hauls more frequently, and the shorter tows (i.e., 10 to 15 minutes) may allow for a more precise location when an artifact is found (Crock et al. 1993:183; NOAA 2004:17). It is also important to consider that when a vessel reports a snag location, the vessel, and in turn the GPS device, is actually not located over the site. The warp length is roughly 3 times the depth of region being fished. This is known as the scope ratio and can vary with regards to depth, ground-gear type, and target species (NOAA 2004:17). The gear is often a great distance behind the vessel during the tow and must be accounted for when considering a reported location.

The range of examples presented here show that fishermen have recovered a wide variety of artifacts from inundated land sites around the world. These contributions are important as they can lead researchers to new submerged land sites. These sites are very difficult to detect as they do not present a topographic rise on the seafloor nor do they contain significant traces of metal for detection by a magnetometer. With the current state of technology, bottom trawling may actually be an effective tool for archaeologists to uncover inundated land sites. New discoveries may help to answer the questions surrounding who the first American were, patterns of migration, and how past cultures exchanged knowledge and technology.

CHAPTER V

CURRENT FRAMEWORK

LEGISLATION

In 2005, the General Fisheries Commission for the Mediterranean banned bottom trawling below 1000 m, and in 2006, the Commission closed entire ecologically sensitive areas near Italy, Egypt, and Cyprus. While this is a positive effort, it is not a long-term solution for protecting underwater archaeological sites. In the U.K., the area around Lundy Island is closed to fishing due to the presence of the two important wrecks *Iona II* and the "Gull Rock Wreck" (Rogers 1997:13). There are a total of 63 sites under the Protection of Historic Wrecks Act (1973) in the U.K., which indirectly restricts bottom trawling. Many nations have begun to regulate bottom trawling within their EEZs. The United States controls its coasts under the National Oceanic and Atmospheric Administration (NOAA). A condition report for the Stellwagen Bank National Marine Sanctuary cited that the primary concern for the region was commercial fishing despite its protected status (NOAA 2007).

The President of Palau has been a strong force in regulating trawling and has banned all bottom trawling within the nation's jurisdiction and restricted Palauan vessels from trawling on the high seas. A number of other nations have recently followed suit. Hong Kong, Belize, Venezuela, and Indonesia have passed legislation banning bottom trawling in their waters and prohibited their vessels from high seas trawling. This is made possible by government funds used to buy the vessels from fishermen, convert them for use in more sustainable and less destructive types of fisheries, and provide subsidies for lost livelihoods (Khan et al. 2006:12). Many other nations have instituted no-trawl zones within their waters. This is generally done in ecologically sensitive areas. These countries include, but are not limited to, Brazil, Canada, China, Malaysia, New Zealand, Norway, and the United States (Prows 2008:8,11).

The majority of the world's oceans are international waters, however, which cannot be universally regulated by any one nation. The United Nations (UN) is the only authority that can implement restrictions on trawling the high seas. Within the UN, the Food and Agricultural Organization (FAO) is the governing body. While the UN has acknowledged the issue, it has passed the responsibility to regional governments. Regional Fisheries Management Organizations (RFMO) are joined on a volunteer basis to help manage regions of the ocean with the support of the UN. For example, the General Fisheries Commission for the Mediterranean (GFCM) consists of 23 member nations and the European Union (EU). Thus far, no major restrictions on trawling have resulted from cultural heritage concerns. The 2001 UNESCO Convention on the Protection of Underwater Cultural Heritage acknowledged bottom trawling as a threat, yet does not address it within the articles. Article 5 of the convention reads, "Each State Party shall use the best practicable means at its disposal to prevent or mitigate any adverse effects that might arise from activities under its jurisdiction incidentally affecting underwater cultural heritage" (UNESCO 2001). This article implies that each nation needs to protect underwater cultural heritage within its EEZ but does not specify fishing, although, in essence it includes trawl regulation. Worse, the convention leaves out high-seas trawling altogether.

MANAGEMENT AND MITIGATION

The potential for an impacted wreck to be demolished down to the seafloor raises awareness that a wreck hit by a bottom trawl may never be found due to the nature of side-scan sonar and other commonly-used equipment (Brennan 2009:49). Local fishermen are an important resource in locating and documenting UCH sites. The possibility for better cooperation exists between Regional Fisheries Management Organizations (RFMO), local fishermen, and archaeologists. Fishermen lose valuable gear when encountering a wreck and would benefit from the precise mapping of shipwreck sites in local regions (Marx 2009:8). For example, the U.K.'s Kingfisher Charts plot thousands of wrecks and underwater obstructions so that they may be avoided (MacMullen 2011:3). Most fishermen are incredibly knowledgeable regarding local seabed features and navigational hazards. Advances in GPS and navigational equipment have allowed captains to plot hazards and know precisely where their gear is in relation to these hazards. Interviewing and surveying the local fishing community has proven effective in documenting shipwreck, snag, and potential submerged landscape locations. Furthermore, fishermen have knowledge of the local hazards and conditions that cause shipwrecks, which may lead archaeologists to investigate specific high probability regions in search of new sites.

Protection of known wrecksites is of equal importance. There have been a number of cases where important wrecks have been identified in areas of heavy fishing, and mitigation techniques have been employed. The wreck of *Mercure*, previously mentioned, and the Roman "Caorle Wreck", are examples of sites where sandbags, nets, and spikes were employed for protection. Sand and sandbags surround and support the wreck, netting lies draped over the entire site, and long spikes surround the perimeter. Unfortunately, both sites were still impacted by trawlers. Interestingly, the site of *Mercure* is protected by the family of fishermen who made the initial discovery, and they patrol the area daily (Carlo Beltrame 2009, elec. comm.). There are a number of other wrecks in Italy that are protected using similar techniques (Davidde 2002:83).

In the Wadden Sea (located in the southeastern portion of the North Sea bordering the Netherlands, Germany, and Denmark), a similarly positive cooperation between archaeologists and fishermen has taken place. After raising medieval ship timbers in their beam trawl net, fishermen then assisted a team of archaeologists, using their own trawler, in an attempt to locate and investigate the wrecksite (Auer 2008:11). The Wadden Sea is home to a number of archaeologically-valuable shipwrecks. The method of covering a site with nets and sandbags has been perfected in the region, beginning in 1988 with the BZN 3 wreck. The netting acts as a sediment trap and can quickly allow for a wreck to be covered and protected. The shape of the protected structure allows for bottom trawls to roll over without getting caught on the wreck (Manders 2006a:72). The same method was employed by the Dutch in the case of the VOC-ship *Avondster* in Sri Lanka (Manders 2006b:58). This technique can only be effective for wrecks with low topographic relief. The protection of larger wrecks can take place in the legislative realm through the use of Marine Protected Areas (MPA), navigational boundaries or through similar initiatives (Firth and Ferrari 1992:69).

FISHERMEN'S PERSPECTIVE

It is essential to consider the fishermen's perspective within this discussion. The fishing industry has faced increasing pressures since its height in the 1980s (Watson et al. 2006:103). Fish stocks have declined, fuel costs have steadily risen, and conservationists have pushed to tighten restrictions on the fisheries. It makes sense that fishermen may be wary of archaeologists. When reporting a find or snag, they are asked to divulge the sometimes secret locations of their most productive fishing spots. There may also be a hesitancy to report snag sites for fear that the region may end up under future legislative protection. Lastly, artifacts raised in trawl nets have a market value that may help to supplement the fishermen's declining income.

Incentives need to be created to encourage fishermen to report finds and to cooperate to minimize the impacts of fishing on UCH. An important step would be to create outreach programs inviting the fishing community to learn more about the UCH in their region, to understand the impact of fishing on UCH, and to learn of past success stories of cooperation between the two communities. Including the individual fishermen as publication authors, naming sites after the finders, and hiring them to assist in further investigations of the sites would all incentivize the fishermen to report their finds and snag sites. However, understanding how their reporting is contributing to our knowledge of the past may be the greatest incentive. Both communities can learn from one another to minimize impacts on their individual interests.

An excellent model of cooperation and outreach can be found in the U.K. Wessex Archaeology oversees a program between English Heritage, Crown Estate, and the British Marine Aggregate Producers Association (BMAPA). This program is designed to raise awareness within the dredging community on what archaeological finds look like and how to handle, care, and document them; this program also explains the reporting procedures adopted by all parties. The publication entitled *Protocol for Reporting Finds of Archaeological Interest* (2009) includes all of this information as well as forms and website addresses. A similar program could be modeled for the commercial fishing industry.

CHAPTER VI

CONCLUSIONS

Since its inception in the 1960's, the field of underwater archaeology has had a tangled and complex relationship with the fishing community. Important discoveries have been made by fishermen through the raising of artifacts in trawl nets and through the reporting of snag sites to cultural heritage managers. However, it is known that bottom trawling poses a serious threat to the survival of Underwater Cultural Heritage (UCH). The commercial bottom trawling industry saw rapid advancement after the implementation of steam, and later diesel, engines. This increase in power and maneuverability allowed for larger gear to be towed and in previously inaccessible areas. Fish stocks have been in decline since the peak of the commercial fishing industry in the 1970s and 1980s. However, new areas are being trawled and new fisheries are being explored at deeper depths and areas previously considered too rough to trawl.

Fisheries and marine science research has provided some useful answers to the question "How does bottom trawling affect UCH?" There has been very little archaeological research done to address this question and, therefore, it is important to utilize previous research from other fields. These studies have given insight into the depth of seafloor penetration by trawl gear, affects of trawling on the chemical composition of the benthic environment, and the power of the gear to displace or recover large boulders, and how smaller organic structures rising from the seabed are affected by the passing of a trawl net.

Studies have shown that the depth of seafloor penetration by various trawl gear varies depending upon seafloor characteristics. The softer the composition, the more penetration will occur. In the most extreme cases, trawl doors can penetrate 20cm or more into the seabed. The impact this may have upon an archaeological site will vary depending upon the site type and characteristics. Fragile artifacts such as ceramics can be broken. Wooden remains may be exposed to oxygen and marine borers. Other artifacts can become shifted and displaced. The penetration of the gear results in visible trawl scars, which may vary depending on seafloor composition. Scarring may remain present for as little as a few hours in a high energy environment, or as much as 1-2 years in a low energy environment with low sedimentation rates.

Bottom trawling can affect the chemical nature of the benthic environment by mixing, removing and suspending sediments. This disturbance can change the dissolved oxygen content, CO_2, pH, and Eh levels. These changes can affect artifact preservation rates. Studies have also shown higher rates of bioturbation after a trawl pass, which can also introduce higher oxygen levels to buried artifacts.

Many studies have focused on the removal of topographic seafloor features including epifauna and boulders. These features can be compared to artifacts of various sizes lying on top of the seafloor. In some cases, boulders weighing several tons have been shifted or recovered. In one study, 67% of epifauna such as erect sponges were reported to be missing or damaged as a result of a trawl pass. Studies of this kind suggest that trawling can either displace or recover both large and small artifacts.

There have been very few studies done to address how and to what extent bottom trawling affects UCH. In the Mid-Atlantic region Joyce Steinmetz observed a 69% disturbance rate among a 52-case sample of shipwreck sites. In the eastern Mediterranean, Michael Brennan found breakage rates of surface amphoras on ancient wrecksites to be as high as 40% after a trawl impact. In the Gulf of Mexico, archaeologists from the BOEMRE have found that every wreck found on the continental shelf in less than 100 m of water has been observed with a trawl net fouled on it. In the territorial waters of NSW, nearly every one of the roughly 260 wrecks found has been impacted by trawling. These results and statements demonstrate the clear need for further research and management efforts.

Individual instances of UCH sites impacted by trawling can be found in the literature. Nets, footropes, doors, beams, floats, and dredge frames have all been found on various wrecksites. Damages vary depending upon the type of site. Ancient wrecks have experienced varying degrees of broken artifacts as well as significant artifact removal and displacement. There have been cases where entire sites have been cleared of surface artifacts. It is unlikely that similarly affected sites will be found using modern sonar equipment. Fragile waterlogged wood will be exposed if present, and subject to attack by bacteria and marine borers. A steel or iron-hulled wreck will experience denting, scraping, twisting, bending, or shearing of the hulls and/or components. This will increase corrosion rates as fresh metal is exposed and may also create new galvanic cells as materials are shifted to come in contact with one another. Components may also be removed from the site altogether.

Inundated land sites have also been affected by trawling. A significant number of lithic and bone artifacts have been recovered in trawl nets. Due to the difficulty in locating these sites after an impact, it is not exactly known how a site is affected aside from the shifting and uncovering of artifacts. However, the artifacts fishermen recover from inundated land sites can still result in a positive situation when reported. Individual finds may increase our knowledge and raise new questions, as in the case of the *Cinmar* artifacts. Archaeologists can focus efforts on high probability regions based on these reported artifacts in conjunction with geologic and geographic data. Future studies may indicate how severe the impacts of trawling are on these types of sites.

It is evident that there exists both the possibility of future cooperation with the fishing industry and techniques to minimize the impact of bottom trawling to known UCH sites. Management and mitigation techniques include using Marine Protected Areas (MPA) for cultural resources, reburial or covering of known wrecks, and, most importantly, increased education and information exchange between involved parties. Further legislation is necessary in order to manage the threat to UCH in international waters; as it stands now, legislation has been left to individual states to protect the UCH within their respective EEZs only and to restrict vessels under their flag from causing harm to archaeological resources. Through continuing studies and a better understanding of the relationship between commercial fishing and UCH, mutually beneficial solutions can be reached to help protect and promote these irreplaceable resources.

NOMENCLATURE

ALSF	Aggregate Levy Sustainability Fund
AMS	Accelerator Mass Spectrometry
BMAPA	British Marine Aggregate Producers Association
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement
DSA	Deep Submergence Archaeology
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
GFCM	General Fisheries Commission for the Mediterranean
GIS	Geographic Information Systems
GPS	Global Positioning System
HTPE	High Tensile Polyethylene
IWCAHES	Isle of Wight County Archaeology and Historic Environment Service
LGM	Last Glacial Maximum
MALSF	Marine Aggregate Levy Sustainability Fund
MMS	Minerals Management Service
MoSS	Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites
MPA	Marine Protected Area

NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NRC	National Resource Council
NSW	New South Wales
PE	Polyethylene
RFMO	Regional Fisheries Management Organization
UCH	Underwater Cultural Heritage
UK	United Kingdom
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization

GLOSSARY

Beam Trawl. A towed net in which the mouth is held open by a beam made of wood or hollow steel (NRC 2002).

Benthic Zone. The region at the bottom of a body of water either at the sediment surface or just above (Rose et al. 2000).

Bioturbation. The mixing and displacement of sediment by burrowing organisms (Duplisea et al. 2001).

Bottom Trawling. A fishing method whereby gear is towed behind a vessel along the bottom of a body of water (Gabriel et al. 2005).

Chain Mat. A grid-like structure of steel chain hung between the trawl head and footrope of a beamtrawl. It is used to help guide the net over rough terrain and keep stones from entering (Rose et al. 2000).

Cod-End. The rear-most section of a trawl net where the catch is collected (Gabriel et al. 2005).

Demersal. Living at, or near, the bottom of a body of water. The term is also used to describe fishing gear used to target bottom-dwelling species (Collie et al. 2000).

Dragging. A common term used to describe the method of fishing whereby gear is dragged behind a vessel on the bottom of a body of water. Interchangeable with "bottom trawling" (Royal 2008).

Ecorr. The measurement of the corrosion potential of a material (North and MacLeod 1987).

Epifauna. Benthic animals that live on the surface of a substrate, including the seabed (Løkkeborg 2005).

Footrope. The lower leading edge of a beamtrawl or otter trawl net. The footrope may be chain, steel cable, or fiber and is often wrapped in a protective material and can be fitted with varying types of rollers or rockhoppers (Recht 2003).

Four Seam Net. Also known as a box net, the four seam net consists of two panels top and bottom, and two side panels. This allows for different types and sizes of materials to be used in the net construction as well as sizing adjustment (NRC 2002).

Galvanic Cell. Formed when two metals are connected by an electrolyte resulting in an electrochemical reaction. In the underwater environment, saltwater is the electrolyte (North and MacLeod 1987).

Groundrope. See "footrope".

Guyot. A volcano formed on the seabed that once rose above sea level and was eroded to below the surface. Guyots are characterized by flat tops (Clark et al. 2011).

Hydraulic Dredge. A metal framed dredge that employs water jets along the leading edge which acts to liquefy the sediment and loosen the target species from the seabed (NRC 2002).

Macrofauna. Organisms smaller than megafauna but larger than .03mm (Løkkeborg 2005).

Megafauna. Organisms larger than 5mm (Løkkeborg 2005).

Net Dump. The resulting dispersal of the contents of a trawl net after coming in contact with an obstruction (Royal 2008).

Otter Doors. Square or rectangular-shaped wood or steel boards hung between a trawl net and warp which turn obliquely while being towed creating hydrodynamic force which holds the mouth of a net open (Recht 2003).

Otter Trawl. A trawl net held open by doors as opposed to a rigid beam (NRC 2002).

Pelagic. The area of a body of water between the surface and the benthic region. Also referred to as mid-water (Enticknap 2002).

Rapido Trawl. A modified beam trawl with a rigid mouth that employs metal teeth along the lower leading edge which penetrate sandy substrates to stir-up flat fish. These trawls are typically towed at a higher than average rate of speed and are common in the northern Adriatic Sea (Pranovi et al. 2000).

Rockhopper. Large molded rubber or steel discs or balls attached along the groundrope to allow the net to move over rough ground without damage (Recht 2003).

Seamount. A mountain rising from the seafloor that does not break the water's surface (Clark et al. 2011).

Spoil Heap. The accumulated sediment associated with the furrows made by trawl doors (Smith et al. 2003).

Tickler Chains. Chains strung in front of the groundrope that stir up the target species from the seabed (Sainsbury 1996).

Trawl Scar. The furrow left by the passing of a trawl door through the sediment (Smith et al. 2007).

Trawl Head. The iron supports that hold up the beam of a beam trawl. These are usually fitted with shoes to inhibit wear from contact with the seafloor (Sainsbury 1996).

Two Seam Net. A trawl net consisting of only a top and bottom panel (NRC 2002).

Underwater Cultural Heritage. As defined by the UN: Underwater Cultural Heritage encompasses all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years.

Waterwear. The result of water acting to erode and polish the surface of an artifact over a prolonged period of time. Usually associated with lithic materials (Crock et al. 1993).

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APPENDIX

TABLE A-1
RECORDED INSTANCES OF SHIPWRECK SITES IMPACTED BY BOTTOM TRAWLING

Name	Date/Era	Depth (m)	Location	Impact	Source
Knidos C	Byzantine	435	Turkey	Trawl scar through site, broken amphoras	Brennan et al. 2011
Knidos J	Roman	410	Turkey	Trawl scar through site, broken amphoras	Brennan et al. 2011
M24 Sub	1942	54	North of Sydney Harbor	Fouled nets, conning tower torn free, accelerated corrosion	Smith 2008
AE2 Sub	1915	73	Sea of Marmara	Fouled nets, dented hull, sprung plates	Smith 2000
TK06-AC	2nd century B.C.	91	Bodrum, Turkey	Broken amphoras, intrusive artifacts, loose rock overburden	Royal 2008
El Nuevo Constante	1766	91	Gulf of Mexico	Snagged net, recovered artifacts	Pearson and Hoffman 1995
Virginia	1941	87	Gulf of Mexico	Multiple fouled nets	Church et al. 2009
Halo	1920	133	Gulf of Mexico	Multiple fouled nets	Church et al. 2009
S.S. *Castine*	1892	32	Gulf of Mexico	Multiple fouled nets, intrusive artifacts	Enright et al. 2006
Josephine	1867	11.6	Gulf of Mexico	Fouled net	Irion and Ball 2001
U.S.S. *Hatteras*	1861	17.6	Gulf of Mexico	Snagged net, engine components shifted	Arnold and Anuskiewicz 1995
El Cazadore	1784	91+	Gulf of Mexico	Snagged net, recovered artifacts	Vorus 1997
Marquesas Wreck	Late 18th c.	-	Florida Keys	Snagged net, recovered artifacts	Vorus 1997

TABLE A-1 CONTINUED

Name	Date/Era	Depth (m)	Location	Impact	Source
Desaru	19th c.	-	Malaysia	Snagged net, artifacts recovered, shaved flat	Sjostrand 2003
Levanzo I	4th c.	90+	Sicily	Est. 90 percent of the artifacts removed	Royal 2009
Lonquan	15th c.	-	Malaysia	Shaved flat	Flecker 2002
Singtai	16th c.	-	Malaysia	Unspecified	Flecker 2002
Ko Si Chang	16th c.	31	Thailand	Fouled nets, broken pottery, survey markers removed	Green 1986
U.S.S. *Monitor*	1862	72	North Carolina	Fouled nets	NOAA 2008a
Paul Palmer	1902	26	Massachusetts	Fouled nets and cables	NOAA 2008b
U.S.S. *Moonstone*	1929	40	New Jersey	Deck gun torn free	Barnette 2008
SS *Hispania*	1912	26	Scotland	Hull scrapes, accelerated corrosion, downed mast	Robertson et al. 2007
U714	1942	57	Scotland	Entire otter trawl fouled	Baird 2009
Lady Darling	1864	30	NSW, AU	Snagged net, iron plates recovered	Smith and Nutley 1998
Isis	1892	10	Victoria, AU	Deck winch and bollard torn free, boiler shifted	Derksen and Venturoni 2011
Mercure	1806	18	Italy	Fouled nets and cables, carronade recovered, artifacts shifted	Beltrame and Gaddi 2002
Eric Nordevall	1837	45	Lake Vättern, Sweden	Repeatedly fouled nets and cables, shifted components	Cederlund 2004

TABLE A-2
INDIVIDUAL ARTIFACT FINDS RECOVERED BY TRAWL FISHERMEN

Artifact	Date/Era	Depth (m)	Location	Source
Slate knife	Middle Archaic	35-51	P.E.I., Canada	Keenlyside 1983
Stone gouge	Middle Archaic	38	New Brunswick, Canada	Black 1996
Stone gouge	-	15.8-17.6	Maine	Price and Spiess 2007
Adze	-	15.8-17.6	Maine	Price and Spiess 2007
Biface	Early-Middle Archaic	43-46	Maine	Crock et al. 1993
Biface	-	40-44	Maine	Crock et al. 1993
Biface	-	60	Maine	Crock et al. 1993
Plummet	Archaic	15	Maine	Crock et al. 1993
Slate knife, biface preform, adze	Middle-Late Archaic	7.6	Maine	Stright 1990
Articulated projectile point, bison femur	Paleoindian	9	Rhode Island	Stright 1990
Blade	Late Archaic	-	Louisiana	David Palmer 2011, elec. comm.
Biface	Undetermined	70	Virginia	Dennis Stanford 2011, elec. comm.
Structure	2930-2610 cal. B.C.	-	Isle of Wight, U.K.	IWCAHES 2011; Flatman and Blue 1998
Structure (post alignment)	Saxon	-	Isle of Wight	IWCAHES 2008
Dugout canoe	Saxon (A.D. 775-892)	-	Suffolk, U.K.	Flatman and Blue 1998
Ship timber	18th-19th c.	-	Suffolk, U.K.	Flatman and Blue 1998
Keel section	-	-	Southern North Sea	Nœvestad 2006
Barbed point	11,600 B.C.	36	Southern North Sea	Ward and Larcombe 2008
Nehalennia altar stones	Roman	-	Netherlands	Louwe Kooijmans 1971

VITA

Name: Christopher Michael Atkinson

Address: Nautical Archaeology Program
Department of Anthropology
Texas A&M University
College Station, TX 77843-4352 USA

Email Address: cm_atkinson@hotmail.com

Education: B.A., Anthropology, Drexel University, 2005