CHAPTER 15

Side Scan Sonar and the Management of Underwater Cultural Heritage

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Introduction

This chapter deals with side scan sonar, not because I believe it is superior to other available technologies but rather because it is the tool that I have used in the context of a number of offshore surveys. It is therefore opportune to share an approach that I have developed and utilised in a number of projects around the Mediterranean. These projects were conceptualised together with local partners that had a wealth of local experience in the countries of operation. Over time it became clear that before starting to plan a project it is always important to ask oneself the obvious question – but one that is often overlooked: "what is it that we are setting out to achieve"? All too often, researchers and scientists approach a potential research project with blinkers. Such an approach may prove to be a hindrance to cross-fertilisation of ideas as well as to inter-disciplinary cooperation.

Therefore, the aforementioned question should be followed up by a second query: "*and who else can benefit from this project*?" Beneficiaries may vary from individual researchers of the same field such as archaeologists interested in other more clearly defined historic periods (World War II, Early Modern shipping etc) to other researchers who may be interested in specific studies (African amphora production for example). Finally there may also be researchers from other disciplines such as marine biology, marine geology and volcanology. From the same data sets gathered by marine archaeologists such scientists can study and consider a variety of interests which may including, but not limited to, habitat mapping, seabed classification and the identification of submerged volcanic vents.

Answers to such questions may not be immediately forthcoming but it is essential to keep potential collaborations in mind when planning methodologies. In the light of this it would be opportune to explore the resolutions and other desiderata that fellow marine scientists require when planning their surveys. Although it may prove impossible to match their exact parameters it could well be that some small compromises are made in order to accommodate these requirements. Given that the expenses related to offshore survey are very elevated, it is hardly conceivable that the data acquired with adapted parameters will be refused by fellow marine scientists. Such a practice does not only make economic sense but is also good scientific etiquette. Such selfless cooperation may lead to scientific reciprocation with data eventually flowing both ways.

The use of Side Scan Sonar in the Field of Underwater Cultural Heritage

In the field of maritime archaeology, side scan technology can be employed for a number of objectives, namely:

1) The survey of a known shipwreck

A shipwreck may have been discovered through other means (such as the snagging of fishing nets, by sponge divers etc.) other than archaeological survey. Modern wrecks are often charted by hydrographic vessels and their position noted on published navigational charts. In the case of such sites, side scan sonar can be used to establish the overall current condition. Following an initial survey that will be used as a baseline study, subsequent surveys will be used to determine aspects such as site degradation, scouring and site integrity.

2) The search for and location of an important event

The sea has witnessed numerous naval battles that range in size from battles between individual vessels to epic proportions. Some of the latter include Actium and Lepanto (Abulafia 2011: 428-451). Side scan sonar can prove invaluable to discover and record traces of such battles especially when the bulk of the objects being sought are small and dispersed. Such objects may include bronze rams (from ancient war galleys) and canon from the Early Modern period. To date, except for the so-called Marsala Punic Warship, no other warship has been detected from ancient times (Frost et al. 1976). This because the ancient trireme was more likely to break up and fragment into smaller pieces rather than sink in its entirety.

3) The search for and location of an important shipwreck (after research in archives)

In more recent times, the loss of a vessel was often recorded. Such records could be produced by, amongst others, survivors, court cases and even insurance companies. Numerous archives throughout the world house countless such accounts. Researchers often resort to archival research in order to learn of the location of a specific shipwreck. Such records hardly ever contain precise coordinates due to a number of reasons. They do however give a general area within which one may plan a survey in order to search for the vessel.

4) Broad or "blind" survey

This method can be compared to field-working in terrestrial archaeology whereby archaeologists walk along pre-determined transects to record and collect archaeological material. In the case of offshore remote sensing, the sonar is towed along pre-determined survey lines and data gathered systematically. The digital side scan systems enable the creation of mosaics with total coverage of the area of study. This enables the production of an archaeological map with essential information on the cultural remains recorded that are fully geo-referenced. Such broad surveys enable the coverage of large tracts of seabed.

Implications

Given that the 'broad survey' covers such large tracts of seabed in deep (beyond 60 meters depth) it is more than likely that such areas are unexplored by humans. This differs to the early days of underwater archaeology when the first discoveries of ancient shipwrecks were made by early divers such as those collecting sponges and corals. George Bass cited these as "the most important contributors of knowledge to the underwater archaeologist" (Bass 1966: 49). The advent of sport diving in the 1950s led to a massive increase of underwater sites being discovered and – more often than not – being looted. The evolution of the diving archaeologist saw the emphasis on singular site excavations such as Albenga (Lamboglia 1952). This approach was retained as the main thrust of many a research agenda for a number of decades. Today, in the northern Mediterranean at least, one can safely say that the majority of sites situated below the 50 meter contour (and that are not covered by silt, sand, *Posidonia Oceanica* etc.) have to some extent or another been discovered. In the southern Mediterranean, the situation differs due to the slow pace with which SCUBA diving has spread in the region.

This leads me to what I refer to as the 'new frontier'. Thus, at this point, it is relevant to ask what if 60 years ago, a young archaeologist suggested to a pioneer of SCUBA diving that within their lifetime SCUBA diving would become a widespread hobby practised by millions all over the world? My assumption is that the diver would not have believed such a situation possible. Today, the archaeological community is in the same position as the aforementioned fictitious archaeologist with the pertinent question to ask today being: "will diving down to 120 meters become widespread within our lifetime?" Courses in technical diving have become widespread and the cost of equipment is plummeting. Based on the increasing numbers of technical divers and the proliferation of new and safer technical equipment, diving to 100 meters, will over the next 20 years, almost certainly become increasingly popular and doable for a significantly larger part of the population (than it is today).

With this in mind it is essential to consider that with regard to undiscovered shipwrecks beyond 50 meters the archaeological community finds itself very much in the same situation as underwater archaeologists did 50 years ago. If no proactive measures are taken it will be technical divers who will be reaching undiscovered sites.

There are a number of advantages that today's underwater archaeologist have over their predecessors:

- Thanks to the pioneers of underwater archaeology, techniques for excavation and conservation are not only fully developed and established but they are also accepted among the broader archaeological community (Bowens, A. 2008).
- International conventions and local legislations exist and provide a broader framework within which one may work on sites as well as manage and protect these same sites.
- The availability of technologies for the study of sites situated at great depths (Søreide 2011: 9-22).
- Most important of all: the archaeological community now has the benefit of hindsight – mistakes can be learnt from and avoided. Today's archaeologists can continue to build on the valuable work of the pioneers.

Remote Sensing to the Rescue

Given the financial crisis that has hit the world's economy sine 2008, resources for culture and heritage are very limited. Furthermore, our knowledge of ancient shipbuilding techniques, amphora studies and site formation processes are at a satisfactory point. The pressures of excavation and recovery on the limited resources available to authorities are perceptible throughout the Mediterranean and beyond. Stores and warehouses are literally bursting at the seams with pottery fragments, lead anchors, whole amphorae and other miscellaneous pieces. The modern-day costs of excavation, and more importantly, conservation and preservation make these activities very hard to undertake in today's economic reality. It is harder and harder to justify full blown underwater excavations when jobs in the heritage sector are being lost and objects from excavations increase pressure on the abovementioned reserve collections and their curators.

Furthermore, the UNESCO convention on underwater cultural heritage clearly declares that the first option with submerged archaeological sites is 'preservation in-situ'.

However, how can one start planning the in-situ management of underwater cultural heritage in waters where we know little if anything at all? The answer lies in the abovementioned broad/blind survey. Before moving on to the methodologies and concepts involved in broad surveys it is important to highlight the cost effectiveness of this work. With a relatively limited budget one may organise and conduct a 5 day survey and cover a large area of approximately 20 square kilometres. These parameters are, of course, dependant on variables such as weather conditions, power of winch and choice of line spacing and overlap.

When planning a broad/blind survey a major choice that needs to be made is to determine where to work. This decision can be influenced by a number of factors such as whether a site that is threatened by construction or dredging (this should however be financed by the developer); in the case of a unit such as a local heritage authority the area can form part of a systematic coverage of the seabed within its area of jurisdiction.

If no such factors bear any influence then one must consider theoretical areas that I refer to as 'zones of convergence'. To expand on this notion – the majority of a ship's journey is carried out on the open sea. However, there are certain points along the journey where vessels will have to converge into a narrower more restricted area. Examples of such zones are the following:

- Offshore islands – vessels converge on these to use them as temporary anchorages or simply as waypoints (Figure 1);

Figure 1: The island of Stromboli - a well known and used waypoint in antiquity

Source: T. Gambin

- Harbours – vessels would have to approach the harbour mouth in order to complete their journey;
- Channels/Straits – vessels would make for these to avoid longer journeys;
- Other areas of navigational importance such as large headlands.

Many of the abovementioned examples are synonymous with dangers to navigation (Morton 2001: 185-93). It is true that offshore islands offered havens but they could also prove to be fatal for ships as such islands had dangerous reefs etc. in their surrounding waters (Gambin 2012). Channels, straits and headlands are often known for their particular winds, wave and current patterns that produce unpredictable sea conditions in very localised areas – conditions that even today are very hard to forecast. However, such conditions did not deter mariners from taking the calculated risk of shortening voyages by sailing in the vicinity of these features.

Such zones of convergence provide a mathematically higher probability of locating shipwrecks – if nothing else, this statement is made on the assumption that more ships navigating in these areas (which are in turn more treacherous than normal) leads to a higher possibility for the loss of vessels. Therefore, if no specific area has been selected for the survey it may be opportune to keep such locations in mind when considering where to work.

Once such an area has been located then it is imperative to ask another set of questions. These are more site-specific:

- Have archaeological remains been brought up from the area from waters up to 50 meters deep? The local partner or even a quick visit to the local museum will soon answer this question. Local divers and fishermen may also provide a lot information - albeit a little sketchy. If objects have been located in shallower waters there is a higher probability factor of finding objects in deeper waters. What caused vessels to be lost in shallow waters may have also caused them to sink in deeper waters.
- Are there dangers to shipping present in the area? Reefs, low-lying rocks, peculiar weather patterns, headlands etc. What constitutes a danger to shipping today would have been more so in the pre-modern era when pilots and mariners depended on their own knowledge and did not possess charts and other modern navigational aids. (Figure 2).
- Was the area important to ancient maritime routes? Here, it is safe to assume that if the area of survey lies within a heavily used maritime route then vessels would have travelled in the zone in great numbers. This subsequently increases the chances for the presence of shipwrecks.
- Is/was trawling practiced in the area? Trawling is a serious threat to underwater cultural heritage however not all trawled areas are devoid of underwater sites.
- Is seabed topography conducive to available equipment? Towed systems - such a side scan sonar - are more conducive to being utilised in areas where the seabed is relatively flat. A very important factor is sediment deposition. There are areas (such as river mouths) where sediment deposition is so frequent and heavy that anything over 100 years old (or even less) is probably buried deep in the mud or sand.
- Has a similar survey been carried out? After highlighting the economic crisis affecting the heritage sector, it would be a waste of resources should valid work be replicated.

Thus it is critical to check whether data for that area is available from other sources. These may include but are not limited to: surveys carried out for marine reserves, habitat mapping and/or hydrographic survey.

Figure 2: A typical offshore rock that poses a danger to shipping

Source: T. Gambin

Once all of the above considerations are taken into account then the more complete the background research should become. However, one must keep in mind that there are never any guarantees with regard to such queries. For example, trawling may be prohibited in the area of survey but it may have been practised anyway.

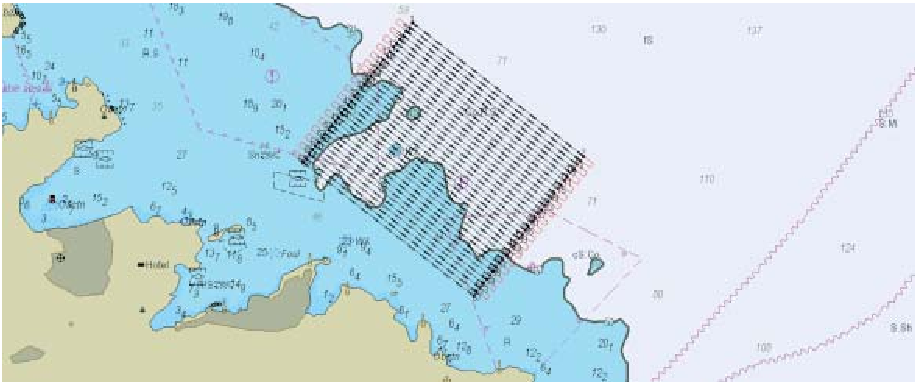
Proposed Methodology

The survey equipment used for the suggested methodology should preferably consist of a dual frequency fully digitised side scan sonar system with medium (circa 400KHz) and high (circa 900KHz) frequencies available. The tow fish will be towed by a purpose-built survey vessel or any other vessel that can take the necessary equipment on board and that is capable of keeping in a straight course. Such a vessel should have the least windage possible. This will reduce the effect of the winds and the waves on the vessel, thus making navigation steadier. The ideal speed for a small survey vessel should be of around 3 knots. Another essential consideration is that of the time required to turn the vessel in order to bring it onto the next survey line. Great caution must be given during this manoeuvre so as to ensure that the tow fish does not dive suddenly and plunge into the seabed. Such an operation takes time, and thus must be kept in mind when planning the duration of the planned project.

The side scan sonar system will be interfaced to a precision GPS which will ensure that all data captured during the survey will be geo-referenced. All navigation and survey line setup and control will be handled by the native software of the sonar system. Tow fish and target positioning will be done using a layback algorithm embedded in the system's software.

The proposed methodology is divided into two phases. Phase one will consist of a long range high altitude survey using the medium frequency setting on the sonar (circa 400 KHz). This will facilitate the quick coverage of the entire area. The foremost aim of this phase is to create a mosaic map of survey area with details of seabed topography and geology. Line spacing for this phase should be set at 160 meters and the the sonar set at a 100 meter range giving a swath coverage of 200 meters (Figure 3). This setting will provide ample overlap for the stitching of the mosaic. This approach, which includes the gathering of initial bottom intelligence, will greatly reduce the risk of hitting seafloor obstructions and will ensure the acquisition of optimal data. It is envisaged that some of the survey methodology for the second phase will need to be modified and tuned further after the completion of phase one.

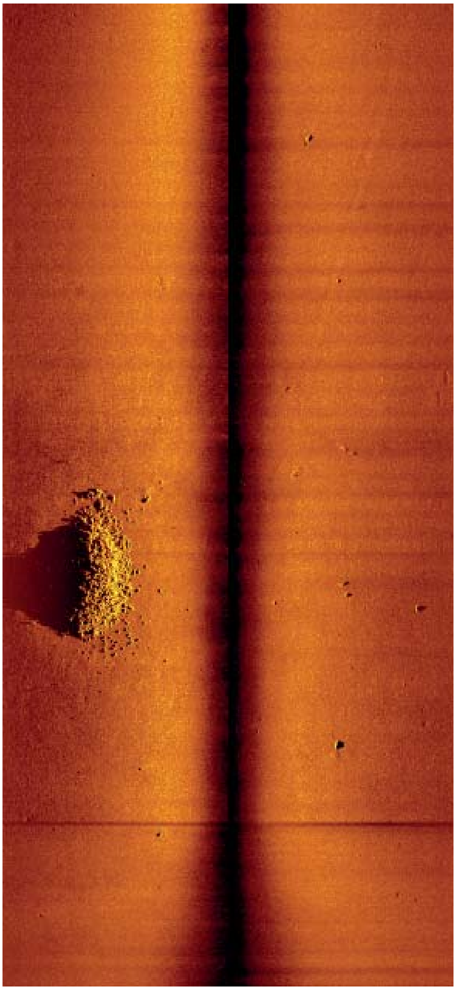
Figure 3: Line spacing for an archaeological survey using side scan sonar



Source: T. Gambin

In phase 2, the tow fish will be 'flown' much closer to the bottom on short range and high frequency (circa 900 KHz) so as to obtain higher resolution sonar data of targets identified in phase one. Given that initial sonar data will give the operator a clear idea of the target height and of the surrounding topography such an operation can, if planned and executed meticulously, be completed with minimal risk. There are two ways of running survey lines for this part of the survey and these are not mutually exclusive. A pre-determined line can provide guidance as to the line that the vessel and sonar must move. Alternatively, the operator can give instructions to the skipper as to the direction and location of the singular survey route. During this phase it is essential to obtain sonar data of the target with the tow fish running parallel to the target. Such an approach will facilitate the acquisition of data necessary for target recognition and measurement (Figure 4).

Figure 4: A 900Khz sonar image of an amphora shipwreck



Source: Ministero dei Beni Culturali/T. Gambin

Once all the data are collected from both phases these will be processed into a mosaic and subsequently saved as a high resolution geo-tiff so the data can be used in GIS processing software (Figure 5). Maps will also be saved in formats that are conducive to the use of other software suites including CAD. An analysis of all bottom targets will follow and this should include a comprehensive target report showing target images, exact locations and measurements. The latter will consist of target length, with and approximate height. A report with high-resolution sonar imagery will contribute to any subsequent ground-truthing that may be planned - be this with a remote operated vehicle and/or through the use of technical divers. The aforementioned post-processing can be done using software suites that are specifically designed for this purpose. These software suites generally create sub-folders that contain data in formats that are compatible to various GIS software.

Figure 5: Sonar mosaic projected in 3D using Google Earth

Source: T. Gambin/G. Kozak

Concluding Remarks

Once deliverables become available, local authorities find themselves in a better position to take more informed decisions that will affect the long-term protection and management of the sites discovered in the context of the survey.

Some of examples of such hypothetical situations:

1. Sites situated in areas that are heavily trawled can be protected by a series of blocks and/or artificial reefs. The creation of artificial reefs will also benefit the fishermen who will continue to trawl areas around the newly protected archaeological site thus proving beneficial to the fishing community (Figure 6);

Figure 6: A whole amphora amongst ceramic fragments from a site that was heavily damaged by fishing implements

Source: Soprintendenza del Mare/T. Gambin

2. Sites in anchoring areas can be cordoned off in no-anchoring areas. In general, large anchoring zones - or so-called bunkering areas - are well delineated on modern nautical charts. Large commercial vessels that tend to utilise such areas are bound to keep updated copies (hard or digital) of these charts. Therefore, once a site is designated as protected a notice of the new 'no-anchoring' zone can be quickly circulated amongst the maritime community;
3. Underwater cameras may be placed on sites via a buoy. To date, one such initiative has been undertaken. This was implemented by the Soprintendenza del Mare at Cala Gadir in Pantelleria at a depth of approximately 30 meters;
4. Wrecks may be opened up as controlled diving sites. This is especially feasible for large shipwrecks such as warships. This is due to the lower quantity of moveable objects that these contain when compared to, for example, an amphora wreck.

However, many of the above considerations may also place the site at risk by bringing it to the attention of rogue divers/looters. But, whatever the risks involved there can be little doubt that using such technologies for the discovery and management of underwater sites puts heritage authorities in a much better position than they were prior to acquiring this knowledge.

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