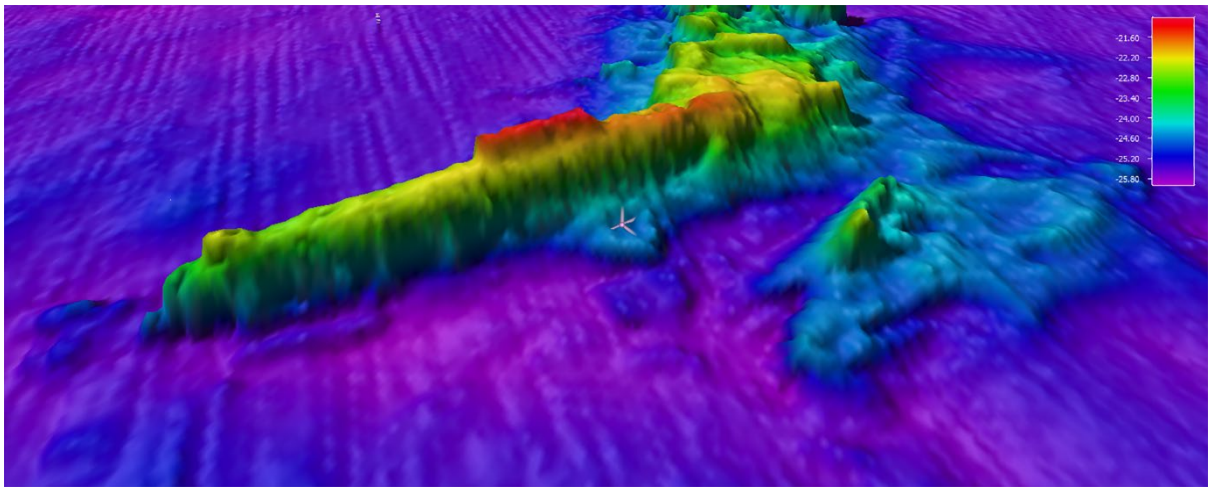
Historic England's First World War Submarine Wreck Project

Approaches to submarine wreck investigations



Summary

This document, published by Historic England – the Government's advisor on the historic environment in England – provides examples of how to investigate a First World War submarine wreck. It is aimed at people interested in planning or undertaking an investigation, to understand what is likely to be important about that wreck, what from an archaeological perspective should be recorded and how that can be achieved. This document also provides advice on assessing condition and risk as well as importance.

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Front cover

Multibeam image of the wreck of UB-107, off Flamborough Head

Contents

Introduction

Submarines are some of the most iconic shipwrecks of the First World War. Used by both Britain and Germany, they had a profound impact on the war. Many were sunk and their wrecks are an important part of England's maritime heritage.

Historic England, as the Government's principal advisor on the historic environment, undertook a four-year project spanning the 1914-1918 Centenary to precisely locate and better understand the wrecks of German U-Boats and British submarines that sank within territorial waters up to 12 miles off the coast of England during the First World War.

As part of this project, Cotswold Archaeology was commissioned to undertake a desk-based Strategic Assessment of submarine wrecks that aimed to inform future policy towards their designation by identifying the best examples. That was followed on by more detailed investigation of some of these examples, by specialist staff from Wessex Archaeology and the avocational divers they worked with.

The lessons learned from that project are captured in this document, which aims to help anyone carrying out an investigation of a First World War submarine wreck to understand what is likely to be important about that wreck, what from an archaeological perspective should be recorded, and how that can be achieved. It also provides recommendations about assessing condition and risk, as well as importance. The recommendations have been drawn from project experience, as well as from other studies of submarines that were lost both before and shortly after the war. It is not intended as formal guidance, but rather provides examples for consideration.

This document is intended to be very practical and primarily for the use of avocational archaeologists and divers, as well as professional archaeologists working with them. It is also intended to inform national and local curators, as well as archaeologists working on offshore development. The advice does not aim to be comprehensive and recognises that technical and methodological advances continue to be made. As far as possible, advice given here does not require the use of expensive technology or deep technical expertise. Other approaches are possible and may be advantageous for a particular wreck or set of circumstances.

Many wreck investigations are focused on identifying the submarine or its type. In the case of the project, all of the wrecks investigated had already been identified (although sometimes incorrectly, e.g. in the case of UC-21). Project fieldwork was therefore focused mainly on confirming identity and gathering more data to inform heritage management decisions.

Submarines have often sunk without the crew being able to escape. They are therefore widely regarded as 'war graves', due to the potential for human remains to be found inside them. The First World War still has great public resonance, so whilst the investigation of submerged archaeology should always be approached from an ethical perspective, it is particularly important in the case of submarines.

If you wish to learn more about the approach of the project to submarine wreck investigation, then a downloadable appendix to this document has been produced which contains more case studies and more detail about some of the matters discussed here, such as condition and risk assessment.

What is a Submarine?

A submarine is any vessel able to navigate totally submerged. Submarines were developed as warships and were essentially torpedo boats that could submerge.

All submarines have the following characteristics. As they are therefore fundamental features of all submarines, searching for, examining and recording them is likely to be regarded as a priority task for any investigation:

- a watertight hull that accommodates the crew and any equipment not designed to be exposed to the water, strong enough to withstand the water pressure when submerged (the 'pressure hull');
- tanks that can be filled or emptied, enabling the displacement of the vessel to be varied to allow it to submerge and surface;
- a propulsion system that can be operated when the vessel is submerged;
- horizontal rudders that enable the submarine to steer down and up ('hydroplanes'); and
- a means of making visual observations on the surface when submerged ('periscopes').

Aft loading hatch of the UB-78. The angle of the hatch relative to the top of the pressure hull indicates that it is for loading torpedoes.

Classifying Submarines

Why is it important to classify submarines?

Whether you are comparing Roman pottery or First World War submarine wrecks, adopting a logical and consistent means of categorising objects and their different characteristics is a cornerstone of archaeological methodology that allows for consistent comparisons to be made. In terms of submarines, one of its most important uses is in identification based upon comparing observed design features, such as length, number of torpedo tubes and type of deck gun, with known features of different types of submarines.

Consistency is important because it allows for comparisons to be made between submarine wrecks. It also enhances confidence that they have been correctly identified. The following are widely accepted means of classifying submarines. They can help describe what has been found, even if the individual submarine has not been identified.

Ways to classify submarines

Submarine or submersible?

There were two schools of thought involved in early submarine development leading up to the First World War. The first advocated what might be called a 'submersible', a torpedo boat that was able to submerge to carry out an attack but which was designed primarily for operations on the surface, emphasising sea keeping, surface speed and habitability. The second school of thought was for what might be called a 'true submarine', a torpedo boat designed primarily for submerged operation. Both types had different design characteristics and both served in the war.

Propulsion types

Very early submarines used a single system to provide propulsion on the surface and when submerged. However, by the beginning of the 20th century surface and submerged propulsion were being separated, with electric motors being used for submerged propulsion and combustion engines for surface propulsion and to charge the batteries that the electric motors relied on for power.

Early Royal Navy submarines of the A, B and C-classes used petrol engines. The German Navy never used petrol engines. Instead, they used paraffin burning Körting engines. However, the hazards of these types meant that after diesel engines were introduced in 1902, they became the dominant engine type. Some submarines such as the British K-class fleet submarines had steam engines, but as they were very slow to dive and prone to accidents that class was not a success.

Area of Operation

Harbour defence/coastal submarines had very limited range and limited seaworthiness. They also tended to be single hull, 'true submarine' types.

Short-sea or overseas submarines – as submarines became larger, they had enough range to patrol offensively off an enemy coast. The D-class British submarines, which started to come into service in 1909, were the first British boats capable of doing this effectively. After that date most new British submarines were classed as 'overseas' boats. German classification was different and was divided between ocean-going U-types and the shorter ranged coastal UB and UC types. However, the later versions of both UB and UC boats had long range and were more than capable of operating offensively off the UK coast and much further afield. The great majority of submarines that fall into this category in English Territorial Waters are German UB and UC boats. However, there are also important British examples, including the D5.

Ocean-going submarines are a larger, very long-range submarine type, able to operate for long duration patrols in mid-ocean.

Function and classification

An anti-ship submarine is a type of submarine whose primary function is to sink surface ships by gun or torpedo attack. In English Territorial Waters the most common types of anti-ship submarine are the various German UB boats, designed to operate in coastal waters around the UK, as well as the western approaches and the Mediterranean.

Mine-laying submarines are those whose primary function is to lay mines in waters frequented by enemy warships and merchant ships, although they are also usually armed with a gun and torpedoes. Mines were normally stored and deployed through inclined tubes in the pressure hull called mine chutes in German submarines. This design feature makes mine-laying U-boats easy to identify. During the First World War, the Germans placed a heavy emphasis on mine laying in the approaches to British ports and on convoy routes. Therefore the wrecks of German minelaying submarines, UC boats, are commonly found in English Territorial Waters along the east and south coasts.

Structure or Machine?

Archaeologists tend to approach the survey of wreck sites as being equivalent to built structures, and as a result survey and map them spatially. There tends to be an emphasis on the hull, bulkheads, decks and compartments, which are often the most prominent surviving features. This is a pragmatic approach, but submarines are complicated machines that can only be partially understood this way.

An alternative approach is to treat a submarine wreck as a machine comprised of a number of different interacting systems and to survey each system. This approach is more complicated, demands more of the investigator and can be frustrating if the evidence for each system lies within the pressure hull and is inaccessible. Nevertheless, it promotes a better understanding of the submarine. Therefore the recommended approach to survey is – where possible - to record them system by system as well as a structure.

The main systems that a submarine is commonly broken down into are discussed in the separate appendix. However, in general they comprise: the propulsion system; tank blowing and venting system; HP air system; hydraulic (telemotor system); auxiliary machinery and equipment; weapons systems; steering gear and control systems; and sensors.

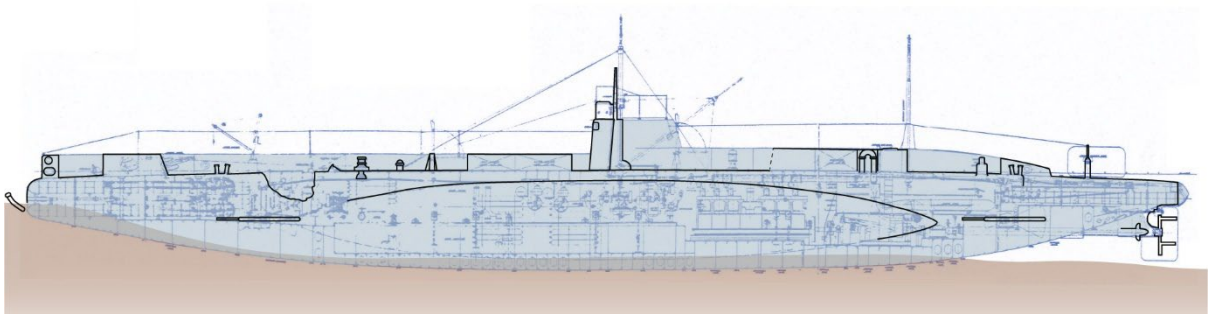


Diagram showing the layout of the wreck of the British submarine D1 on the seabed

Descriptive Systems for Reporting Submarine Wrecks

Descriptive systems are simply how the results of a submarine wreck investigation are organised and presented. A wide range of systems have been developed and implemented, including:

- a 'wreck tour' describing what divers will see when they dive a wreck (as often used by dive magazines and other publications);
- a description of the wreck drawn from a plan of the submarine wreck (for example see McCartney 2015);
- Watson and Gale's 1990 'Site Evaluation for Marine Sites and Monuments' used to describe shipwreck sites;
- BULSI – Wessex Archaeology's system used to develop a 'biography' of the wreck looking at **B**uild, **U**se, **L**oss, **S**urvival and **I**nvestigation

More detail about these systems and how they can be applied and why to use them can be found in the appendix.

Researching a Submarine Wreck – Sources

It is not possible within this document to provide a comprehensive guide to the resources available for researching a First World War submarine wreck. However, the following advice can be given as a starting point.

Look into readily available online sources, such as Historic England's Heritage Gateway and Wrecksite. These provide summaries and information about where to find other sources.

Some other sources to consider include YouTube – for historic and diver footage. Published dive guides can also provide valuable information about individual wreck sites, while other studies of submarines can also be invaluable (see for example Young 2006 and 2009; McCartney 2002; and Termote 2017). Comparing recent descriptions or videos with older ones can also provide insight into how a wreck site is changing over time.

Historic context for wreck sites can be gleaned from other sources (such as McCartney 2015; Firth 2021).

There is no shortage of information about British submarines, and a great overview can be found in Akermann 1989. There are also extensive archives available, for example at the Royal Navy Submarine Museum, National Archives, Imperial War Museum, National Maritime Museum and the Naval Historical Branch.

For German submarines, a great place to start is the uboat.net website. Other sources include Rössler 2001 and Termote 2017. In addition to the archives mentioned above, the Deutsches U-Boot-Museum in Cuxhaven, Germany holds an expanding archive. U-boat plans can be found on specialist websites such as The Virtual Dockyard.

Inspecting and Surveying a Submarine Wreck

Geophysics

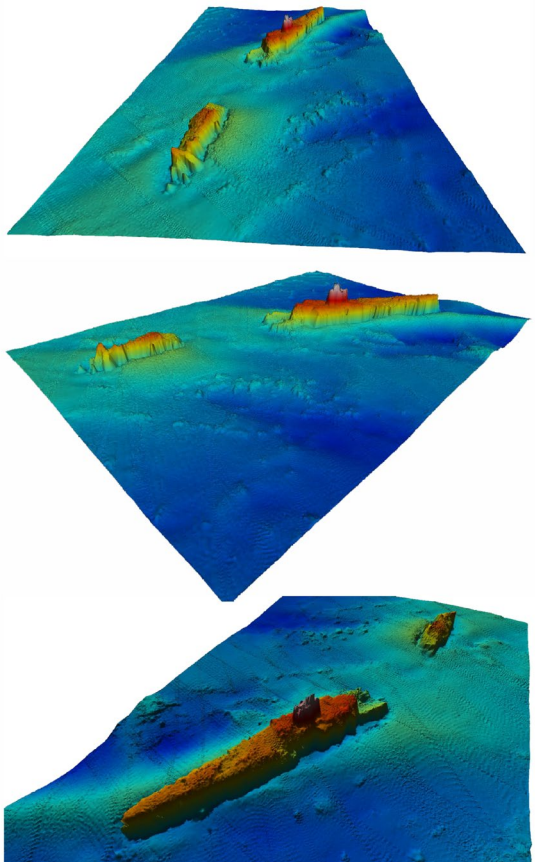
Geophysical survey data was an essential tool of the First World War Submarines project. Submarine wrecks are normally easy to detect because they have a very distinctive shape. Additionally, archaeological assessment of geophysical survey data can search large areas of seabed, produce a reliable position and dimensions, map debris around the hull, provide an initial plan of the wreck to prioritise fieldwork objectives, as well as provide an understanding of how natural processes such as scour are affecting a wreck.

More information about how the project used geophysical survey data can be found in the appendix.

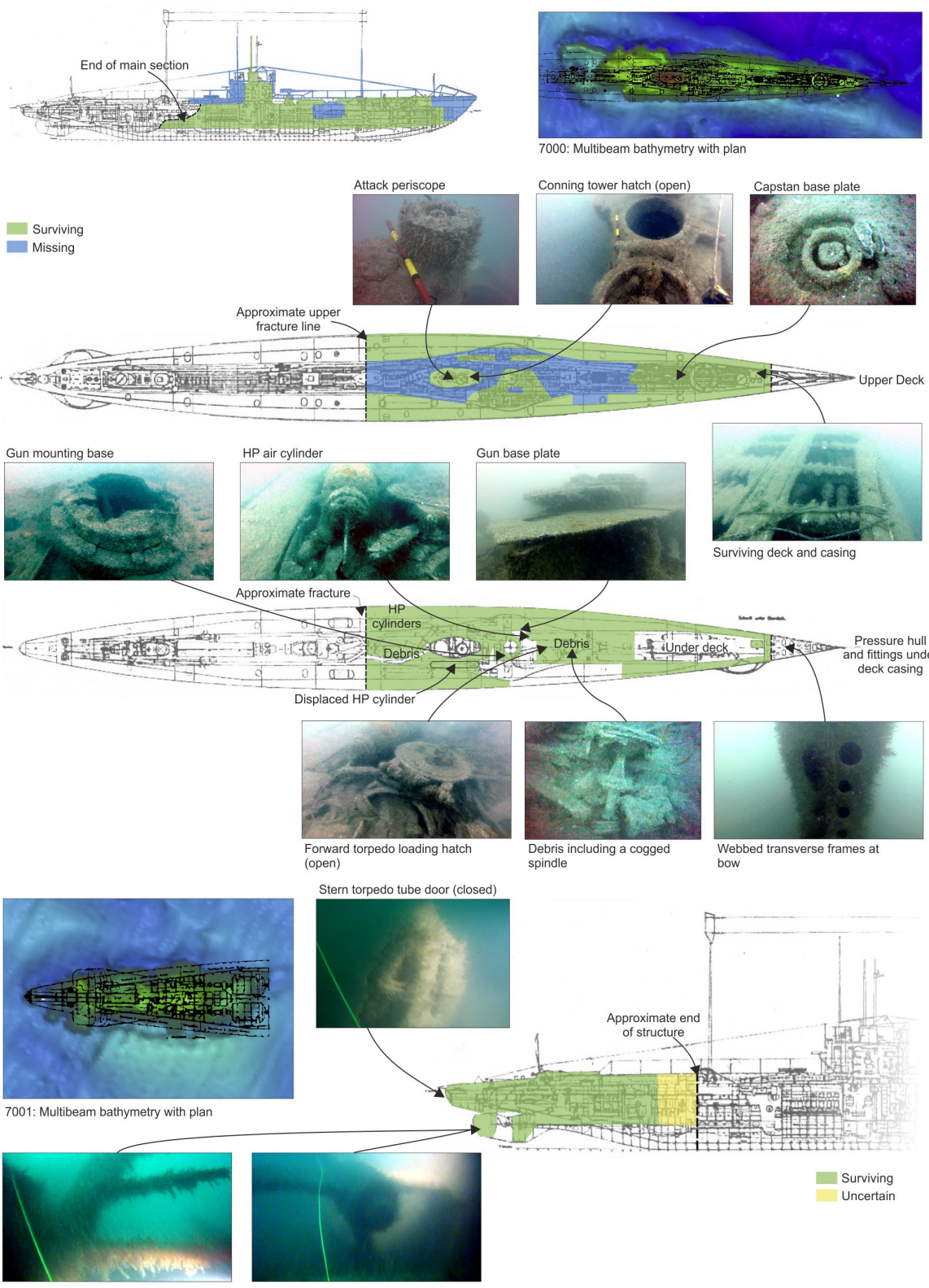
Combining geophysical data, archival plans and diver video can be used to create a description of submarine wrecks.

In 2014, Historic England asked Wessex Archaeology to carry out an archaeological survey of the wreck of UB-109, a well-known dive site off Folkestone, Kent. By collating published and unpublished diver descriptions and looking at records of the wreck held by the National Record of the Historic Environment and the UK Hydrographic Office, it was established that the wreck was in two sections, having been blown in two by a mine.

To map such a large site on the seabed using diver measurements would have been too time consuming, and the wreck's depth at 21-23 m meant that dive times were particularly limited. However, a geophysical survey overtaken over the wreck site established the size of the site, its orientation and the distance between sections.



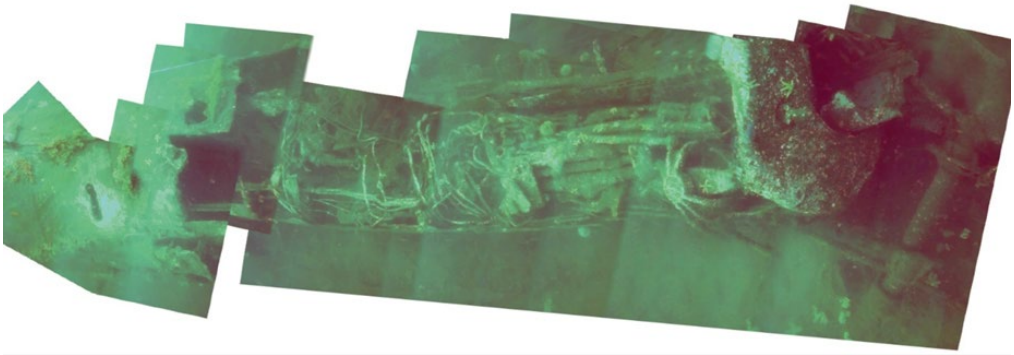
Using the geophysical data and an archival plan of the wreck site, dives could then be planned to maximise results. Wessex Archaeology worked closely with local dive clubs Folkestone 501 and Canterbury Divers to concentrate on significant wreck features.



Deciding on Priorities

A submarine wreck is a large and complex object that will take considerable time and effort to fully record. It is therefore recommended that the recording of key features should be prioritised. The following series of tables provide examples of key wreck features to record.

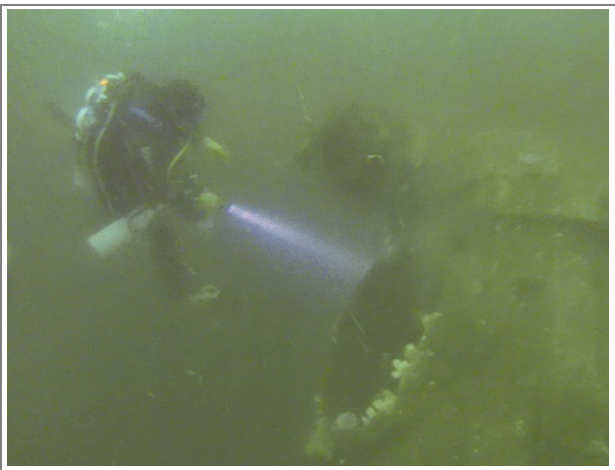
Torpedo Tubes

Question	Examples of what this can tell you
Are they there?	UC I minelayers had no torpedo tubes. However, the absence of torpedo tubes associated with extensive damage to the pressure hull at bow or stern is often an indication that they have been salvaged for their non-ferrous metal. This was observed during the investigation of UC-70.  Photomosaic produced from individual video frames showing the open pressure hull at the stern of the UC-70. This damage has been caused by the removal of the non-ferrous torpedo tube for salvage.
How many?	The number of torpedo tubes can help to identify the type. For example, UB I and II boats had two torpedo tubes but UB III boats had five. UB III boats were of a similar length to the earlier paraffin engined U-boats but had two more bow tubes. UC I boats had no torpedo armament.
Where – bow or stern?	The distribution of tubes can also help identify the boat. For example, it wasn't until the U-43 that U type boats started to be fitted with four bow tubes. UB I and UB II boats did not have a stern torpedo tube. UB III boats did. Unlike German submarines, the British incorporated broadside firing torpedoes to their larger boats beginning with the E-class.
Internal or external?	UC II and III boats were fitted with two external tubes, one either side of the mineshafts on the top of the hull, and one internal tube at the stern which overhung the rudder. The outer part of an internal torpedo tube normally protrudes from the pressure hull.
How arranged?	UC II external torpedo tubes were arranged one either side of the mineshafts, with the tube door level with the front of the pressure hull. On UC III boats these torpedo tubes were positioned further aft, either side of the bridge and pointing slightly outwards to give clearance from the hull when a torpedo was launched. UB II boats had their bow torpedo tubes mounted one above the other on the centreline. The smaller paraffin burning U-boats also had two bow tubes, but these were mounted side by side. British D-class submarines had a similar 'over-under' arrangement to the UB IIs. If the bow and stern are undamaged and there are no torpedo tubes, this is an indication that the tubes were mounted externally.  Image taken from video of the port side internal 18 in torpedo tube of the B2, a single-hulled boat.

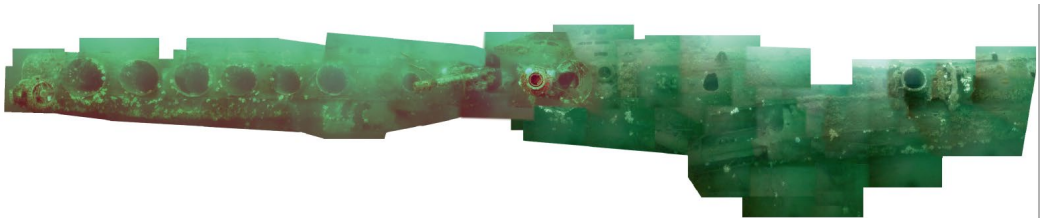
Question	Examples of what this can tell you
Diameter of tube?	British submarines carried 18 in (0.45 m) or 21 in (0.53 m) diameter torpedoes. UB I and the paraffin-powered early U-boats (to U-18) were armed with 0.45 m diameter torpedoes. Otherwise German submarines were armed with 0.50 m (19.7 in) diameter torpedoes.
Door closed or open?	The outside door of a torpedo tube would normally only be opened just before firing. An open door (as opposed to a missing door) suggests that the submarine may have been lost when preparing to fire.
Do they contain torpedoes?	External torpedo tubes could not be loaded at sea. Therefore, if the tubes are empty then the submarine is likely to have been in action.

Mine Chutes

Question	Examples of what this can tell you
Does the submarine have mine chutes?	Mine chutes are larger than circular hatches and do not have lids. Instead, the chutes were covered by grates. If these are still in place, the chutes may be harder to spot, particularly if the grates are covered by marine growth.  Possible mine chute grate from the UC-92, a very broken up submarine wreck just off Castle Beach in Falmouth.
Where are they and how many?	If a submarine has large circular tubes through its pressure hull forward of the conning tower that slant backwards, it is a German minelaying submarine. Two 1.0 m diameter stern openings that look like oversized torpedo tubes are characteristic of the 19 UE-class ocean minelayers built by the Germans. The tubes were used to deploy the mines from dry storage inside the pressure hull. British minelaying submarines deployed their mines through vertical tubes in the saddle tanks. E-class minelayers had ten single mine tubes on each side, L-class boats 7-8.  Photomosaic of the upper mine chute openings of UC-70, a UC II boat.

	 Forward mine chute of the UC-70, with diver for scale.
Are there mines in the chutes?	Absence of mines in any of the chutes indicates that the submarine has laid its mines and is at least part way through its patrol.

Hatches

Question	Examples of what this can tell you
How many?	Submarines would be fitted with several hatches to allow access into and out of the pressure hull. The number varied by the size and type of boat, but typically might include a torpedo loading hatch for each torpedo room, an engine room hatch, a conning tower hatch (normally two – one at the top and one between the conning tower and the rest of the submarine) and perhaps a hatch forward of the conning tower to serve the deck gun. The hatch at the base of the conning tower effectively isolated it from the rest of the pressure hull.  Photomosaic of the top of the pressure hull of the UC-70.
Size shape and angle?	Small hatches are likely to have been for crew access and ventilation. Torpedo loading hatches would either be angled to make it easier to load (this allowed quite a small hatch to be used, for example on the UB-109) or a larger flattened hatch (for example on the U-8). Design differences in the hatches and their locking mechanisms can potentially be used to distinguish between British and German boats and the different types.  This hatch in the top of the pressure hull is designed for crew access and for loading of stores and small equipment, as well as for providing ventilation when alongside.
Where are they?	Hatches are strictly functional – a large or angled hatch forward of the deck gun is likely to indicate the position of the aft end of a forward torpedo room.
Open or closed?	Open hatches are an indication of crew escape at the time of sinking; subsequent diver entry; or catastrophic blast damage (check the hatch cover and rim for signs of damage).

	 Open upper hatch of the UB-109 conning tower. The hatch was opened by the crew to make their escape and is reported to have been opened and closed more than once by late 20th century divers.

Periscopes

Question	Examples of what this can tell you
How many?	By 1914 new submarines were equipped with two periscopes – a high power one for long range searching and a low power one for the close range attack. Single periscopes are usually features of early British designs, such as the A and B-classes. They were also a feature of early German coastal boats the UB I and UC I, so a submarine with sloping mine tubes along the centreline and two periscopes is likely to be a UC II or III. A few submarines such as the U-8 had a third periscope protected by a cutwater forward of the conning tower.  Control room periscope of the UC-70, looking down and showing the periscope tube within the sheath.  The sleeve of the attack periscope of the UB-109 on top of the submarine's conning tower.
How arranged?	Attack periscopes are normally the forward of two and are usually smaller and slimmer, to escape detection at the close ranges required for attack. Periscopes might be operated from the conning tower or the control room below. The watertight glands where the periscope emerged from the pressure hull or conning tower might be enclosed and reinforced by a sleeve which acts as a cutwater. This was a typical feature of larger German submarines.

Deck Guns

Question	Examples of what this can tell you
How many?	Only a very small number of large U-boat submarine cruisers and ocean-going minelayers carried two permanently mounted deck guns. All other submarines were equipped with a single gun, except UB I and UC I boats which had none. British submarines carried deck guns after D4, but only very large submarines of the X and K/M-classes carried two permanently mounted guns. Guns were occasionally removed by Royal Navy divers, for example from the UB-55 and UB-58. Furthermore, a combination of corrosion and trawling is likely to have accounted for several deck guns, although they are sometimes located on the seabed below the mounting or nearby.
Type?	The size, calibre and design of the deck gun can help identify the nationality, type and date of the submarine.   88 mm deck gun of the UC-70 *in situ*.  Detail of the lower part of the UC-70 deck gun mount, riveted to the pressure hull.
Where are they?	A deck gun, or its mounting if the gun is no longer there, will be forward of the conning tower, or the watertight hatch between the conning tower and the pressure hull if the former is no longer in place. The deck gun therefore indicates the direction of the bow. If there is a deck gun aft of the conning tower, this indicates an unusual design.

	 Part of the UB-109's conical deck gun mount.
Ammunition lockers?	Ammunition for deck guns was stored both within and outside of the pressure hull. Each round of ready-use ammunition for deck guns was usually stored in its own pressure-proof ammunition locker built into the deck or casing. If there are any missing, this often indicates that the boat had been in action, although this could also indicate a post-war loss. As the deck and its casing is often missing, the lockers may not be *in situ* and could be amongst debris that has fallen off the pressure hull onto the seabed.

Propellers

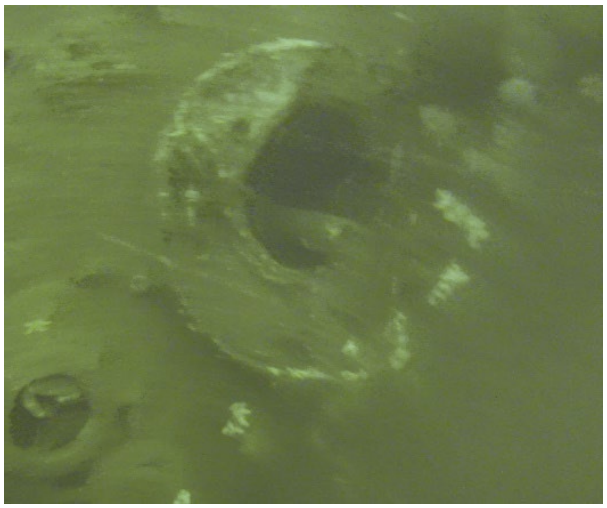
Question	Examples of what this can tell you
Are they still there?	If not, they are likely to have been salvaged. Look for evidence that the shaft has been cut using a saw or explosives.
How many?	The number of propellors can indicate the submarine type. For example, UB I and II boats had a single propeller, as did UC I boats. However, UC II and III and UB III boats had two propellers. If the propellers are missing, count the number of shafts (taking care to check that there is not a second shaft if you have only found one propeller).
What are they made of?	First World War U-boats had bronze propellors (the colour should reveal this, although the surface may be obscured by marine growth – if in doubt check with a magnet)
Shipyard stamps?	Normally on the blade of U-boat propellers. This should give the identity of the U-boat and the manufacturer. However, examples have been found of propellers being changed out during maintenance, which may result in incorrect identification. See McCartney 2015 for examples of propeller stamps.

Hydroplanes and rudders

Question	Examples of what this can tell you
How many and where are they?	The arrangement of the hydroplanes can narrow down the identification of the submarine. Holland and A-class British submarines had a single set of hydroplanes aft. From the B-class onwards, they had two sets. These were initially on either side of the conning tower, before moving forward to the bows on the later B-class. German submarines had two sets, one at the stern and one at the bow. Hydroplanes may have been lost, either because of the damage that sank the boat or subsequently.  The balanced single rudder of UB-78 is detached and lying on the seabed below the stern of the submarine.
What shape are they and their frames?	Hydroplanes (sometimes called diving rudders or just 'planes'), which control vertical movement, varied considerably in shape and other aspects of their design. Many had a fairing which acted as a supporting frame and protection (for example it could stop a moored mine cable from snagging on a hydroplane). The design of the hydroplane can be compared with submarine plans to identify the type.

	 Forward port hydroplane of the UB-78

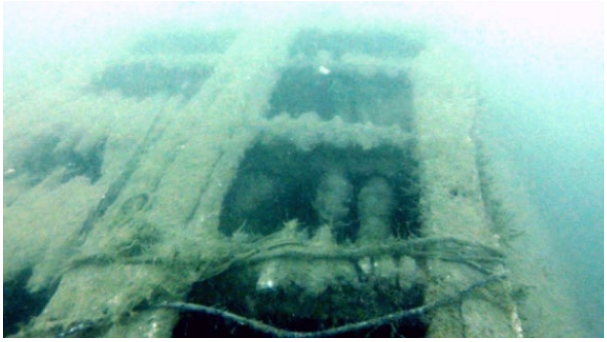
Conning Tower

Question	Examples of what this can tell you
Is it still there?	If the conning tower is no longer in place, this indicates that either severe damage was caused during the loss of the submarine, or that corrosion and/or a powerful trawl has removed it or caused it to fall off. If the conning tower is missing, the hatch between the conning tower and the control room in the pressure hull will indicate where it was and there may also be sections of L-bar girder or other parts of it still attached to the top of the pressure hull.  The conning tower of the UC-70 is missing. What can be seen is the lower conning tower hatch that gave access to the control room in the pressure hull below.
Shape and design features	Conning towers themselves were fairly similar. However, the arrangement of the periscopes and masts for lights or aerials in relation to the upper hatch and the presence or absence of ports can be compared to the plans of different types of submarines.
Is the deckhouse/sail still present?	The floodable casing that was built around or attached to the watertight conning tower are rare survivals but can again be compared to submarine plans.
Any equipment inside?	The arrangement of installed equipment such as compasses or steering wheels can be compared to the more detailed plans and may be identifiable as belonging to the British or Germans. The absence of small, collectable pieces of equipment also indicate salvage and it may be clear from inspection whether this has happened recently.

Radio Masts

Question	Examples of what this can tell you
Location	The location of radio mast bases, which normally pivoted, can be compared to detailed submarine plans to provide evidence about the type and nationality of the submarine. If the masts are no longer there, the brackets on which they pivoted to be raised or lowered may be.

Decks

Question	Examples of what this can tell you
Shape and type	Submarine decks tended to consist of small wooden planks supported by a floodable metal structure attached to the top of the pressure hull. Whilst the deck may not survive and the casing may be corroded and largely missing, there is usually a surviving stub on top of the pressure hull which will show the shape and extent of the raised deck. This can be compared with plans to help determine the type of submarine.  UB-109 forward deck.

Deck 'furniture' – fixtures and fittings

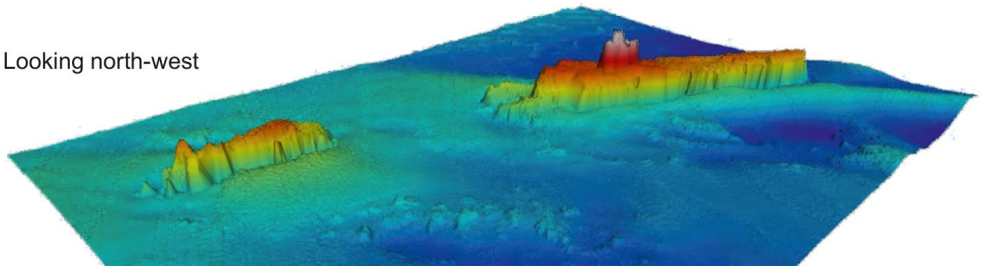
Question	Examples of what this can tell you
Location and type	A whole range of equipment would be fitted to the top of the pressure hull, including air cylinders, winches, capstans, mast bases and bollards. The locations of these can be compared to submarine plans to determine the type of submarine.  UB-109 capstan baseplate. The capstan itself is missing.  HP air cylinder on the deck of UB-109, looking forward at the cylinder head, valve and charging/discharging pipe.

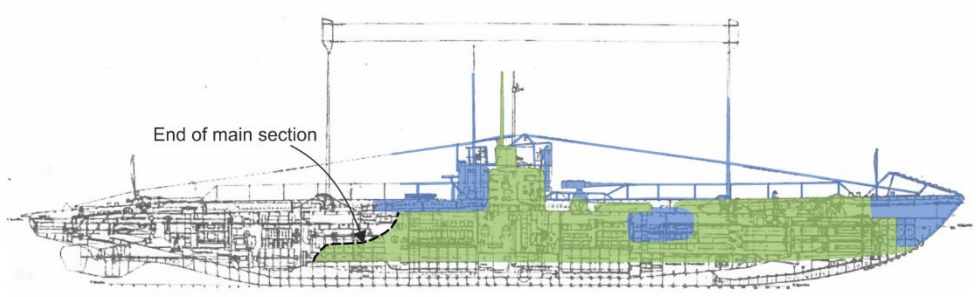
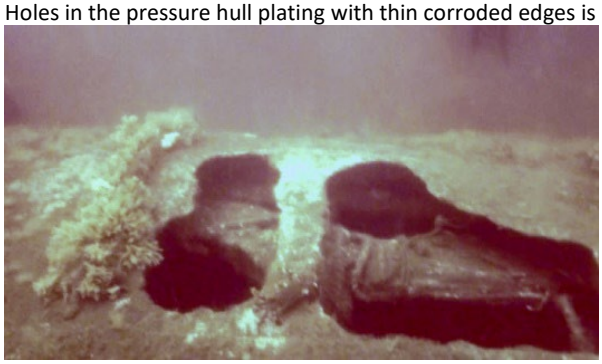
	 The open forward torpedo loading hatch of the UB-109.
Exhaust and ventilation systems	Part of the exhaust system of a submarine internal combustion engine is normally attached to the top of the pressure hull below the deck, including the large cylindrical silencers and the valves and pipework. The design of these systems varies and can be compared with plans, even if they are incomplete and have been moved. If the exhaust system is damaged, parts may have fallen to the seabed below. Air intake masts for ventilation and the diesel engine and blowing systems would have been fitted inside the free-flooding casing immediately aft of the conning tower and their arrangement can also be compared to plans.  Part of the air intake system of the UC-70.

Hull

Question	Examples of what this can tell you
Is it a single, saddle tank or double hull design?	Damaged sections of the thin plating of saddle tanks or outer hull often survive. Where they do not, the stubs of the frames supporting the outer plating can often be found. Otherwise valves in the pressure hull can help determine that the submarine had external fuel or ballast tanks and was therefore not a single hull design. Most submarine wrecks in ETW are saddle tank or double hull designs.

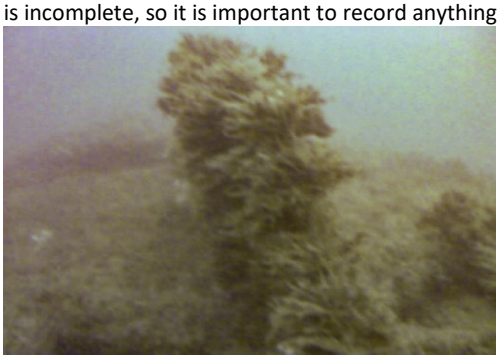
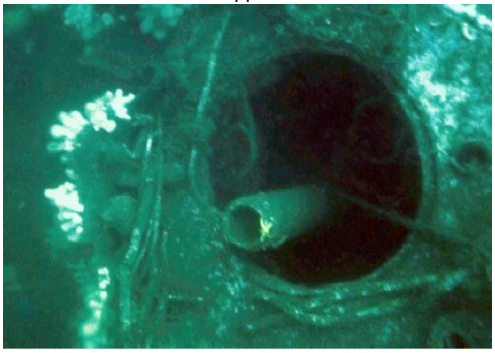
Damage and decay

Question	Examples of what this can tell you
Is the submarine complete?	If the submarine is in two parts, it is likely to have been sunk by the very powerful explosion of a torpedo or mine. Depth charge damage can be hard to distinguish, as British depth charges were not very effective. Plates or frames pushed inwards are indicators of an external explosion.  Multibeam image of the two sections of UB-109, sunk by a mine explosion
If not, what is missing and is it in separate sections?	Submarine hulls will often break at transverse bulkheads close to the point of the explosion, as these strong points can halt the propagation of fractures in the pressure hull caused by explosions. The free-flooding sections of the bow and stern of a submarine are not as strongly built as the pressure hull. Therefore if they are damaged, for example by a mine explosion, then they may not survive as coherent sections.

	 Diagram of the surviving forward section of the UB-109, with missing parts of that section in blue..
Is there any displaced or damaged equipment?	 This cogged spindle was found loose on the deck of the UB-109.  UB III boats such as UB-109 were based on the UC II design. Comparison with the *in situ* capstan at the forward end of the pressure hull of the UC-70 (a UC II boat) suggests that this is part of the UB-109's capstan, which is missing from the forward end of its pressure hull.
If there is a hole, have the edges of the hole been pushed in?	This would indicate force applied from the outside and therefore probably battle damage (unless salvage is suspected).
Is there evidence of plate thinning?	Holes in the pressure hull plating with thin corroded edges is indicative of advanced corrosion.  Large holes in the outer hull tanks of UC-70, possibly caused by plate thinning.
Is there evidence of fresh corrosion?	This should appear as red or orange oxidation on unconcreted metal surfaces and is a sign of active corrosion. It is caused either by damage or disturbance, or by the natural sloughing off of concretion where it is only weakly attached to the metal surface.

	 Active corrosion of the damaged section of the pressure hull of the UB-107
Is there evidence of damage caused by commercial fishing?	 The conning tower of the UB-30, a UB II boat, looking forward.

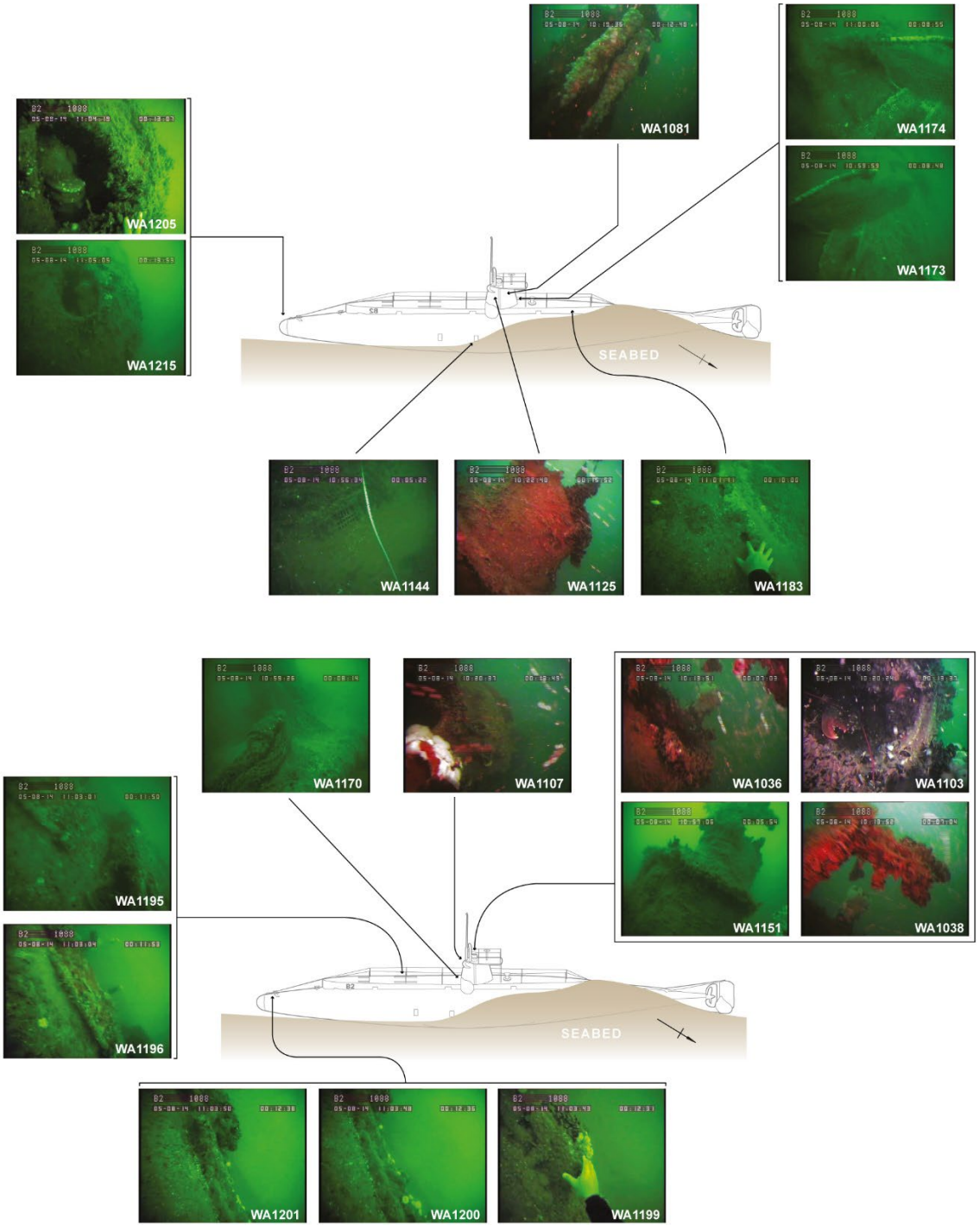
Unusual Features

Question	Examples of what this can tell you
Is there anything unusual or unexpected?	Knowledge of the design, in-use modifications and working practices of all submarines in the First World War is incomplete, so it is important to record anything unusual.  Video still of the unusual upper rudder of the U-8.  The hatch between the missing conning tower of the UC-70 and the control room below.

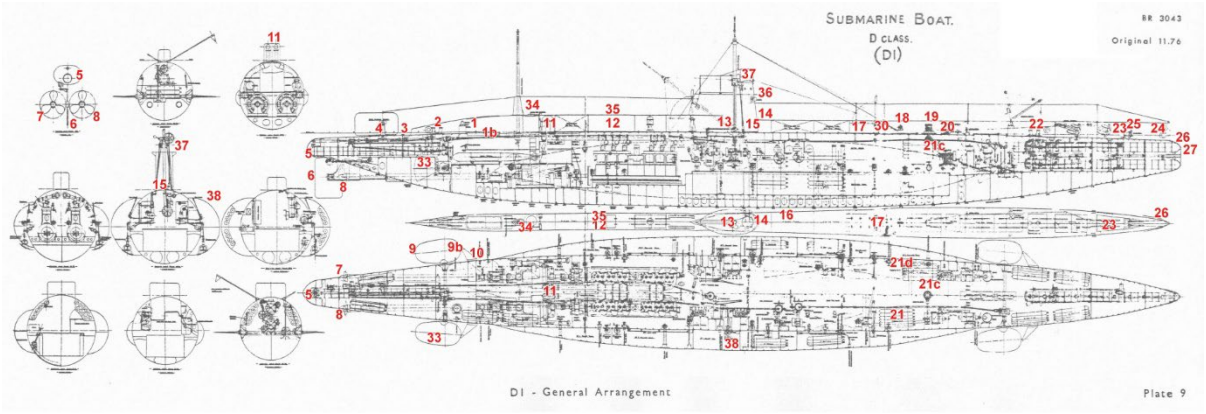
External Inspection and Survey Methods

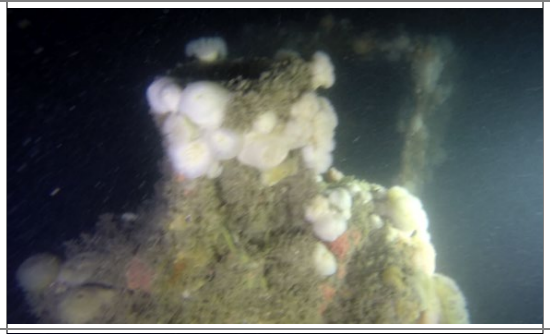
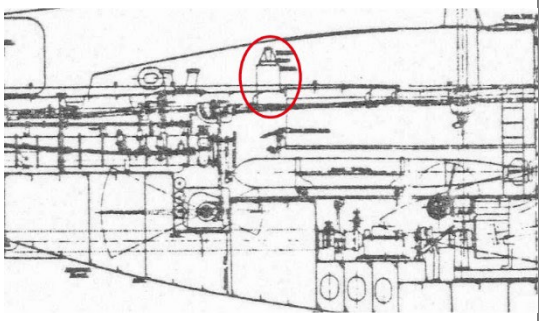
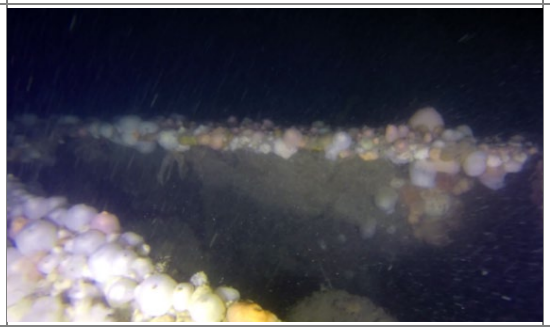
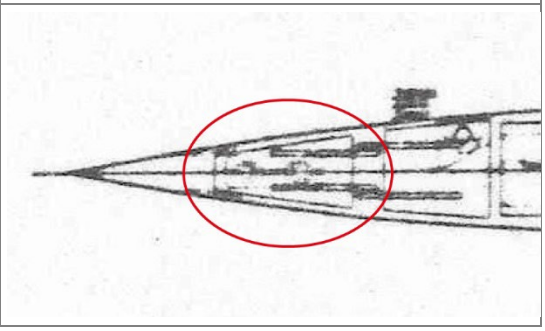
Due to the robust nature of pressure hulls, submarine wrecks tend to be easy to understand and therefore for divers and ROV pilots to navigate around, even in poor visibility. Furthermore, submarine wrecks are relatively easy to compare to submarine plans. This makes them fairly easy to survey from the outside. Exterior methods can include visual inspection, direct measurement, photography, video, photogrammetry, sonar/laser, acoustic positioning and marine growth/environment survey.

Video and diver descriptions gathered during the inspection of a submarine wreck can be integrated with plans to produce a detailed inspection report. The report would include images (such as from the B-2 below) as well as a detailed description of each feature.



The high quality results of previous work can also be used to produce a comprehensive description of a submarine wreck, for example the use of existing video for HMS D1 – comparing locations on plans and identifying particular features in the data.



Obs ID	Images (courtesy of Jacob Mackenzie)	Location (BR3034, 1974; Tall, 1996)
1		
2		

Internal Survey Methods

Surveying within the pressure hull is difficult and potentially dangerous. Furthermore, it can disturb human remains and cause damage to delicate and corroded internal structure and equipment. Before any internal surveys are conducted, the risks should be carefully considered, such as: working in a confined space; sharp and/or snagging hazards; tight openings; potential for structural collapse; movement may stir up fine sediment, reducing visibility; rapid escape may be problematic or impossible if things go wrong; and potential for unexploded ordnance.

Overall, it is probably better to find ways of inspecting the inside of a pressure hull without actually going inside. This may involve simply looking through holes in the hull but may also involve putting a camera and light/s on a pole and lowering them through a hatch or inserting them through a hole in the hull.

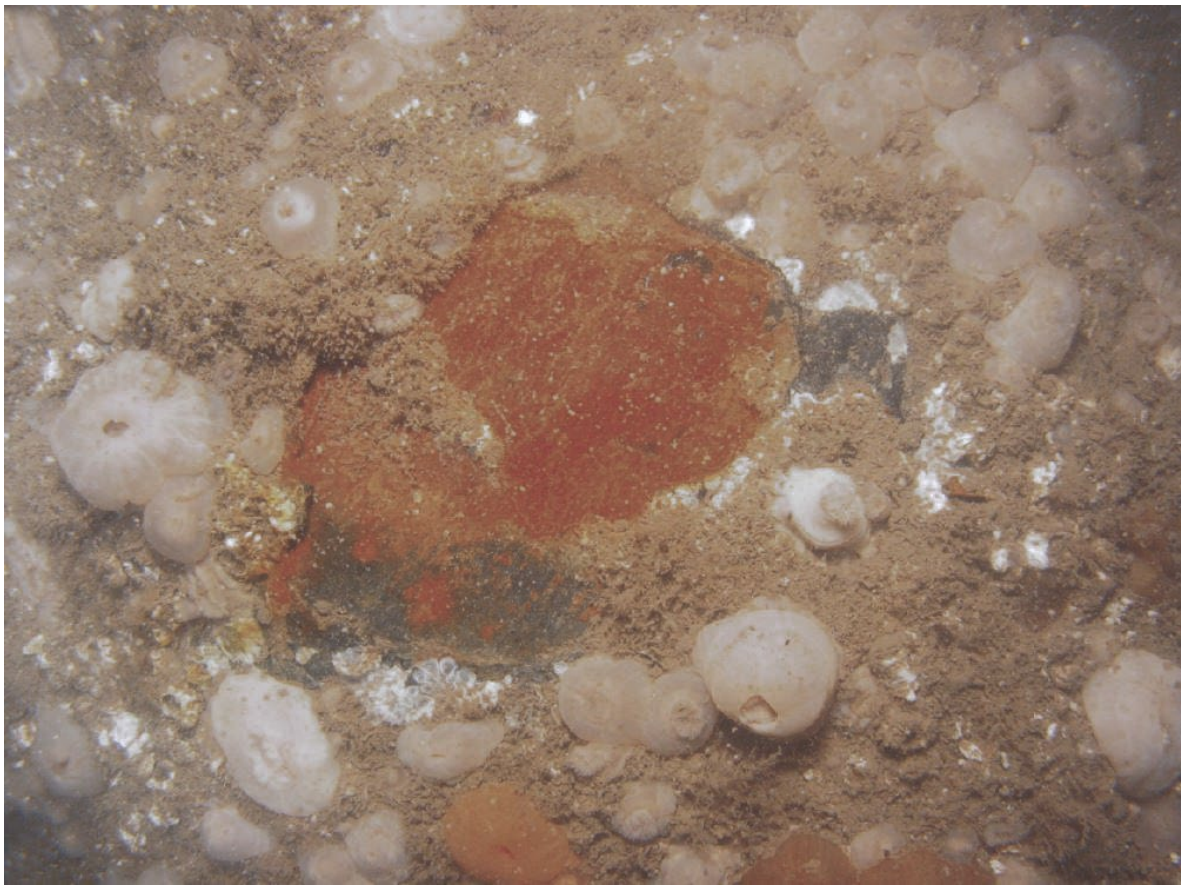
Assessing the Condition of a Submarine Wreck

The condition of a submarine wreck is its current state relative to a previous 'baseline' state. The First World War Submarines project took as its baseline the condition of the submarine in normal use, in as far as that was known. Understanding the condition of a wreck is very important in determining its vulnerability and to risk assessing it.

It is important to how much of the submarine in its baseline condition survives, what the overall condition of the fabric (structure) of the wreck is, what the reasons for the loss that has occurred are and what the 'condition trend' (rate and type of decline) is.

Historic England's *Historic Wreck Sites at Risk: A Risk Management Toolkit* provides a detailed methodology for assessing risks for sites. A number of categories are identified for assessment: survival, condition and trends. The separate appendix has a case study showing how the toolkit was applied to a submarine wreck investigated during the project.

For submarines, one of the key factors to consider is corrosion, which can be affected by metal composition and structure; composition of the seawater; temperature; water movement; marine growth; and seabed composition and depth of burial. Corrosion can be assessed through methods such as a visual inspection, pH testing of seawater, corrosion potential measurement (for example using a device such as a Buckley Bathycorrometer; electrical continuity surveys and direct thickness measurements. Much more detail about these methods can be found in the appendix.



Fresh corrosion on the pressure hull of the early submarine *Resurgam* observed in 2006.

Significance and Protection

Following National Planning Policy Framework guidance (Ministry of Housing, Communities and Local Government 2021), the significance of a heritage asset, including archaeological sites, historic buildings and historic wrecks, can be broadly defined as its value to this and future generations because of its heritage interest. Heritage interest can be archaeological, architectural, artistic or historic (Historic England 2019).

The Strategic Assessment produced by Cotswold Archaeology applied a number of questions to inform the process, such as whether a submarine wreck was at particular risk, whether it was part of a group and whether it was in good condition.

A submarine wreck can be protected by legislation such as the *Ancient Monuments and Archaeological Areas Act* 1979, the *Protection of Wrecks Act* 1973 and the *Protection of Military Remains Act* 1986. Decisions on scheduling or designation are made by the Secretary of State, based on advice received from Historic England. The selection guidelines (Historic England 2017) explain criteria such as period, rarity, documentation/finds, group value, survival/condition, fragility/vulnerability, diversity, and potential. Examples of how these criteria can be applied to submarine wrecks can be found in the separate appendix.

Video still of the aft end of the largely intact conning tower of UB-78

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Various reports on First World War submarines by Wessex Archaeology are available on Historic England's website: https://historicengland.org.uk/research/current/discover-and-understand/military/the-first-world-war/first-world-war-home-front/what-we-already-know/sea/submarine-wrecks/

A more detailed bibliography can be found in the appendix to this document.

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