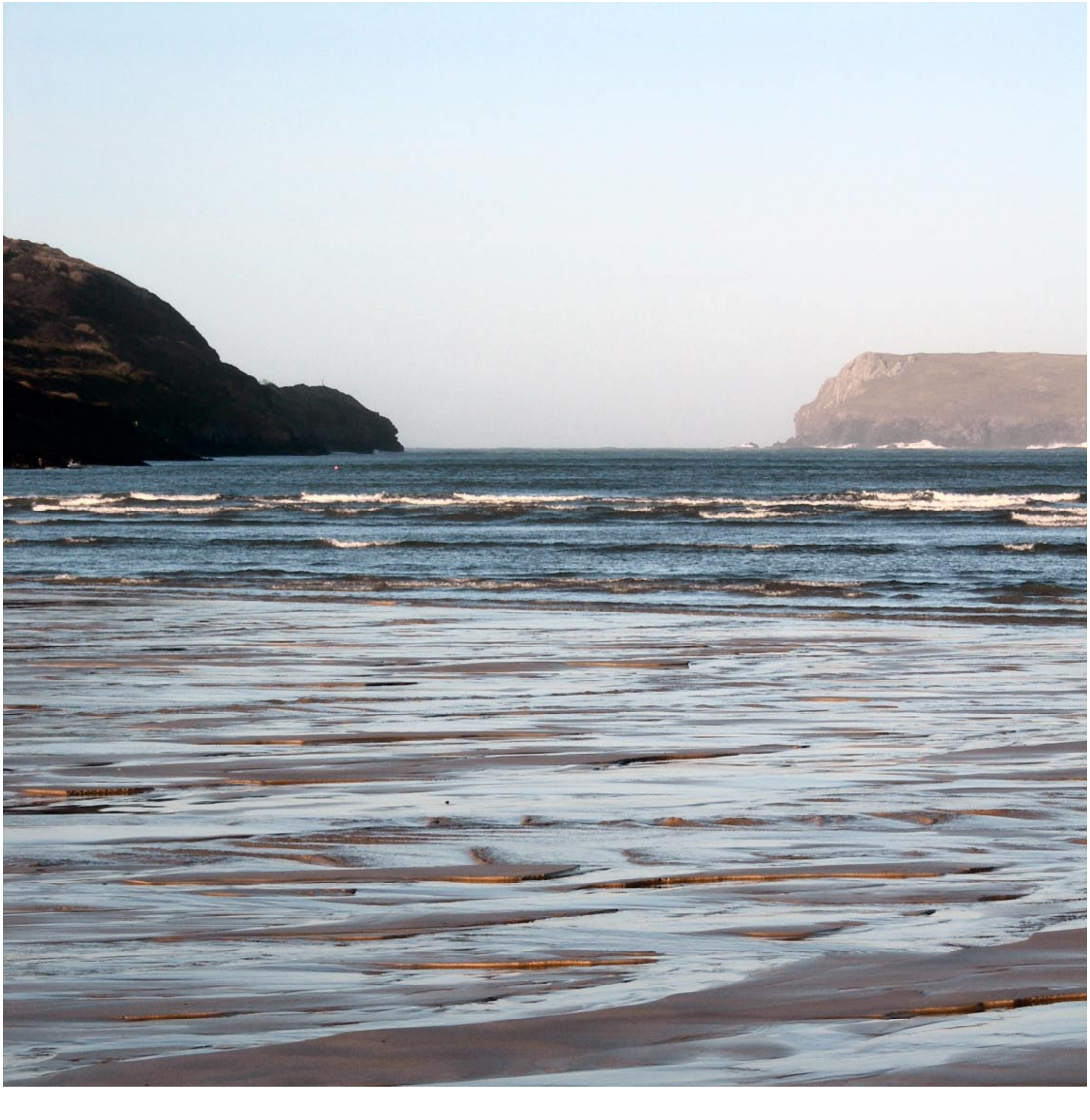
The Search for HMS Whiting
Survey Plan and Report



July 2010

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The geophysical survey work was completed with the assistance of Kevin Camidge from CISMAS and Mark Beattie-Edwards from the Nautical Archaeology Society.

The vessel used for the survey was the *Lady Mary* of Padstow, skippered by Jim West

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Introduction

Scope of Work

The intention of this survey is to locate the remains of *HMS Whiting* sunk on the Doom Bar at Padstow in Cornwall on 15th September 1816. This document describes the geophysical survey methods to be used, records the estimates and assumptions made about the current state of the ship to be found then goes on to describe the search procedure in detail.

General Location

The site is located on the Doom Bar at the entrance to Padstow harbour on the north coast of the county of Cornwall in the U.K. (Fig 1). Padstow lies some 50 miles to the north-east of Lands End and is the only completely secure harbour on this stretch of coast until Avonmouth near Bristol.

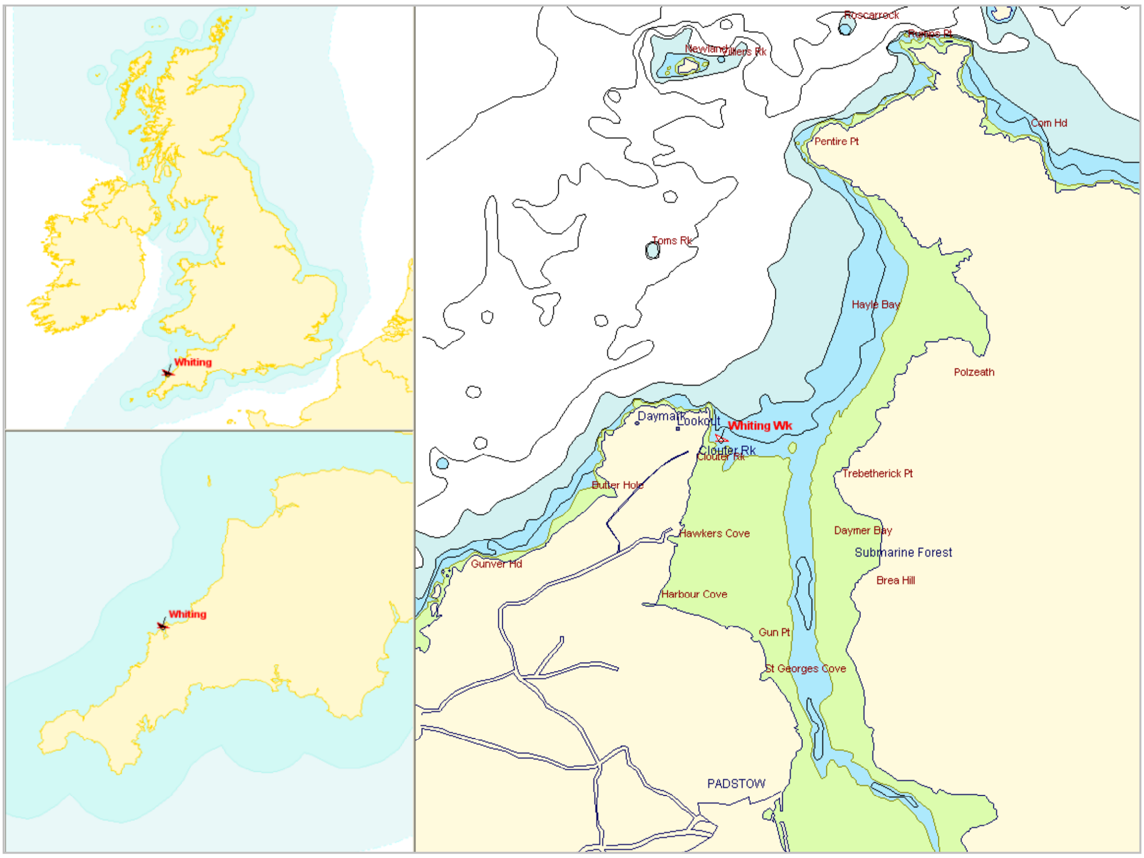


Figure 1: Location of the site at Padstow

The harbour of Padstow is located within the estuary of the river Camel and is guarded at its mouth by a great sandbank called Doom Bar. The entrance is bounded by Stepper Point to the west and Pentire Point to the east.

The Admiralty hydrographic chart for the area is No. 1168 Padstow Harbour.

Tide details: HW Dover -0550 MHWS 7.3m, MHWN 5.6m, MLWN 2.6m, MLWS 0.8m

Figure 2: View of Stepper Point looking north from Gun Point at low tide

Historical Background

The Ship

Note that this section of the report is included to highlight features of the ship and its loss relevant to the search and identification and is not intended as a complete record of the history.

The Baltimore pilot schooner *Arrow* is historically significant in naval architecture owing to her superior 'round tuck pilot schooner' design which was the product of a formidable Maryland maritime pedigree. Speed and manoeuvrability were provided by a uniquely shaped hull, raked masts, topsails and lightened construction (Footner 1998). The *Arrow* was built in 1811 in the Fell's Point yard of renowned shipbuilders Thomas and Joseph Kemp. With a keel length of 71ft 3in, a 23ft 4in beam and a depth of hold of 10ft 4in. her owners were the celebrated Baltimore merchant firm of Hollins and McBlair. *Arrow* was described as having been built 'privateer fashion' with 'a sharp hull and exceptionally long spars' similar to the Baltimore pilot schooner *Lynx* shown in Fig. 3 (Higgins 2010).

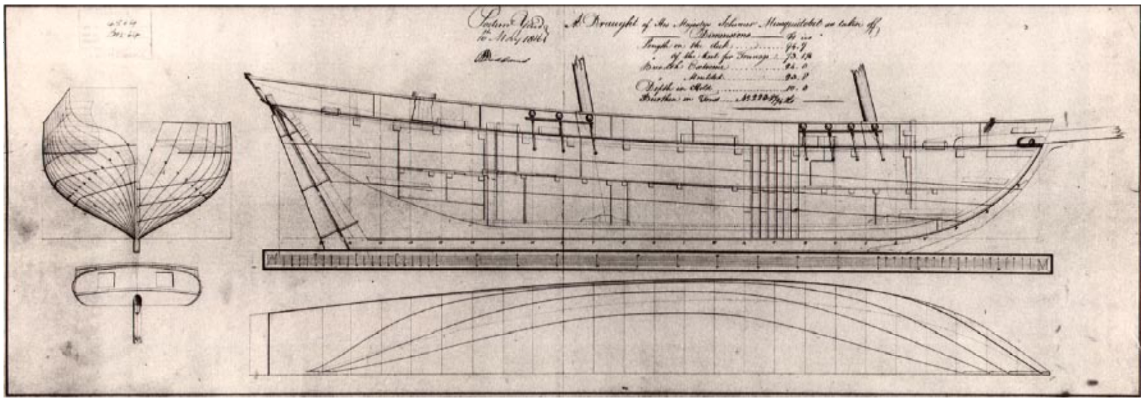
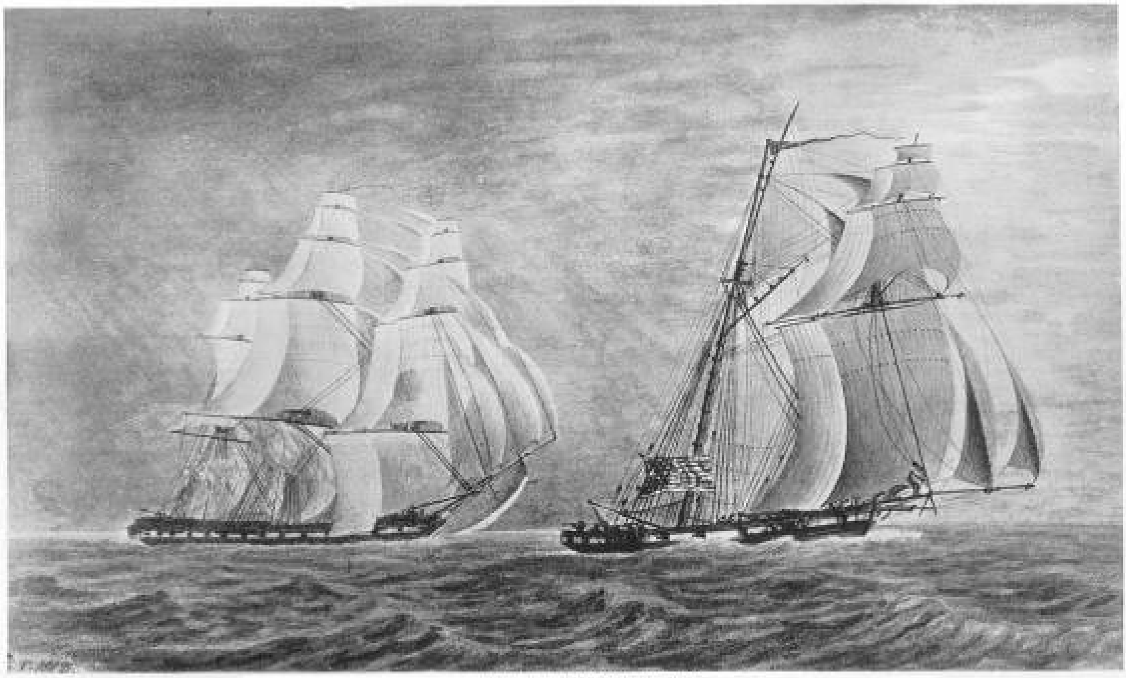


Figure 3: Plan of *HMS Musquidobit*, ex-Baltimore schooner *Lynx* (NMM)

As *HMS Whiting* the ship was a 12 gun schooner carrying 10 x 12 pounder carronades and 2 x 6 pounder guns and a crew of 50.



H.M.S. "ANDROMACHE."
FORMERLY THE FRENCH FRIGATE "JUNON," BUILT IN 1787, TAKEN IN 1799 AND NAMED "PRINCESS CHARLOTTE"; RE-NAMED "ANDROMACHE" IN 1812. RE-CAPTURED THE SLOOP "CYANE" IN 1805, AND IN 1813 TOOK THE FRENCH FRIGATE "TRAVE." BROKEN UP IN 1828. THE PICTURE SHOWS HER CHASING AN AMERICAN SCHOONER IN THE WAR OF 1812.
(*Water-colour by Tobin, 1813*).

Figure 4: *HMS Andromache* chasing an American schooner (Moore 1926)

The Loss of the *Whiting*

Initial Loss

Whist cruising the Irish Sea to prevent smuggling the *Whiting* made for Padstow to gain shelter from a gale. On the 15th September 1816, as the ship entered the harbour close to Stepper Point a gust of wind took the schooner aback and she touched her forefoot on a sandbank. The best bower anchor was let go to hold her, the head swinging round to the north to face the harbour entrance. Advantage was taken of this by setting sail to try and sail out, but the baffling winds would not allow it and on drifting back she ran hard aground again at the stern. All boats were hoisted out, taking a cable ashore, but despite heaving for some time she would not move. The guns were moved forward to try and lift the stern and further attempts made to haul her off, but she remained stubbornly in position until at length the cable parted. It was decided to leave further efforts until the next high tide, and she lay quietly on the sandbank for some hours. As the time of high water approached it was found that she was making water, so the pumps were manned, and these soon had to be supplemented by bailing as the water rose. In the event, they were unable to control the water or haul her off.

The court martial transcript from October 1816 (ADM 1/5455) provides interesting detail about her initial salvage and later abandonment:

'16th Sept. At low water employed saving what stores could be got at. At 7 cut away the masts to ease the hull.

17th Sept. At low water people employed getting stores out of the hold and on shore.

18th Sept. At low water employed lightening the vessel as much as possible.

19th Sept. At low water employed saving all the stores possible to be got at, a party preparing slings to weigh the schooner.

20th Sept. Sent four coasting vessels down to the schooner ready to land alongside at low water on the 21st and try to weigh her.

21st Sept. Got the slings round and hove the vessel down at low water but with heavy strain. At 2 10 PM the slings gave way vessels run up the harbour people employed fitting new slings.

22nd Sept. Vessels hauled alongside again & at low water took in the ends of the new slings & hove down and when strain came on they gave way. As low water found the schooner had fallen over on her starboard bilge and to have a great quantity of sand in, and having buried herself so much, that it was impossible to sling her again.'

The wreck was abandoned and sold by the Royal Navy.

Petition

In 1827 the merchants of Padstow made a petition to the Admiralty (ADM 1/4985) as the wreck of the *Whiting* was causing an obstruction to the entrance to the harbour. The original channel was 75 fathoms wide but the effect of the wreck of the *Whiting* was to reduce this to 45 fathoms and to reduce the depth of the channel from 3.5 fathoms to only 2. Any attempts to remove the wreck by the inhabitants of Padstow had failed so the merchants petitioned the Admiralty to get them to remove the wreck. The Navy responded that they had sold the wreck and could therefore not comply with the request.

The Padstow Harbour Association

In 1829 the Padstow Harbour Association for the Preservation of Life and Property from Shipwreck was formed and they proposed a scheme for assisting vessels into the harbour at Padstow. At this time the entrance through the Bar was close inshore on the west side under Stepper Point, vessels coming under the lee of the point were often taken aback by eddies in the wind. The Association proposed that a series of capstans and bollards be sited along the landward side of the entrance and a set of buoys laid on the other side of the channel allowing ships to be winched through the narrow channel. A 40 ft high tower called the Daymark was to be built on Stepper Point. This proposal is shown in a lithograph (Fig. 4) which also shows the remains of the *Whiting* on the Bar, still visible after 13 years.

This was a development on previous work by John Griffin who in 1761 had installed three substantial bolts and rings into the cliffs of Stepper Point that could be used for warping in ships (French 2007). The location of the rings is a key piece of information as they are mentioned by Lt Jackson during his Court Martial:

'He sent the midshipman to make WHITING fast to the ring - the hawser parted and another was made fast - that subsequently parted resulting in WHITING bilging on her port side. When the tide next changed, WHITING was raised and then bilged on her starboard side, when the tide ebbed'.

In the 1920s the channel moved from the western side to its current position in towards the east (Duxbury & Williams 1977). Part of the Harbour Association plan was to remove a section of rock from Stepper Point to minimise the wind eddies and the excavation was stated but never completed. Subsequent quarrying at Stepper Point eventually completed this task.

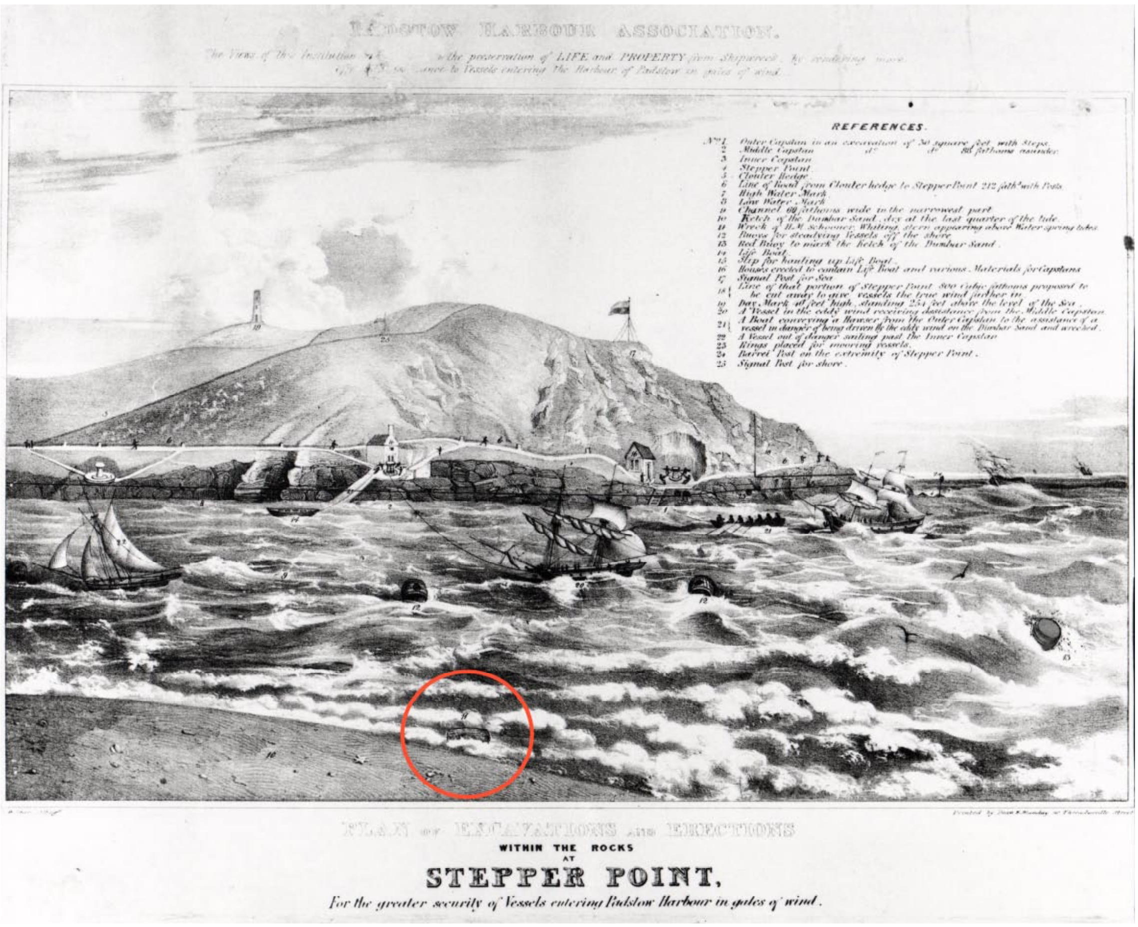


Figure 5: Padstow Harbour Association Lithograph (Padstow Museum)

The remains of the capstans and bollards installed by the Harbour association are still visible on the shore along Stepper Point.

Royal Navy Survey

The wreck was surveyed by C. Brown, the master of *HMS Caledonia* in June 1830. The report (CRO V/BO/38/6) stated that 'excepting part of one of the stern timbers, she was entirely covered with sand'. The depth of water was from two to six feet at low water.

The report also states that 'the sand over her is so hard, that the iron spit with which we sought for the wreck could not be driven more than one and a half foot into the sand with the whole strength of a man'. The hardness of the sand prevented any salvage work and the shallow depth of water meant that a diving bell could not be used. At this time the locals reported that the stern rail of the wreck could be visible three feet above the sand and that the hull could be walked on at low spring tide from the stern to the main hatchway. The report recommendation was to remove the exposed stern section as that was causing the obstruction but leave the main part of the wreck as 'The removal of the whole of the wreck we are of opinion is not practicable by any means, being so deeply embedded in the sand'.

Other Accounts

Accounts of the loss of the *Whiting* in books about shipwrecks in the area give mixed accounts and erroneous information, possibly of note to those using these resources when looking for shipwrecks:

- Cornish Shipwrecks: Volume 2, The North Coast reports that she was 'refloated by naval pontoons' (Carter 1970 p142).

- In the book Dive the Isles of Scilly & North Cornwall (Larn and McBride 2003 p163) it mentions that the *Whiting* was 'built by Arrow' and that 'all the ships guns were thrown overboard'. The fact that the hull was later refloated by Captain Odgers is also mentioned.

- The Shipwreck Index (Larn 1995) merely quotes the request to salvage the wreck and the report about Captain Odger's intentions to salvage it.

- Gossett (1986, p97) also reports that she had been refloated.

- Hepper (1994 p154) includes a detailed account of the sinking but only refers to the wreck being abandoned but not the attempted salvage.

- Lyon & Winfield (2004) gives dimensions and build information and reports that the wreck was sold.

Summary

The information about the wrecking and subsequent activity provides a fairly precise location for the wreck. The later accounts describe the effect of the remains of the hull on the bathymetry of the Doom Bar and the problems it caused the merchants of Padstow. The reports state that the majority of the hull was still buried in the sand 14 years after the sinking and that the sand itself hindered any salvage attempts. At this time there is no evidence to say that the hull had been salvaged or that the hull had uncovered and eroded away or had moved so it is assumed that she remains where she was initially wrecked on the western side of the Doom Bar.

Padstow Guns

Two guns in possession of the Padstow Town Council were thought to have come from the *Whiting* but these have since been found to be of the wrong date and type.

Environment

Topography and Geology

Northern part of Stepper Point consists of purple and pale green slate turning to dark slate at Hawkers Cove (Reid 1910). The quarry on the northern tip of Stepper Point was used to provide roadstone and for construction of the runway of an airbase at Crugmeer near Padstow. The slate rock is not inherently magnetic and should not adversely affect magnetometer survey work in this area.

The seabed consists of sand with rock outcrops close to the shore; the sand readily fluidises but once settled compacts into a solid mass. The most notable event in relation to the story of the *Whiting* is the shift in the position of the channel entrance to Padstow. The 1839 chart of Padstow shows the channel on the western side, close in to Stepper Point. The Ketch (or Catch) of the Doom Bar is on the east side of this entrance and is described as being 1 cable (220m) from Stepper Point (French 2007).

Figure 7: 1839 Chart

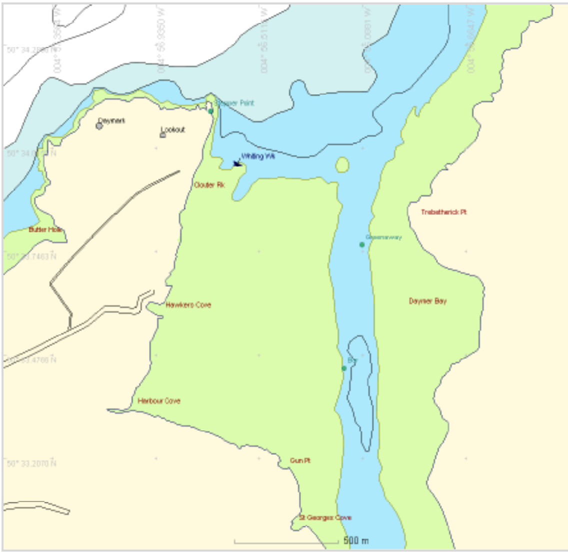


Figure 6: 2010 Chart

The modern Admiralty chart shows the channel entrance now on the eastern side and the original channel has been filled in by sand.

Underwater Visibility

The underwater visibility is heavily dependent on the amount of suspended sand in the water so visibility is reduced after a storm. It has been suggested that the visibility also improves during neap tides when the water flow in and out of the harbour is reduced.

Hazards

There are a number of hazards within and close to the search area. The primary hazard is the Doom Bar itself and work should only be undertaken close to the Bar in calm conditions. The rocks of Stepper point also constitute a hazard when working close inshore.

The area of the wreck is used by local lobster fishermen so on the seabed can be found a number of lobster keep pots with associated ground lines, ground weights, lines and surface buoys. The keep pots themselves are 1m cubes made from steel mesh. The pots are now closer to Stepper Point than before as they had to be moved to the north-west as in the original position the lines were frequently tangled in a wreck.

Figure 8: Keep pot

Estimated Position

The accounts of the sinking of the *Whiting* say that she went ashore on the Ketch which is the most northerly part of the entrance to the channel into Padstow on the eastern side. The 1827 petition to the Admiralty states:

'in September 1816 His Majesty's Schooner *Whiting* sunk in the western edge of the said Dunbar Sand where she now lies'.

The lithograph from the Padstow Harbour Association shows the remains of the *Whiting* in relation to Stepper Point and the capstans and bollards they proposed to install. The actual location of the capstans is shown on a later Admiralty chart so could be added to the site plan. On visiting the site the remains of the capstans and bollards could be seen, confirming their charted positions.

It was then possible to georeference the print onto the site plan (Fig. 9). Assuming the drawing was made with the artist facing perpendicular to the shoreline, a line could be drawn on the site plan through the remains of *Whiting* shown on the lithograph to the shore. As it was known that the ship went aground inside the channel on high water neaps, a position along that line could be estimated on the site plan (Fig. 10).

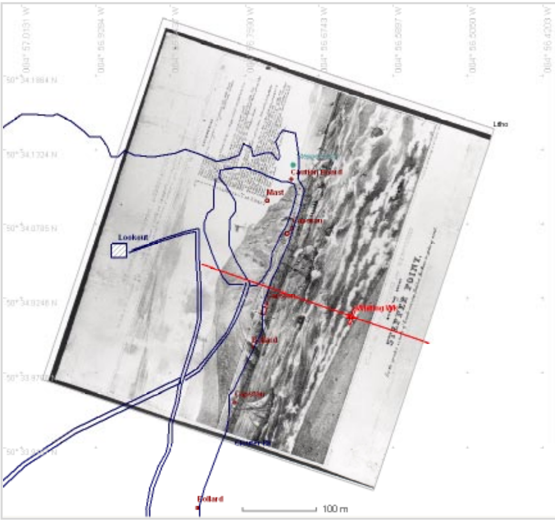


Figure 9: Georeferenced print

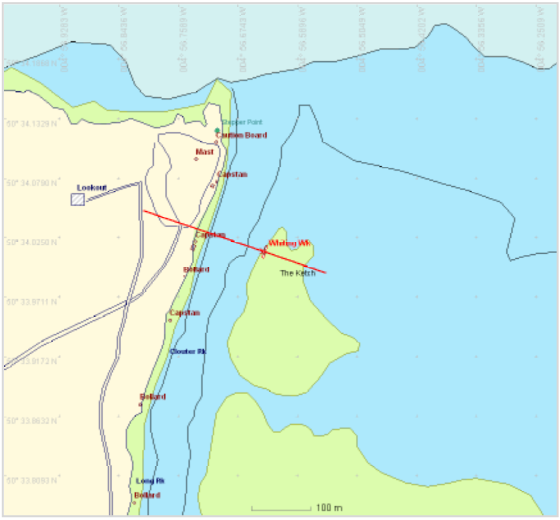


Figure 10: Position line

The estimated position for the *Whiting* is:

50° 34.017 N 004° 56.628 W

This position is 115m off Stepper Point and opposite the middle capstan (Fig. 11)

All geographical position co-ordinates in this paper are given on the WGS84 datum. All grid co-ordinates are given on the Universal Transverse Mercator projection Zone 30 N on the WGS84 datum. Depths are reduced to Lowest Astronomical Tide (LAT).

Figure 11: The estimated location of *Whiting*

Estimated Target Characteristics

Introduction

As the actual position of the remains of *Whiting* are not known we need to use marine geophysical survey methods to locate the ship. This process involves using sonar and magnetic field measurements to detect targets; these are anomalies or differences detected by the survey instruments. The size and shape of target that the remains of *Whiting* presents will depend on the original size, shape and materials used in the construction of the ship. These are then further modified by salvage attempts and the much longer action of the sea and its environment eroding the remains. We can use historical information to predict the characteristics of the ship we are to find then use other, similar wreck sites to predict the present condition of the ship. From these estimates we can then determine the most appropriate and efficient search methodology.

In general terms it can be assumed that the older the ship is the harder it is to find underwater but factors such as the size of ship and the depth of water also play a part. Modern steel wrecks are more easily located with sonar and magnetometer than older ships built primarily of wood. Of the wooden ships on the seabed the older ones tend to have less iron in their construction than ones built at a later date. Older ships have had more time to be degraded, eroded and buried within their environment so are harder to detect with sonar.

The remains of wooden ships have been found in a number of ways, some accidental but a few have been deliberately located. These ships have been found by location of iron guns and anchors, identification of ballast mounds or location of the ship's hull. Iron objects of sufficient size can be detected using a magnetometer even if the objects themselves are buried. The Emanuel Point Ship (1559) was located from a 400 nT magnetometer target in 4m water depth, later identified as wrought iron anchor 3.14m long (Smith 1999). The anchor from the *Mary Rose* recovered in 2003 was of a similar age yet still provided a significant and detectable magnetic target in a similar depth of water (Hildred 2010).

Ballast stones and blocks show up on side scan sonar records as a mound protruding from the seabed or as a hard reflecting area on a softer sand or silt seabed. The timbers themselves may be visible on a side scan sonar trace if they are visible on the seabed however it is more likely that they are completely buried, in which case the structure may be detected using a sub-bottom profiler. The *Mary Rose* (1545) hull was located using a very early model of sub-bottom profiler in 1969 (McKee 1982 p66)

Whiting Target

Wrecking

HMS Whiting was wrecked on 15th September 1816 at the top of high water on a neap tide. The *Whiting* initially struck the Doom Bar head on but then swung round with her head toward the mouth of the harbour. With a heavy ground sea running she drove back onto the sand and grounded astern. Attempts to haul her off failed as the tide receded. Seven hours after grounding she was filled with water to within two feet of the lower deck showing that the hull was now leaking. Pumping her out failed as the pumps choked with sand. Later on that day the hull filled with water and fell over on her port bilge and she was later found submerged and abandoned. The masts were cut away and stores were recovered from the vessel between 16th and 19th September. Salvage attempts between 20th and 22nd September failed but pulled the hull over onto her starboard bilge but by then the vessel was heavily sanded in and buried. A subsequent salvage attempt by Capt. Ogders also failed.

Construction

The initial state of the *Whiting* hull is known from the records of her building:

Keel length	30m
Breadth	7m
Depth in hold	2.7m
Tonnage	225 tons

The vessel is built of wood, probably live oak, is fastened with wooden trenails and is not fitted with iron knees.

The Doom bar appears to provide a good preservation environment for wooden ships providing hope that some of the hull of the *Whiting* still survives. In March 2003 a section of timber hull appeared from the sand (Fig 12), the date of this wreck is not known but the wooden trenails that fasten the planks suggest this is not a recent sinking.

Figure 12: Timbers on Doom Bar, March 2010

Estimated Mass of Iron

Construction

The *Arrow/Whiting* was not built using iron frames so iron fittings would not form a significant contribution to the total mass.

Ballast

The weight and type of ballast used in *Whiting* is not recorded but iron ballast or kentledge was in common use at this time. The iron ballast was in strips known as 'pigs' and varied in size from 3ft x 6in x 6in to 1ft x 4in x4in. Lavery mentions that by 1796 the amount of iron ballast was standardised for each type of ship but unfortunately gives no further details. A similar vessel, the United States Schooner *Alligator* built in 1820, carried 19 tons of kentledge (USN NHHC 2009). For efficiency the ballast would be put as low as possible in the ship so would be difficult to recover from the *Whiting* once the hold had filled with sand.

Armament

At the time of her loss the *Whiting* was fitted with 10 x 12lb carronades and 2 x 6 lb guns. The carronades were shorter and lighter than ordinary guns and were designed for firing shot over short ranges. A 12lb Carronade of this period was 2ft 8in (0.81m) long and weighed 6 cwt (304kg). A 6lb gun of 1782 could be between 6ft and 9ft long (2m – 3m) and weigh between 16cwt and 24 cwt (810kg to 1220kg) (Lavery 1987 p102-108).

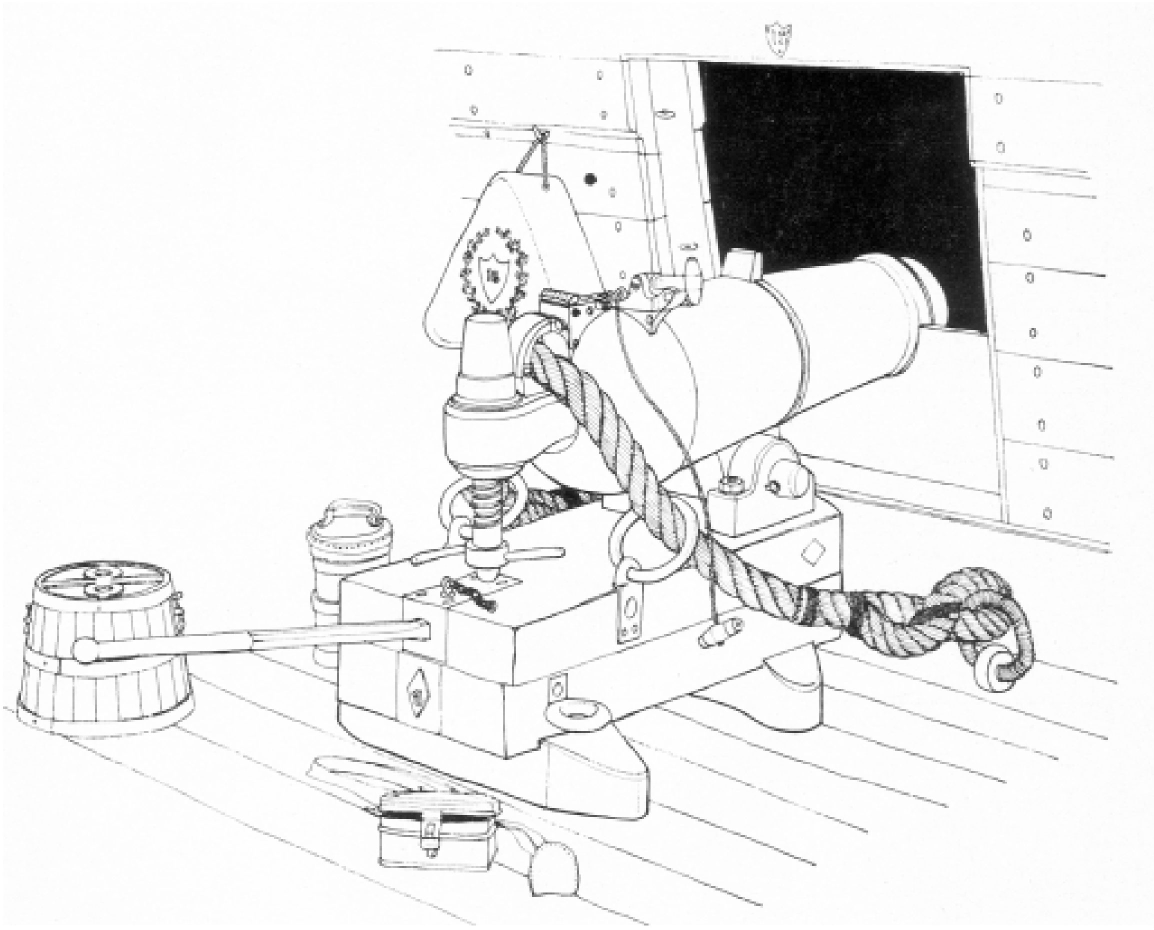


Figure 13: 18lb Carronade (1818)

During the wrecking the guns were dismounted and taken forward to help raise the stern off the Bar but there is no record of the removal of the guns from the ship.

The quantity of shot for the guns on board at the time of sinking was not known but we do know she had four weeks stores on board. The court martial mentions 'At low water people employed getting stores out of the hold and on shore'; the removal of shot is not mentioned but this could be covered by the term 'stores'.

Anchors

The *Whiting* probably carried three large Admiralty pattern longshank anchors 12 ft (4m) long and weighing 17 cwt (863 kg) plus a stream anchor weighing 6 cwt (305 kg) and a kedge anchor weighing 3 cwt (152 kg) (Curryer 1999, from Fincham 1825).

The best bower was let go at the time she first struck and the cable was later cut attempting to get out. It is not known if the other anchors she carried were removed during the salvage, but they would be worth salvaging and as large, single items would be easy to recover. Therefore it is probable that they are no longer on site.

Summary

The majority of the mass of iron on the ship would be the ~19 tons of iron ballast as the total mass of guns would be approximately 5 tons. The ballast would be difficult to recover being in the lowest part of the hold, so if still in place the ballast could be detected as a ~20 ton magnetometer target.

Other Targets

Other significant targets in the search area include the remains of other wrecks so targets detected in the area are not necessarily caused by *Whiting*. Anchors from wrecks who have managed to claw off the Doom bar may also be present.

The lobster fishermen put keep pots in this area but they do not contain a significant mass of iron so it is unlikely that they will be detected during the magnetometer survey.

Methodology

Introduction

When searching for any object on the seabed, it is important to apply detection methods that are appropriate for the expected target in the given search environment. Given the range of search tools available we can determine how each can be used and the constraints that each tool applies to our search strategy. From this we can determine an overall search plan and so estimate the duration of the data collection and processing phases along with the cost.

Search Strategy

The search will consist of a number of phases:

1. The search phase will be used to collect measurements and data from a number of instruments
2. The processing phase will take the measurements and data and reduce it to a simple set of targets
3. The investigation phase involves visiting each target in turn to identify it.

The instruments that we can deploy in the search phase include the magnetometer, side scan sonar, multibeam echo sounder and sub bottom profiler. These instruments are either fitted to or towed behind a boat which then runs a particular search pattern over the area of interest. The search pattern will be a set of parallel runlines each a known distance apart so the vessel sails up one line, turns around then sails down another, collecting information as it goes.

Positioning

For the magnetometer, side scan sonar, sub-bottom profiler and single beam echo sounder surveys a surface position accuracy of 5m or better is required. This accuracy can be achieved using differential Global Positioning System (GPS) using a local source of correction information, some wide area corrections providers or from the wide area augmentation system (WAAS).

Magnetometer

A magnetometer is an instrument that can measure the Earth's magnetic field so can be used to detect the presence of iron objects that affect or 'bend' that magnetic field. A marine magnetometer is most usually towed behind a boat with a cable providing power and communications to a computer on board that records the measurements. Changes in the magnetic field measurements from a single magnetometer can indicate the presence of iron objects nearby but the direction in which the objects lie is unknown. Using multiple magnetometers connected together can improve object location estimates but can also help to reduce interference which masks the signals we are looking for.

A magnetometer is a short-range instrument that can only detect small iron objects at close distances; for example 1 tonne of iron can be detected up to 12m away under good conditions. Because of this limitation the magnetometer is usually towed close to the seabed (if conditions allow) to minimise the distance between instrument and targets. In shallow water the magnetometer may be towed on or close to the surface as the distances to targets are short compared to the runline spacing, and towing close to the bottom is unsafe as the towfish may hit rocks and debris on the seabed. In this case as the water is shallow (average 10m) and the seabed is likely to contain debris the magnetometer will be towed close to the surface.

Given our lower estimate for the mass of iron to be 20 tonnes we can work out the maximum distance we can be from that mass of iron and still detect it. The change in signal we are looking for will have to be visible in amongst the background noise recorded by the magnetometer. Given good conditions we can detect signals down as low as 3nT but this can be adversely affected by how the magnetometer is towed, the quality of the electrical power provided to the instrument and the sea state during the search phase.

From the table below we can determine the detection distances for each mass of iron assuming a minimum deflection of 5nT:

Distance	1 tonne	5 tonnes	10 tonnes	20 tonnes
5m	80 nT	400 nT	800 nT	1600 nT
10m	10 nT	50 nT	100 nT	200 nT
15m	3 nT	15 nT	30 nT	60 nT
20m	1.1 nT	6 nT	12 nT	25 nT
30m	0.4 nT	2 nT	4 nT	8 nT
40m	0.15 nT	0.8 nT	1.5 nT	3 nT
50m	0.08 nT	0.4 nT	0.8 nT	2 nT

To detect a target of 20 tonnes we need to pass within a distance of no more than 30m. To calculate the maximum distance to any target given the line spacing and water depth we use:

Maximum distance $= \sqrt{(\text{water depth} + \text{burial depth})^2 + (\text{line spacing} / 2)^2}$

If deeper areas are run at low water and shallow at high water we can assume an average water depth of 10m. A line spacing of 20m gives a 14m maximum distance in 10m water depth and this is well within our 30m detection distance for a 20 tonne mass of iron. However, the area to be searched is small so the line spacing can be reduced to 10m while still allowing the area to be searched in a reasonable time and also allows for errors in surface positioning and vessel steering.

Magnetometers measure the magnetic field between 10 times per second and once per second. If the magnetometer is moving this data rate equates to a distance travelled and thus a distance between each measurement. Typical tow speeds are 3 knots and 5 knots for this kind of work.

3 kt (1.5 ms^{-1}) @ 10 Hz = 0.15 m per measurement, 1 Hz = 1.5m between measurements
5 kt (2.5 ms^{-1}) @ 10 Hz = 0.25 m per measurement, 1 Hz = 2.5m between measurements

This suggests that a magnetometer that can provide measurements 10 times per second and a tow speed of less than 5 knots would be appropriate.

Side Scan Sonar

If any of the remains of the *Whiting* are visible above the seabed then it may be possible to detect them using a side scan sonar. This instrument transmits pulses of sound sideways from a towfish so any objects standing proud on the seabed will reflect the sound which can then be detected and recorded by the sonar. The side scan sonar also picks up reflections from the seabed itself so it is possible to determine differences in the texture of the sand and sometimes buried objects can affect this texture. For this search we would be looking for very small targets caused by the remains of the hull so we should aim for a method that increases the available detail. The seabed in the area should be relatively flat sand so even small targets may be detected.

The side scan sonar can sometimes cover a width of hundreds of metres either side of the tow boat but in this case we would reduce this ‘swath’ width. The amount of detail that can be recorded increases if the swath width is reduced and the water here is shallow so the detail would be lost at longer ranges. A high frequency side scan sonar is needed for this search as it can resolve more detail than a lower frequency system and the extra range afforded by a low frequency system is not required. The sonar should be run on its minimum range setting using the highest ping rate and shortest pulse length to maximise the detail recorded.

Sub-Bottom Profiler

A sub-bottom profiler is effectively an echo sounder that can ‘see’ a little way into the seabed, using sound to produce a cross section of the seabed under the vessel’s track. How far the profiler signals can penetrate the seabed depends on the frequency of sound it uses to make the measurements. The resolution of the system or how well it can discriminate detail also depends on the frequency, as the frequency decreases the penetration increases but then detail is lost. Here we are also looking for old, wet wood buried or part buried in sand. For objects to show up on a profiler they need to look sufficiently different (as far as the profiler is concerned) but unfortunately the wet wood and the sand seabed look very similar – old wrecks are hard to detect this way. However, the effect that the wreck has had on the seabed itself may be more easily detected as the wreck may have dug itself a hole by scouring after it sank and we may be able to see the 'ghost' of the scouring action using the profiler.

The profiler will only record information about the seabed directly under the boat so to get complete coverage of any site would require runlines about 5m apart, this would take too long and would be too expensive to attempt. This instrument is best used in two phases, firstly during other work such as the magnetometer survey as it gives rather general information about the seabed and does not incur any extra vessel time. If 10m runline spacing suggested above were used then the profiler sections would be 10m apart to there is a reasonable chance that the wreck would be detected. As a secondary phase, any promising targets detected by the other instruments can then be specifically investigated in detail using the profiler.

Single Beam Bathymetry

If a multibeam echo sounder is not deployed then a low-cost single beam system is needed to obtain low resolution topography. Some bathymetry information is needed to create a 3D model of the seabed topography and also to correct the magnetometer measurements for differences in water depth.

The echo sounder can be run at the same time as the magnetometer survey so does not need any additional vessel time. Some sub-bottom profiler systems can output basic bathymetry information so this could be used instead. Tide correction can be limited to using computed tide height only as a precision of only 0.5m is required.

Search Area

The primary search area has dimensions of 400m x 275m, heading 70º True. This search area is wider than required as the wreck is thought to be on the west side of the Ketch, but the additional lines can be run if no significant targets are detected in the western half of the search box.

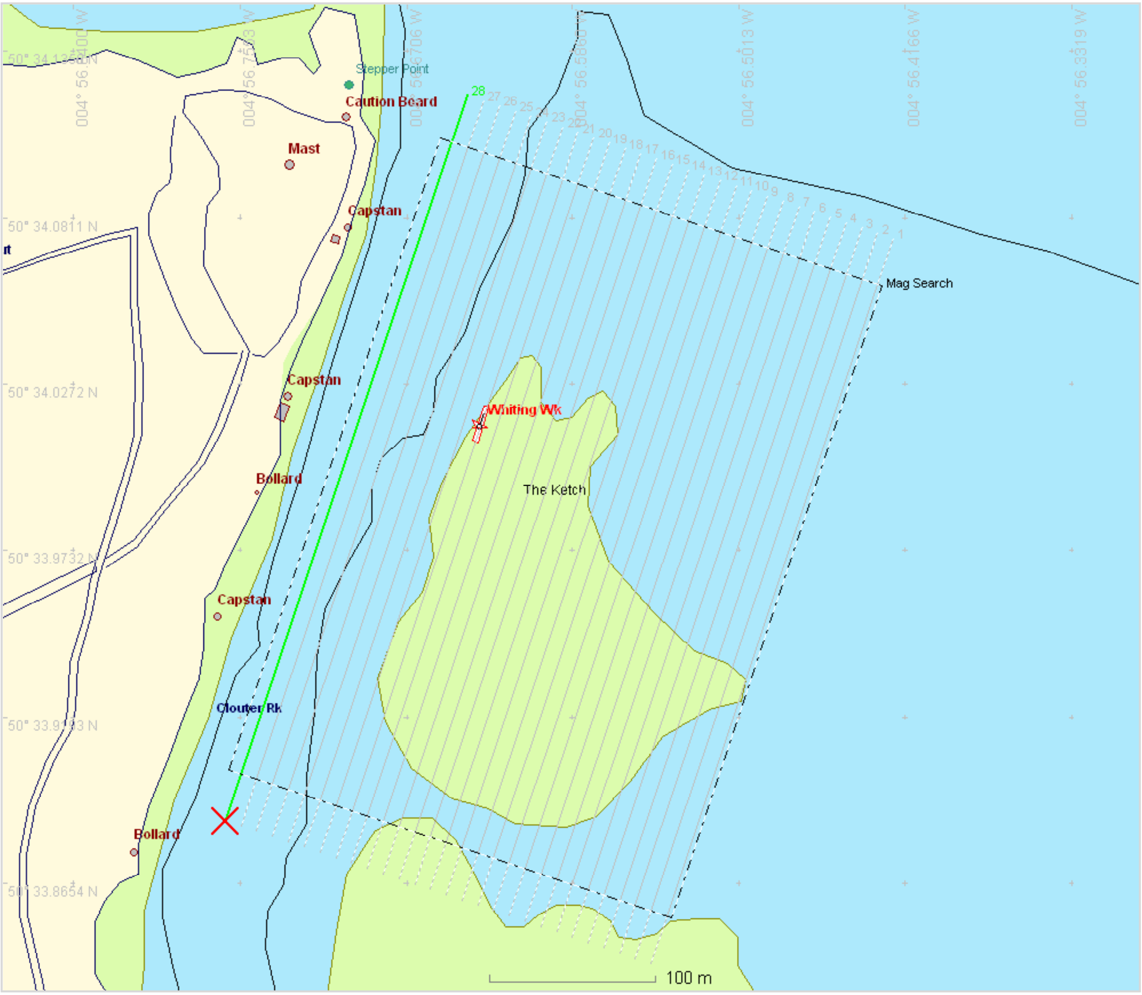


Figure 14: Search Area

With a line spacing of 10m gives total line length of 11.2 km excluding run in, run out and turns. At 5 kt (9 kmh^{-1}) this will take approximately 2 hours to complete.

Results

General

The geophysical survey was undertaken between 18th and 20th May 2010 from the fishing charter boat *Lady Mary* of Padstow, skippered by Jim West.

Positioning

Positions were provided by a Garmin 76C hand held GPS receiver aided by WAAS corrections giving an estimated precision of 4m. Coverage of the primary search area was estimated at 95% with significant amounts of repeat data over each target, while the secondary search area (10 run lines east side) were only part completed.

Magnetometer

Equipment

A Geometrics 881 caesium magnetometer was used for this survey making measurements at 10Hz with logging and processing using Site Searcher software.

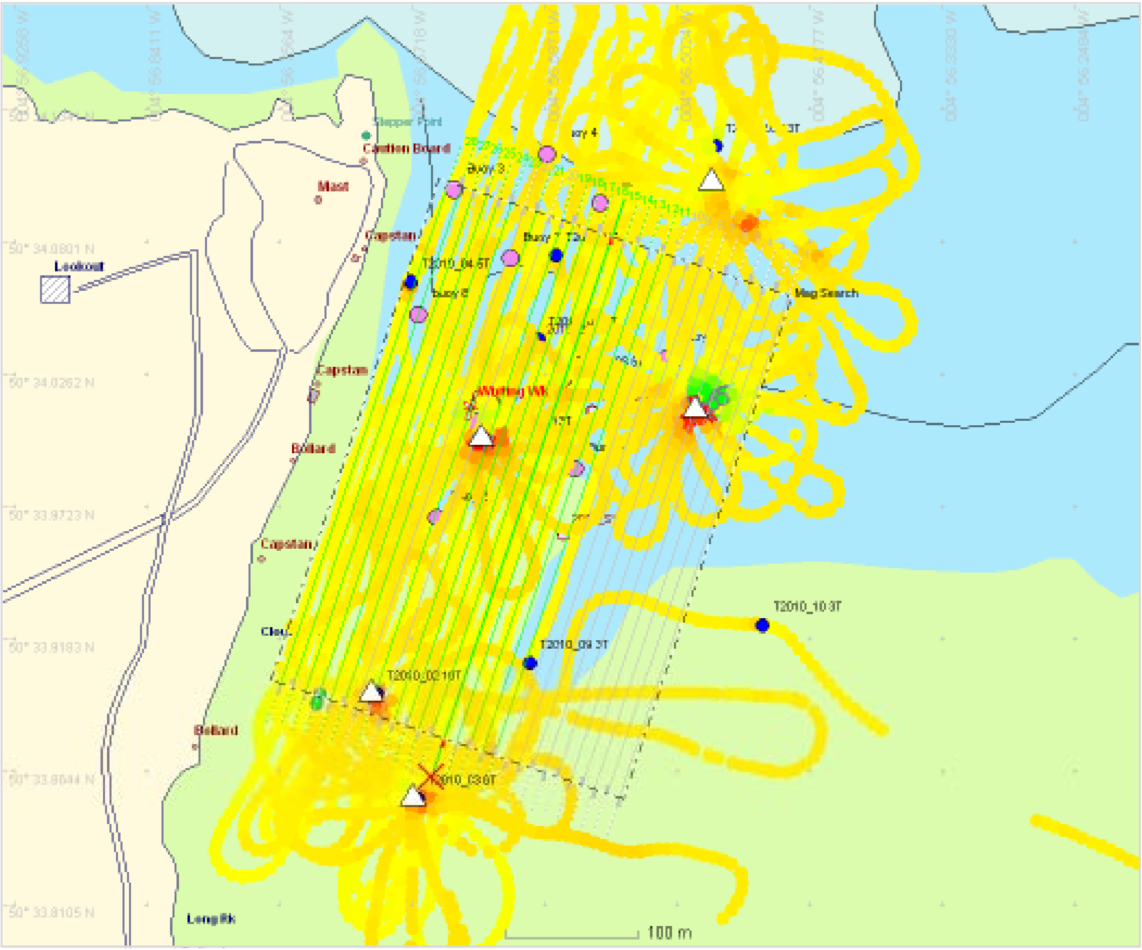


Figure 15: Magnetometer Tracks

The primary, western half of the search area was completed in one morning and a second morning was spent boxing-in the targets found during the first day and during the earlier side scan sonar survey.

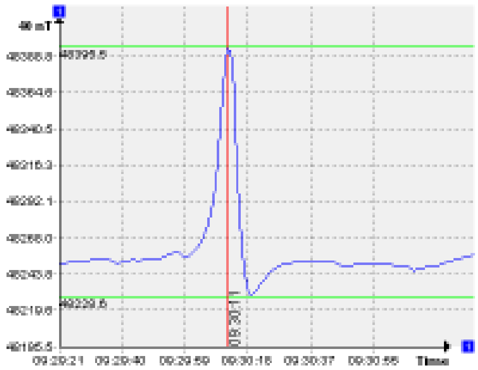
The list of targets below gives the position for each target and the water depth at that point. The Size shown is the maximum peak to peak signal variation over the target on any data collection run. The estimated minimum mass of that target is based on the target size and the assumption that the target is at seabed level and directly under the towfish. The half width value allows us to estimate the distance from towfish to target and calculate the horizontal distance to target assuming it is on the seabed and not buried (Camidge et al, 2009, p59).

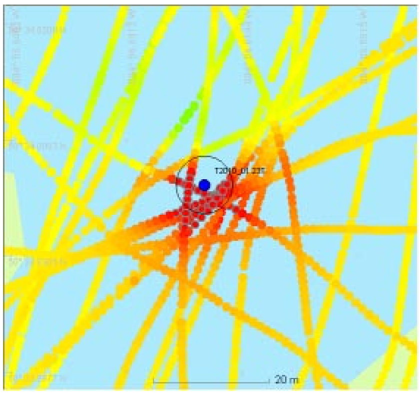
Targets

T2010_01

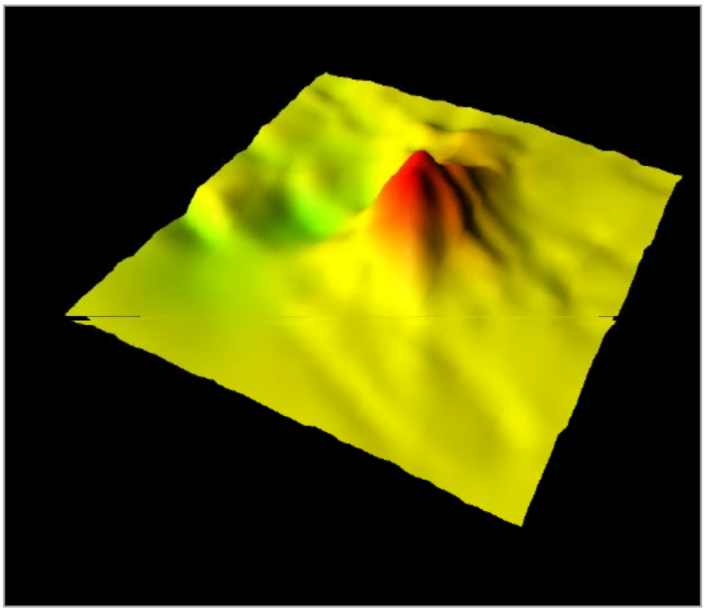
Name	T2010_01
Latitude	50° 34.0056 N
Longitude	004° 56.6192 W
Depth	10 m
Size P-P	268 nT
Estimated mass	23 tons
Half width	11.5 m
Distance to Target	1 m horizontal
Priority	High
Reference	Mag10 10:04:10

Comments:
Large clean target which is repeatable on a number of lines. Small negative anomaly to the north and larger positive anomaly to the south. Only 23m from estimated position of the *Whiting*





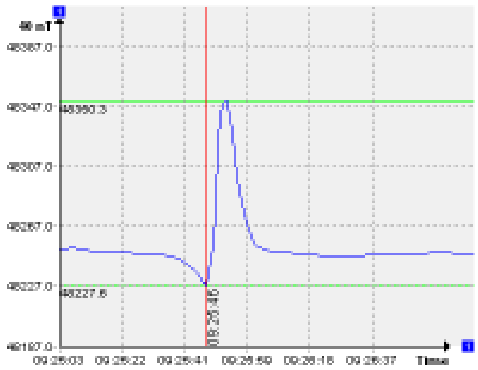
The plot above shows the measurement runs made across the target and the 3D anomaly model made from the measurements. From an altitude of approximately 10m target is detectable over an area 30m x 30m.



T2010_02

Name	T2010_02
Latitude	50° 33.9032 N
Longitude	004° 56.6818 W
Depth	10 m
Size P-P	127 nT
Estimated mass	11 tons
Half width	15 m
Distance to Target	5 m horizontal
Priority	High
Reference	Mag6L 09:25:50

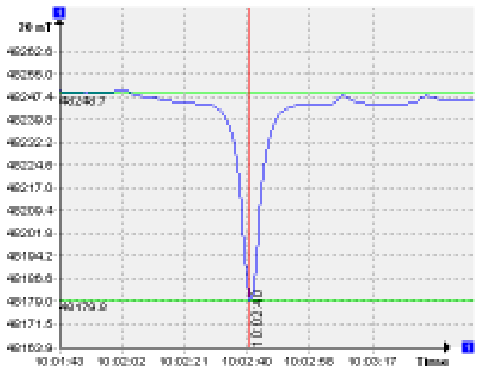
Comments:
Repeatable, clean target with small negative anomaly to the north and larger positive anomaly to the south



T2010_03

Name	T2010_03
Latitude	50° 33.8579 N
Longitude	004° 56.6543 W
Depth	10 m
Size P-P	165 nT
Estimated mass	14 tons
Half width	13 m
Distance to Target	3 m horizontal
Priority	High
Reference	Mag7 09:12:52

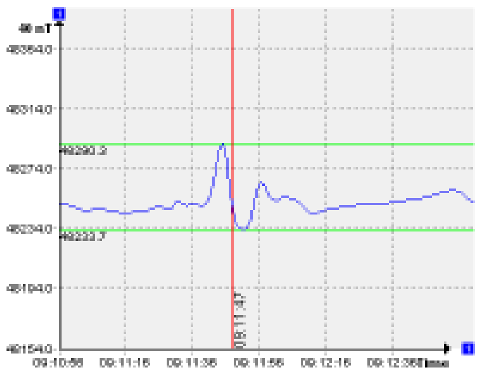
Comments:
Repeatable, clean target with negative anomaly to the north-west and positive anomaly to the south-east



T2010_04

Name	T2010_04
Latitude	50° 34.0680 N
Longitude	004° 56.6675 W
Depth	10 m
Size P-P	69 nT
Estimated mass	6 tons
Half width	10 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag6L 09:04:54

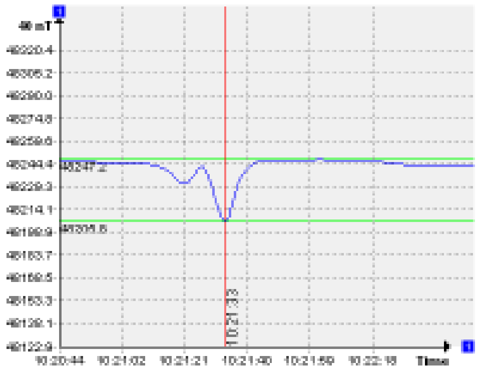
Comments:
Small, repeatable, scattered target



T2010_05

Name	T2010_05
Latitude	50° 34.0973 N
Longitude	004° 56.4548 W
Depth	10 m
Size P-P	104 nT
Estimated mass	32 tons
Half width	13 m
Distance to Target	3 m horizontal
Priority	High
Reference	Mag12 11:08:35

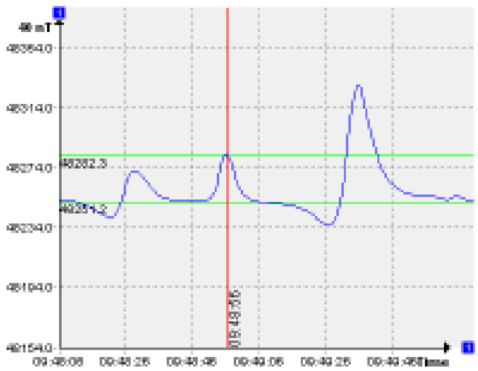
Comments:
Repeatable, clean target with small negative anomaly to the north and larger positive anomaly to the south. Associated with targets 11-14.



T2010_06

Name	T2010_06
Latitude	50° 34.0460 N
Longitude	004° 56.5855 W
Depth	10 m
Size P-P	33 nT
Estimated mass	3 tons
Half width	10 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag6L 09:48:56

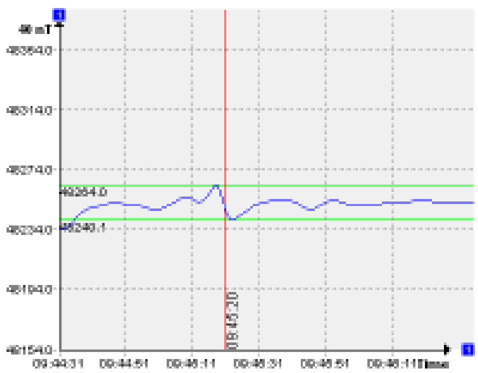
Comments:
Small positive anomaly detected on only one line. See also T2010_SS4



T2010_07

Name	T2010_07
Latitude	50° 34.0804 N
Longitude	004° 56.5757 W
Depth	10 m
Size P-P	32 nT
Estimated mass	3 tons
Half width	10 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag6L 09:48:25

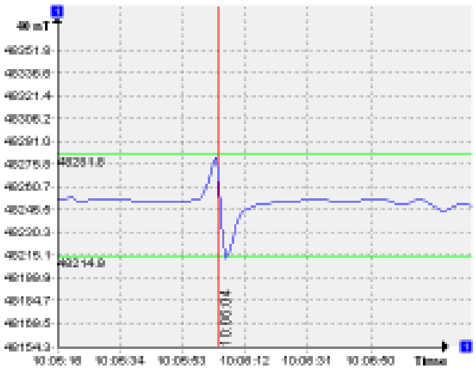
Comments:
Small, repeatable bipole



T2010_08

Name	T2010_08
Latitude	50° 34.0298 N
Longitude	004° 56.5674 W
Depth	10 m
Size P-P	67 nT
Estimated mass	5 tons
Half width	10 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag6L 10:06:05

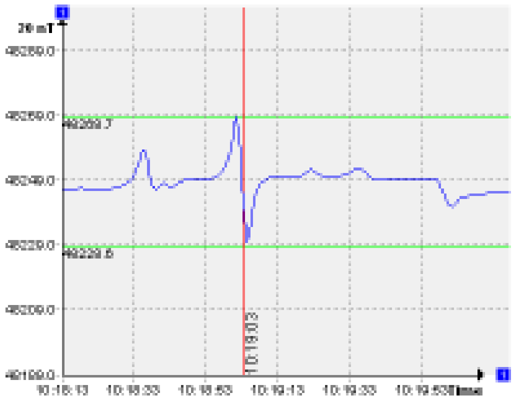
Comments:
Small target, repeatable bipole



T2010_09

Name	T2010_09
Latitude	50° 33.9142 N
Longitude	004° 56.5855 W
Depth	10 m
Size P-P	39 nT
Estimated mass	3 tons
Half width	10 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag6L 10:19:03

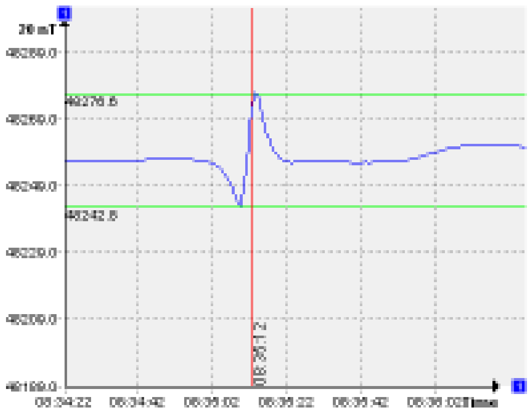
Comments:
Small bipole anomaly detected on only one line



T2010_10

Name	T2010_10
Latitude	50° 33.9321 N
Longitude	004° 56.4373 W
Depth	10 m
Size P-P	34 nT
Estimated mass	3 tons
Half width	11 m
Distance to Target	1 m horizontal
Priority	Low
Reference	Mag5L 08:35:11

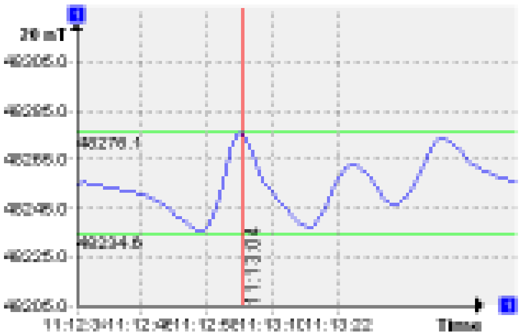
Comments:
Small bipole anomaly detected on only one line, out of search area



T2010_11

Name	T2010_11
Latitude	50° 34.1152 N
Longitude	004° 56.4710 W
Depth	15 m
Size P-P	53 nT
Estimated mass	16 tons
Half width	17 m
Distance to Target	3 m horizontal
Priority	Medium
Reference	Mag12 10:49:28

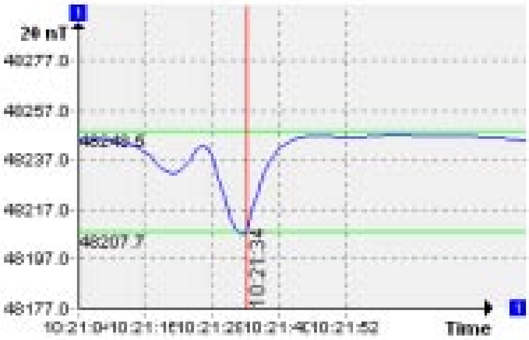
Comments:
Repeatable bipole anomaly, part of T05, T11-14 scatter.



T2010_12

Name	T2010_12
Latitude	50° 34.1247 N
Longitude	004° 56.4814 W
Depth	15 m
Size P-P	40 nT
Estimated mass	12 tons
Half width	17 m
Distance to Target	3 m horizontal
Priority	Medium
Reference	Mag6L 10:21:33

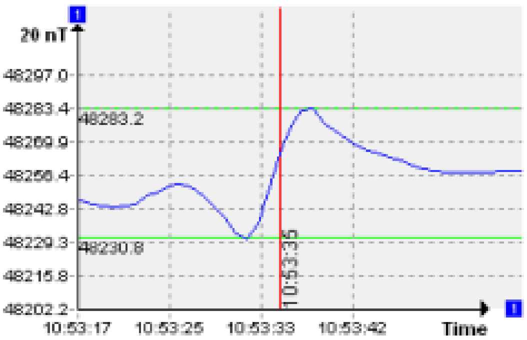
Comments:
Repeatable bipole anomaly, part of T05, T11-14 scatter.



T2010_13

Name	T2010_13
Latitude	50° 34.1061 N
Longitude	004° 56.4759 W
Depth	15 m
Size P-P	53 nT
Estimated mass	16 tons
Half width	17 m
Distance to Target	3 m horizontal
Priority	High
Reference	Mag12 10:53:35

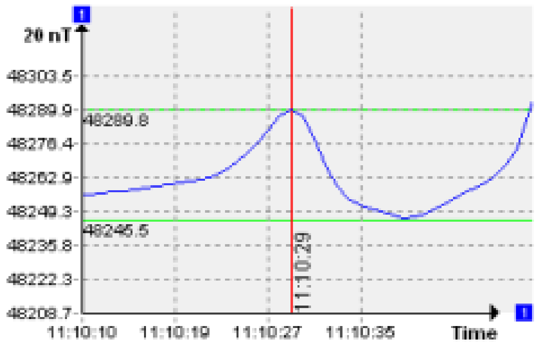
Comments:
Repeatable bipole anomaly, part of T05, T11-14 scatter.



T2010_14

Name	T2010_14
Latitude	50° 34.0842 N
Longitude	004° 56.4088 W
Depth	13 m
Size P-P	43 nT
Estimated mass	13 tons
Half width	14 m
Distance to Target	2 m horizontal
Priority	Medium
Reference	Mag12 11:10:31

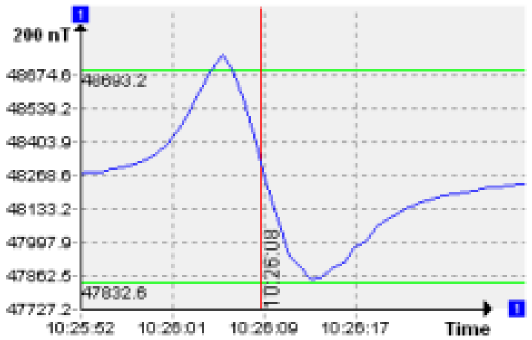
Comments:
Repeatable bipole anomaly, part of T05, T11-14 scatter.

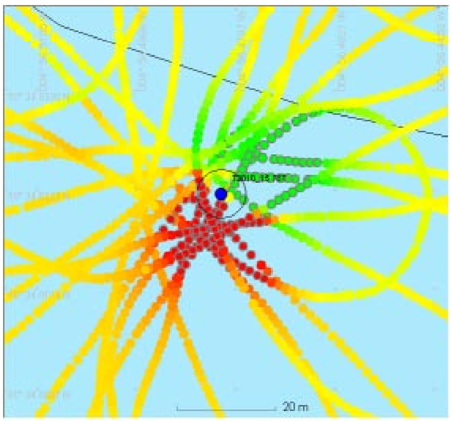


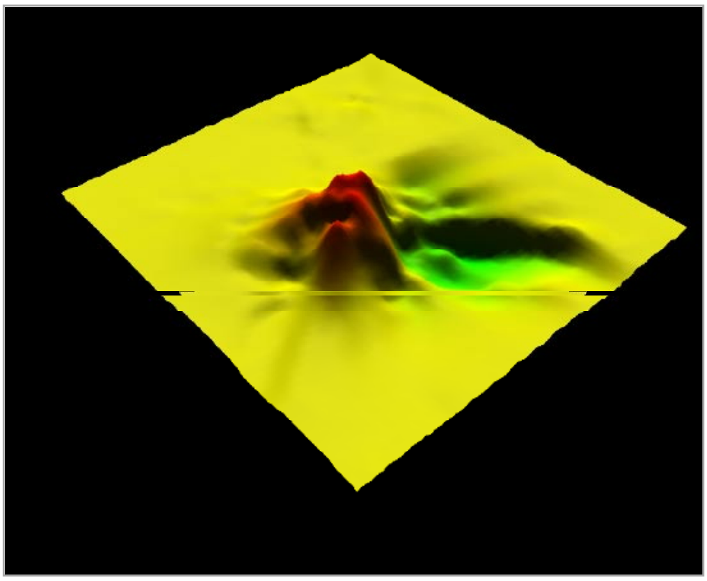
T2010_15

Name	T2010_15
Latitude	50° 34.0225 N
Longitude	004° 56.4813 W
Depth	10 m
Size P-P	911 nT
Estimated mass	78 tons
Half width	12 m
Distance to Target	3 m horizontal
Priority	High
Reference	Mag11 10:26:05

Comments:
Large bipole target with positive to the south west and negative to the north east
See also side scan target T2010_SS1







The plot above shows the measurement runs made across the target and the 3D anomaly model made from the measurements. From an altitude of approximately 10m target is detectable over an area 30m x 50m.

Note on Magnetometer Signals

With both targets plotted as 3D anomaly models (T2010_10 & T2010_15) it should be noted that the shape and size of the signal recorded by the magnetometer depends on the track of the magnetometer fish over the target. For target T2010_15, a run right across the target from south west to north east would result in a bipole (both positive and negative) signal that represents the true size of the iron target. However, a single run from south east to north west across the magnetic low of the northern part of the anomaly (green) would suggest a much smaller iron target. This is why targets should be 'boxed-in' with at least two runs at 90 degrees to each other over the assumed maximum for the anomaly, and repeated if a larger maximum value is detected in the process.

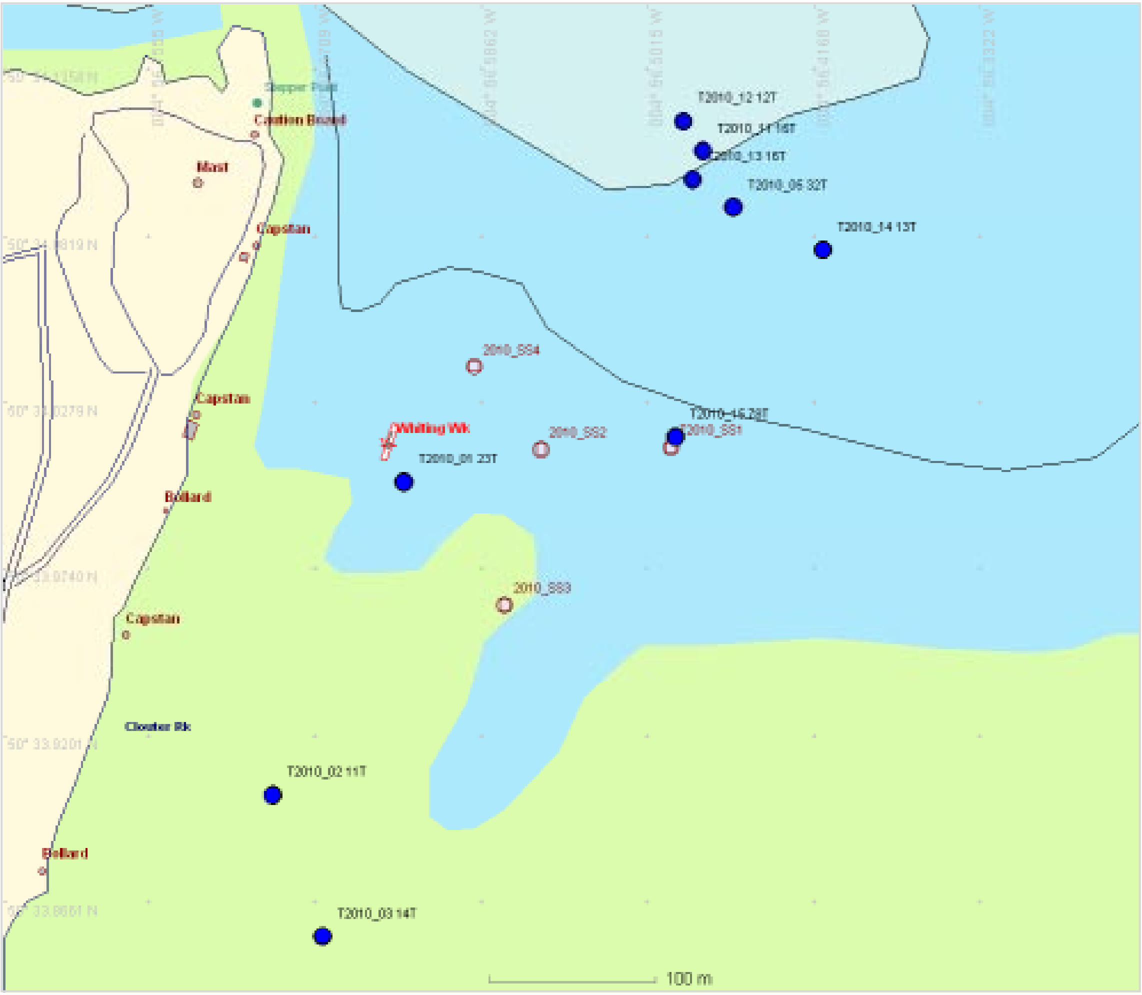


Figure 16: Magnetometer Target Positions

Side Scan Sonar

Equipment

Side scan survey data for part of the search area was provided by Jetsteam in Feb 2010 (Fig 17). Only a low resolution image of the processed data was provided but it was possible to make out a number of targets in the area covered. It is unfortunate that the most important part of the seabed around the predicted position for Whiting was not covered by this sonar survey.

A suitable high-resolution side scan sonar was not available for the search but a low-resolution Imagenex SportScan was tried, but there was a fault in the tow cable and it could not be used.

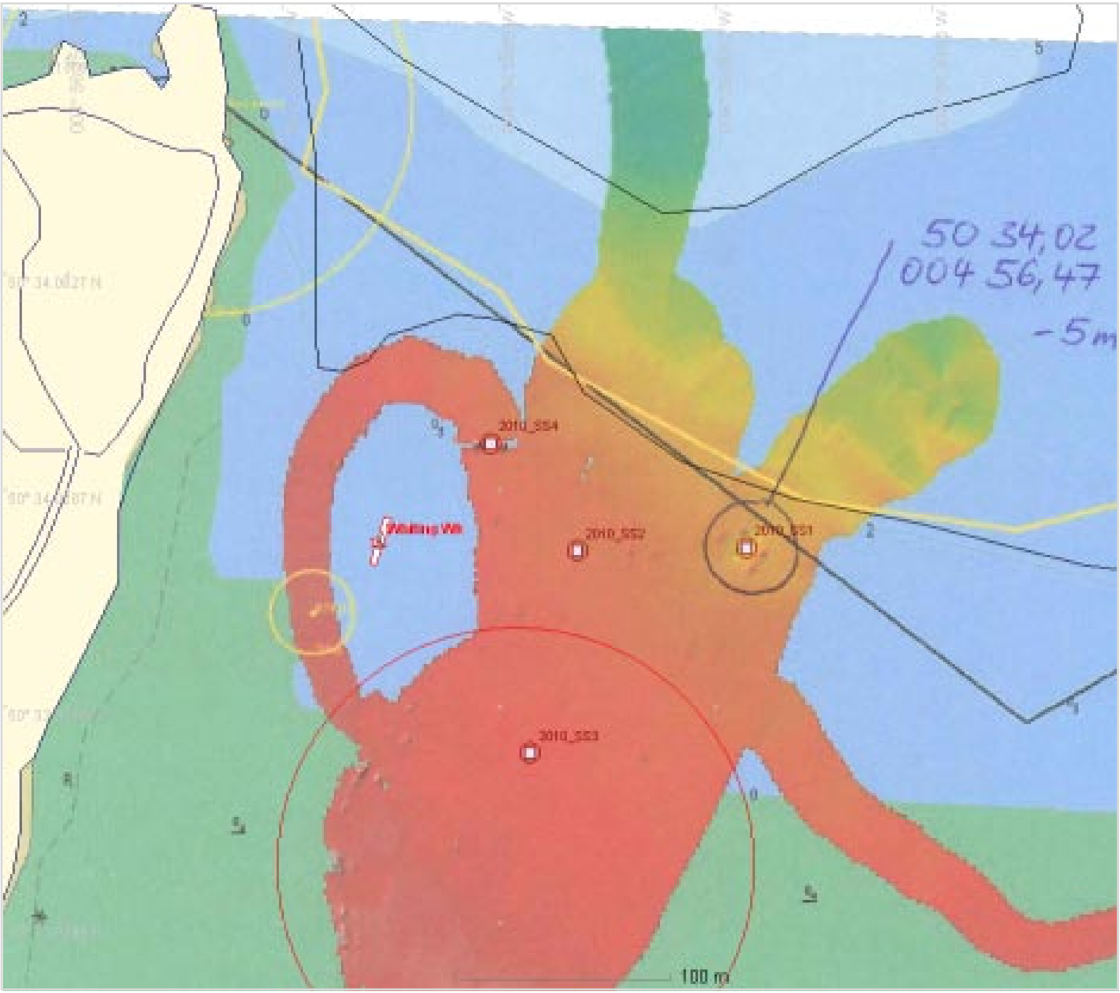


Figure 17: Low resolution side scan sonar image

Targets

T2010_SS1

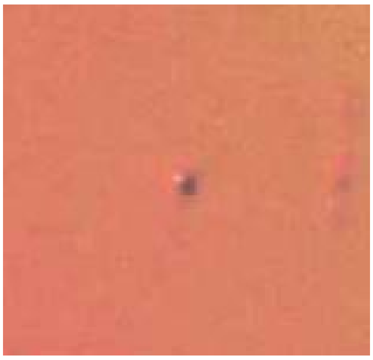
Name	T2010_SS1
Latitude	50° 34.0191 N
Longitude	004° 56.4835 W
Depth	10 m
Length	23 m
Width	18 m
Priority	High

Comments:
Large target proud of the seabed with a slight depression between. See also T2010_15

T2010_SS2

Name	T2010_SS2
Latitude	50° 34.0174 N
Longitude	004° 56.5497 W
Depth	10 m
Length	5 m
Width	5 m
Priority	Low

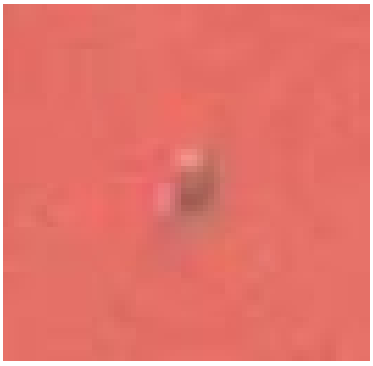
Comments:
Small target with no shadow, no magnetometer target



T2010_SS3

Name	T2010_SS3
Latitude	50° 33.9666 N
Longitude	004° 56.5661 W
Depth	10 m
Length	4 m
Width	4 m
Priority	Low

Comments:
Small target with no shadow, no magnetometer target



T2010_SS4

Name	T2010_SS4
Latitude	50° 34.0436 N
Longitude	004° 56.5849 W
Depth	10 m
Length	4 m
Width	4 m
Priority	Low

Comments:
Two targets 4m x 4m with shadow, 12m apart.
See also magnetometer target T2010_06

Sub Bottom Profiler

Equipment

On this survey a SyQuest StrataBox sub-bottom profiler was used. This is a low power marine sediment imaging instrument transmitting 300W at 10kHz and capable of 6cm resolution. The beamwidth of the transducer is not specified in the manual.

Unfortunately the instrument did not detect any significant targets buried in the sand. Detecting targets using sound in compacted sand is notoriously difficult so this result is not surprising.

The trace below shows a run across target T2010_01 where the yellow/green line at 6m depth represents the signal return from the seabed (Fig 18). The width of the bottom trace shows that sound was only penetrating a maximum of 1m into the seabed so targets below this would not be detected. The undulations on the seabed trace are due to vessel motion and do not represent the true seabed shape.

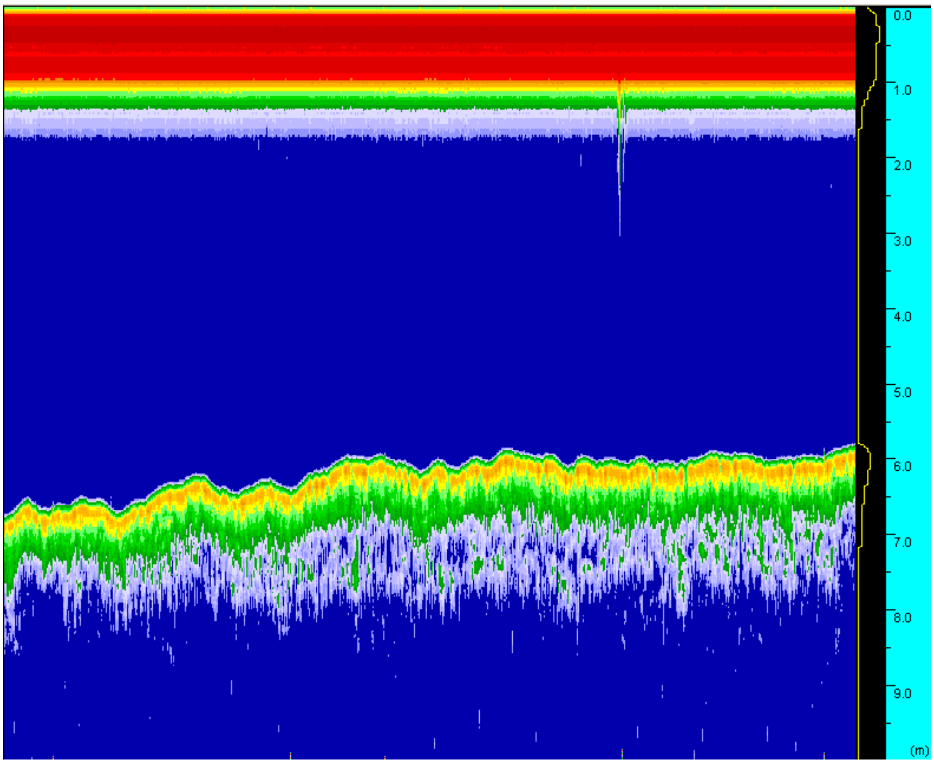


Figure 18: SBP Trace over T2010_01

Conclusions

The geophysical survey undertaken to search for the remains of Arrow / HMS Whiting detected a number of magnetic and sonar targets within the search area.

The estimated precision for the surface positioning was approximately 5m over the whole survey area, hence small enough to be able to use divers to relocate any targets detected. Coverage of the primary search area was estimated at 95% so it is unlikely that any targets were missed due to gaps in the data set.

The results from the magnetometer survey show that it was capable of detecting magnetic targets larger than 3 tons, so there is a high probability of detecting the 20 tons of iron estimated for the Whiting's ballast.

The side scan sonar data is incomplete as the original data provided did not cover the whole survey area and the side scan sonar to be used during the survey was faulty. This means that some surface visible non-magnetic targets in the search area may not have been detected.

The sub-bottom profiler did not detect any significant targets, this suggests that the profiler was not capable of detecting targets in this sediment rather than there being no targets to detect. Some buried non-magnetic targets in the search area may not have been detected.

Magnetic target T2010_01 has an estimated mass of 23 tons of iron and is only 23m from the estimated sinking position of the Whiting so is the target most likely to be the remains of this ship. Unfortunately the side scan data does not include the area in which this target lies so it is not possible to determine if it is visible on the seabed.

Magnetometer targets T2010_2 (11 tons) and T2010_3 (13 tons) may well be the remains of small shipwrecks. The positions of these targets are suggest that they will become exposed at low spring tides so could be investigated on foot.

Targets T2010_5 and T2010_11 to 14 may be related as they form a rough line 100m long oriented north west to south east. These may be a debris trail from a shipwreck.

Side scan sonar target T2010_SS1 and magnetometer target T2010_15 represent the same anomaly on the seabed and are most likely to be a wreck 23m x 18m that includes 78 tons of iron.

It is recommended that the high priority targets be investigated by divers and where possible investigated on foot at extreme low tide.

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Target List

Reference: PADWHT 180510

All positions given in WGS84, depths to LAT in metres (estimated)

Name	Tons	Latitude	Longitude	Depth	Priority
T2010_01	23T	50° 34.0056 N	004° 56.6192 W	3	High
T2010_02	11T	50° 33.9032 N	004° 56.6818 W	0	High
T2010_03	14T	50° 33.8579 N	004° 56.6543 W	0	High
T2010_05	32T	50° 34.0973 N	004° 56.4548 W	5	High
T2010_11	16T	50° 34.1152 N	004° 56.4710 W	5	High
T2010_12	12T	50° 34.1247 N	004° 56.4814 W	5	High
T2010_13	16T	50° 34.1060 N	004° 56.4759 W	5	High
T2010_14	13T	50° 34.0842 N	004° 56.4088 W	5	High
T2010_15	78T	50° 34.0224 N	004° 56.4813 W	3	High
T2010_04	6T	50° 34.0680 N	004° 56.6675 W	2	Low
T2010_06	3T	50° 34.0460 N	004° 56.5855 W	3	Low
T2010_07	3T	50° 34.0804 N	004° 56.5757 W	4	Low
T2010_08	5T	50° 34.0298 N	004° 56.5674 W	3	Low
T2010_09	3T	50° 33.9142 N	004° 56.5855 W	1	Low
T2010_10	3T	50° 33.9320 N	004° 56.4373 W	1	Low
T2010_SS2		50° 34.0174 N	004° 56.5497 W	3	Low
T2010_SS3		50° 33.9666 N	004° 56.5661 W	1	Low
T2010_SS1	See T2010_15				
T2010_SS4	See T2010_06				