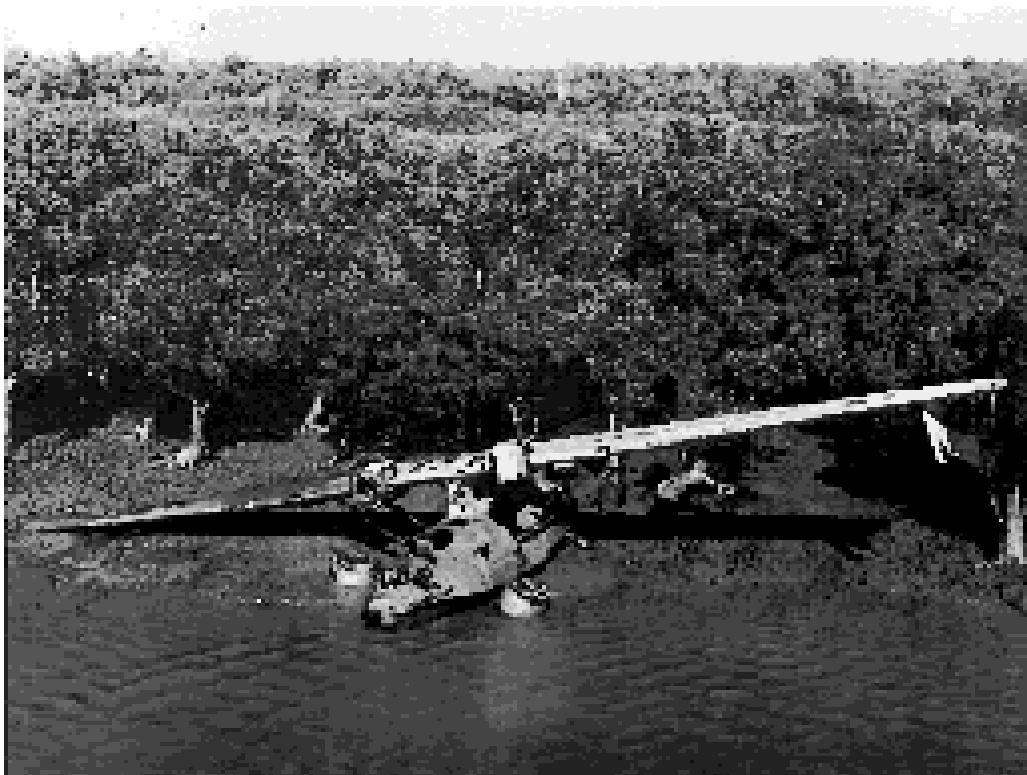


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Editors: Jeremy Green and Myra Stanbury

The Australian Institute for Maritime Archaeology

President: Bill Jeffery, State Heritage Branch, Department of Environment and Natural Resources, GPO Box 1047, ADELAIDE SA 5001. Ph: 08 8204 9311; Fax: 08 8204 9250; Email: jefferb@dep.sa.gov.au

Secretary: Terry Arnott, State Heritage Branch, Department of Environment and Natural Resources, GPO Box 1047, ADELAIDE SA 5001. Ph: 08 8204 9245; Fax: 08 8204 9250; Email: arnottt@dep.sa.gov.au

Treasurer: Patrick Baker, Western Australian Maritime Museum, Cliff Street, FREMANTLE WA 6160. Ph: 089 431 8443; Fax: 089 335 7224; Email bakerp@museum.wa.gov.au

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STATE COUNCILLORS:

South Australia:

Peter Bell, 17 Sherwood Terrace, BEAUMONT SA 5066. Ph: 08 8379 6498; Fax: 08 8338 2460; Email: pbell@adelaide.on.net.au

Victoria:

Peter Harvey, Heritage Victoria, Level 2 NAURU House, 80 Collins St, MELBOURNE VIC 3000. Ph: 039 628 5025; Fax: 03 9628 5650; Email: peter.harvey@dpc.vic.gov.au

Ross Anderson, Heritage Victoria, Level 2 NAURU House, 80 Collins St, MELBOURNE VIC 3000. Ph: 039 628 5025; Fax: 03 9628 5650; Email: ross.anderson@dpc.vic.gov.au

Malcolm Venturoni, MAAV, 20 Sixth Avenue, CHELSEA HEIGHTS VIC 3196. Ph: 03 9772 4727; Mobile: 015 814535; Email c/- Peter Harvey

Tasmania:

Mike Nash, Parks, Wildlife and Heritage, PO Box 44A, HOBART TAS 7001. Ph: 0362 332 387; Fax: 0362 240 884; Email mike.nash@delm.tas.gov.au

Keith Moon, Maritime Archaeology Association of Tasmania, 152 Mt Rumney Road, MT RUMNEY TAS 7170. Ph: 03 6261 0469; Email: kemoon@ozemail.com.au

New South Wales:

Tim Smith, Heritage Office, Governor Macquarie Tower, 1 Farrer Place, SYDNEY NSW 2000. Ph: 02 9391 2037; Fax: 02 9391 2336

Cos Coroneos, 46 Gale Road, MAROUBRA NSW 2035. Ph/Fax: 02 9344 3120; Email: cosmosc@ozemail.com.au

John Riley, GPO Box 52, BONDI NSW 2026. Ph: 02 9389 5341

Queensland:

Peter Gesner, Queensland Museum, PO Box 3300, SOUTH BRISBANE QLD 4101. Ph: 07 3840 7673; Fax: 07 3846 1918; Email: P.Gesner@mailbox.uq.edu.au.

Warren Delaney, Queensland Museum, PO Box 3300, SOUTH BRISBANE QLD 4101. Ph: 07 3840 7600; Fax: 07 3846 1918;

Northern Territory:

Paul Clark, Northern Territory Museum of Arts and Sciences, GPO Box 4646, DARWIN NT 0801 Ph: 088 999 8283; Fax: 088999 8289; Email paul.clark@nt.gov.au

Tim Smith, Northern Territory University, DARWIN NT 0909. Ph: 08 8946 6324; Email: tim.smith@ntu.edu.au

Western Australia:

Dena Garrett, Western Australian Maritime Museum, Cliff Street, FREMANTLE WA 6160. Ph: 089 431 8435; Fax: 089 335 7224; Email: garattd@museum.wa.gov.au

Brian Richards, 36 Loris Way, KARDINYA WA 6163. Ph: 089 337 1638; Fax: 089 310 8480; Email: brianr@cleo.murdoch.edu.au

Commonwealth:

Kieran Hosty, Australian National Maritime Museum, GPO Box 5131, SYDNEY NSW 2000. Ph: 02 9552 7710; Fax: 02 9552 2318; Email: khostey@anmm.gov.au.

New Zealand:

David Churchill, Maritime Archaeological Association of New Zealand, 22 Nassau Avenue, Grenada North, Wellington, New Zealand. Ph: 04232 8006; Mobile: 025 531003

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A review of stabilisation works on the wreck of the *William Salthouse* in Port Phillip Bay.

Peter Harvey

Maritime Heritage Unit, Heritage Victoria, Level 22, NAURU House, 80 Collins Street, MELBOURNE VIC 3000



Figure 1. One of five steel mesh fences placed onto the site in 1985.



Figure 2. Attempt to fill scour holes by underwater sediment dredging. Note the large amount of suspended sediment.

Abstract

The *William Salthouse* in Port Phillip Bay is amongst Victoria's most significant shipwrecks. Since its discovery by sport divers in the early 1980s the archaeological integrity of the site has been threatened by erosion of the sediments in which it rests. In the past ten years the wreck has been subjected to a number of attempts to halt this erosion. This paper reviews the history of stabilisation works on the *William Salthouse* and explain, in detail, the most recent work and its results.

Background

The barque *William Salthouse* was built in 1824 and, for the next seventeen years, was used in trade between Britain and its colonies in the West Indies. The *William Salthouse* was wrecked whilst entering Port Phillip heads after a voyage from Canada with a speculative cargo for Melbourne. A more detailed treatment of the history and wrecking of the *William Salthouse* can be found in Staniforth and Vickery (1984).

Site discovery

The wreck was re-discovered in August 1983, by two Geelong divers, Peter Kennedy and Dennis Bolton, during a drift dive near the Popes Eye Bank in Port Phillip Bay. The location of the newly discovered wreck quickly became common knowledge amongst divers and soon became the focus of concentrated disturbance by souvenir hunters. In the frenzy of looting that followed, considerable disturbance and apparent de-stabilisation of the site took place (Staniforth & Vickery, 1984).

When the wreck was first examined by staff of the Maritime Heritage Unit (MHU)¹ in December 1982 cargo, timbers and bottles were seen to be strewn around the site and material scattered up to 50 metres away from the main wreck deposit. Despite the disturbance which had occurred as a result of looting, it was found that a considerable part of the hull and its contents had survived in its original context. Tidal scour was noted during the inspection and estimated to be about 125 mm per day. It was also noted that the wreck site was situated in the top of a large dune formed from mobile sediments (Strachan, 1988). Exposed sections of the wreck supported very little marine growth and had suffered little deterioration.

Official inspection of the site led to its provisional declaration as an historic shipwreck under the terms of the *Historic Shipwrecks Act 1981* (Vic). Despite declaration, the looting continued. This led to the further step of declaring a 250-metre radius protected zone around the site on 9 February 1983.

Further inspection of the site during March 1983 indicated that declaration of the protected zone appeared to have put an end to unauthorised disturbance (Strachan, 1988).

Test excavation

Because of concern that the site would deteriorate further in the tidal flow, an emergency test excavation was planned and conducted in 1983 (Staniforth & Vickery, 1984). The major aim of the project was to make a detailed plan of the site which could be used in future management. Excavation work had as its principal aims



Figure 3. Dredge *Matthew Flinders* during dumping of spoil on the site.



Figure 5. Un-supported hull beginning to break open and spill wreck contents.

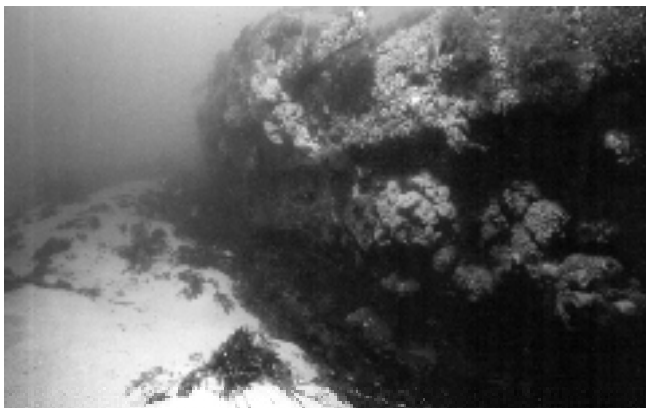


Figure 4. Scour hole and unsupported hull structure near the bow of the wreck.



Figure 6. A butress of sandbags supporting the hull.

the documentation of stowage methods used in the vessel and the recovery of artefacts threatened by scouring or theft by divers. Other aims included the raising, for later display, of artefacts reflecting the needs of the first decade of European settlement in Victoria (Staniforth & Vickery, 1984). Publicity for the project was also expected to heighten public interest and awareness of the need for protection and investigation of maritime archaeological heritage (Strachan, 1988).

Prior to the start of the test excavation, loose material, which had been scattered over the site as a result of the looting, was gathered up and placed in bags which were then re-buried at the bow of the wreck to prevent it being washed off the site by tidal currents (Strachan, 1988). During the excavation two trenches 2 metres wide were cut across the site. One was placed just forward of the mainmast, through the main cargo hold area, and the other was placed aft of the mainmast (Staniforth & Vickery, 1984). The excavation recovered a large amount and variety of cultural material which has been conserved and is currently held at the Heritage Victoria conservation laboratory.

During the ensuing two years, a number of inspections of the site were conducted. In October 1983, scour holes around the wreck were observed to have increased in size,

and a number of artefacts had been dislodged. Some of the loose artefacts were raised to prevent their loss. Further inspection, in 1984, indicated that scouring appeared to have been reduced and that the stern of the wreck was completely covered with sand (Strachan, 1988).

Public access

The *William Salthouse* and the 'treasures' it contained shot to fame amongst the Victorian SCUBA diving public. This was probably the result of extensive press coverage which had been obtained at the time of the initial discovery and looting of the wreck, and during the course of the test excavation of the site.

With the completion of the excavation, it was decided to set in place a system of permit access which would allow a limited numbers of divers (12) to visit the site at strictly controlled times. The first permit was issued for March 1984.

Dive charter operators quickly took advantage of the high levels of diver interest in the site and became the major users of the access permit system. Many private boat operators also obtained permits to dive on the site. In the period between January and April 1987, in excess of 180 divers visited the site. During this period, MHU staff visited the site, more or less regularly, with the aim



Figure 7. An assembled 'Cegrass' mat showing pattern arrangement of elements on the grid.

of monitoring the activities of permit holders as well as monitoring the physical condition of the wreck. At this stage, such monitoring was almost entirely qualitative, relying on observation and estimation of changes to the sea-bed and wreckage.

During the monitoring visits, MHU staff noted that a large proportion of the visitors to the site were newly qualified or trainee divers exhibiting poor buoyancy control which resulted in frequent, often violent, contact of the diver with the sea-bed and wreckage. These check-up dives also revealed that many divers, despite having been warned of the legal consequences of disturbing the wreckage, could not resist hand-fanning to uncover objects of interest and then moving them about the site. It was also noted during these visits that scouring around the wreck appeared to have increased.

Early in 1985, five small fences were placed on the site in an attempt to reduce scour around the wreck. The fences measured 1 metre long by 50 centimetres high and were supported by a star picket at each end. They were intended to trap the seaweed that drifted across the site and form a barrier which would cause a build-up of sediment in the areas which had been subject to scouring (Fig. 1). Another inspection of the site, in September 1985, revealed that while the fences had remained in place they had little effect in reducing scouring. A further attempt to reduce the size of scour holes at the bow by using a hand dredge to pump in sand from off the site was also unsuccessful (Fig. 2).

Bulk dumping of sand on the site was also attempted with the dredge *Matthew Flinders* (Fig. 3) depositing a full cargo of dredge spoil on the site. This also had a limited net effect with only a light dusting of sand evident on the wreck at the completion of the exercise.

Concerns on the part of the MHU staff about the inability of any of the measures tested to slow or even halt the erosion on the site, and also about the cumulative effect of the accidental and deliberate disturbances caused by divers, led to the closing of the site to the diving public in June 1988.



Figure 8. Assembling the mats.

Just prior to, and after, the closure of the site, it was extensively re-surveyed to gather quantitative information on the extent and severity of erosion. The results of this work confirmed previous observations that sediment was being rapidly eroded from the site (Fig. 4) and that, without prompt intervention, the remaining hull structure would collapse (Fig. 5) and spill its contents onto the sea-bed (Strachan, 1988; Hosty, 1988).

A number of solutions to the erosion of sediments from the site were examined and, because of the urgency of the problem, it was decided to adopt the temporary measure of supporting the undermined sections of hull structure with buttresses made from sandbags (Fig. 6). A detailed account of this work can be found in Hosty (1988). The sandbagging of the site provided a valuable 'breathing space' of about twelve months, in which options for a more lasting solution to the problem could be examined.

The sandbag buttresses successfully supported the sides of the wreck and thus prevented further collapse. Some mitigation of scouring near the wreck was also observed. Although the sandbag walls were successful in halting



Figure 9. Stock of folded mats ready for transport to the site.

the break-up of the wreck, by late 1989 the hessian bags used in the construction of the walls had begun to break open and some toe-scour was becoming evident at the outer ends on the buttresses. However, the sandbags had provided the time necessary to evaluate more permanent options for the stabilisation of the site.

Artificial sea-grass matting

The MHU obtained information about two similar artificial sea-grass systems designed to cause deposition of sediments: Scour control Mats provided by Sea-bed Scour Control Systems Ltd of Suffolk UK; and 'Cegrass Erosion Control System, provided by Cebo UK Ltd, based in Aberdeen, UK.

The primary aim of the site stabilisation is to provide long-term stability to a site by stabilising and binding sea-bed sediments. Both of the systems examined by the MHU work by reducing current velocity near the sea-bed. This prevents sediments from being entrained by the current and causes sediment suspended in the flow to be deposited in the mats. While both systems promised a similar result, simplicity of deployment and the absence of a need for specialised equipment favoured the selection of the Cebo product.

Description

Cebo Cegrass is manufactured from closed cell foamed polypropylene in approximately 1.6 cm wide strips. Twenty-four strips are attached to a plastic clip to form an element. The elements used on the *William Salthouse* site were either 90 cm, 120 cm or 150 cm long. Elements were attached to steel mesh sheets measuring 600 cm by 240 cm with a grid spacing of 20 cm. The steel mesh is readily available and commonly used for concrete reinforcing. Assembled mats required a weight of 9 kg/m² for successful anchoring to the sea-bed.

The base of the elements is formed into a clip which allows them to be attached directly onto the steel mesh. The supplier's specification required individual elements to be attached to the steel mesh in the pattern shown in Figure 7.

Assembly

Prior to having the Cegrass elements attached to them, the steel mesh mats were cut in half and re-joined with galvanised steel shackles in order to form a hinge. The hinged steel mat was then laid out on the ground and the Cegrass elements clipped to the mesh in the specified pattern (Fig. 8).

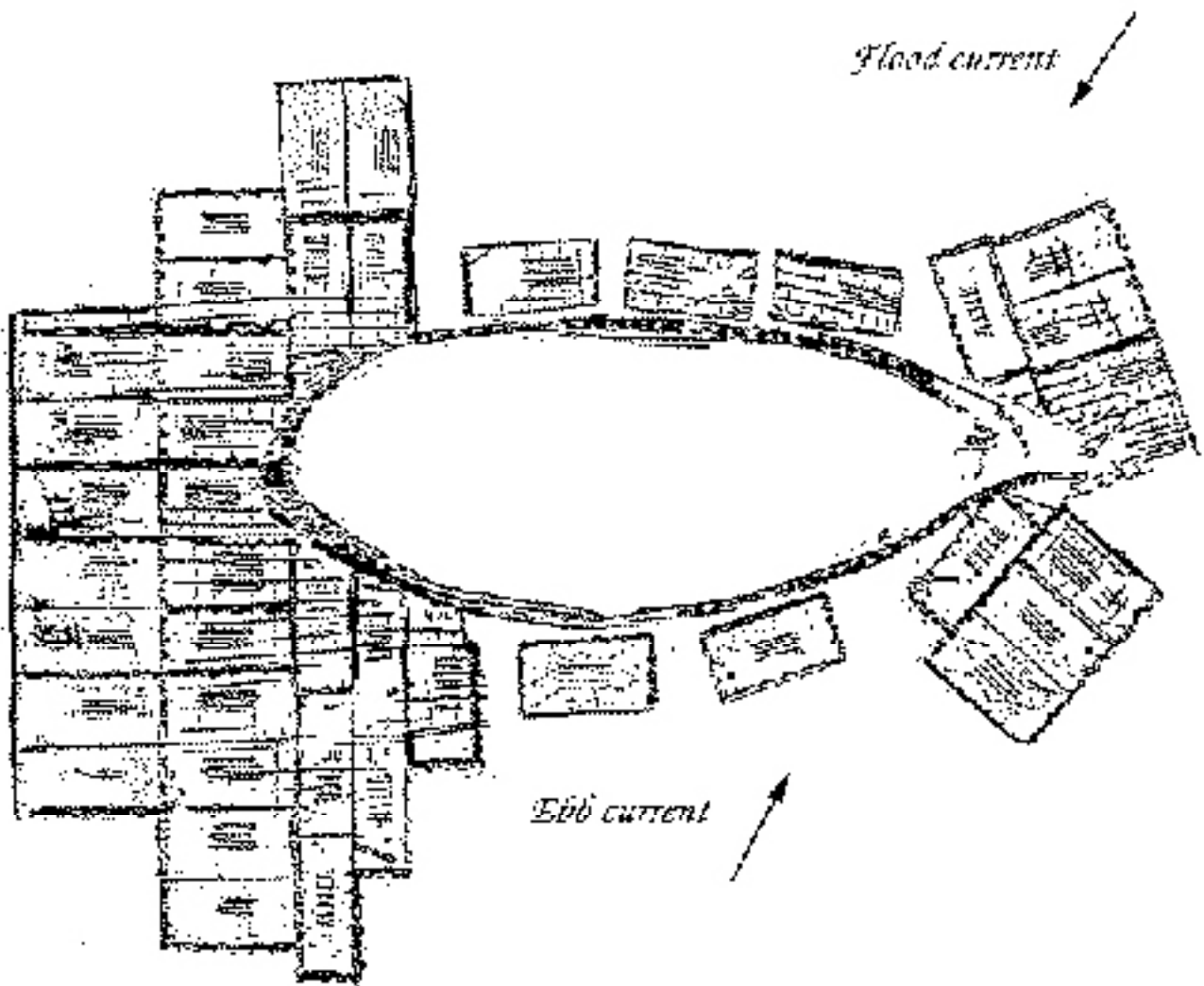


Figure 10. Arrangement of 'Cegrass' mats around the wreck.

After all the elements had been attached, the fronds were folded toward the centre of the mat and light hempen string was used to tie them close to the mat. [When underwater, this prevented the fronds from rising into their normal position so that divers could easily ballast and join the mats without becoming entangled and damaging the elements.] After the fronds were tied down, the mats were folded in half with the fronds on the inside, tied shut and stacked ready for transport to the site (Fig. 9). Folding the mats made it easier for divers to move them into position on the sea-bed and also protected the fronds from damage in transit.

Ballast

The original specification for the Cegrass recommended that the mats be ballasted with short sections of heavy scrap chain. The required quantities of scrap chain were not available and the cost of buying new chain for the job was prohibitive. An alternative ballast material was found

in the form of used railway track. The track was cut into approximately 30 cm lengths with a gas torch and two 3 cm chain links were welded to each section.

Transport

Both the ballast and the Cegrass mats were transported to the site using the MHU's 7-metre work boat. The ballast was dropped to the sea-bed near the wreck in clusters of five or six sections. Plastic soft drink bottles attached to the clusters with a short lanyard enabled the ballast to be relocated if it became buried on the sea-bed. Cegrass mats were transported to the site up to five at a time. On arrival at the site a dive team entered the water with a surface float and proceeded to the location on the site where the mats were to be deployed. Once the divers were in position, the line was tied to the mats and they were slid into the water.

Groups of two or three mats were found to be slightly buoyant. However, the addition of a diver's weight belt

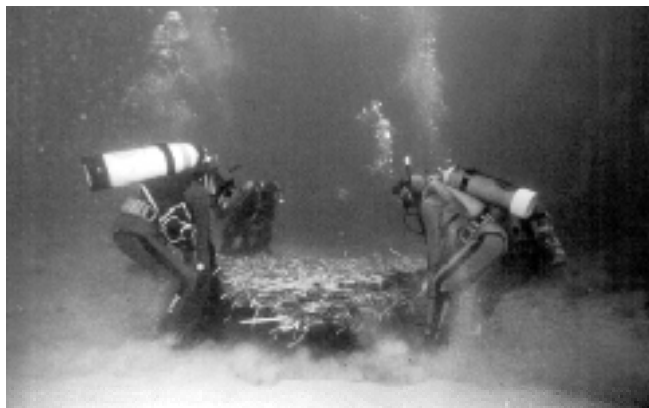


Figure 11. Folded mats are manoeuvred into position by teams of up to four divers.



Figure 14. Sediment deposits *c.* one week after placement of mats.



Figure 12. The mat is unfolded.

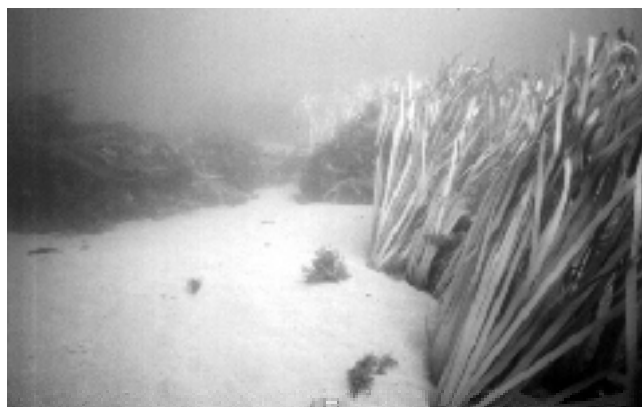


Figure 15. Sediment deposits *c.* one week after placement of mats.



Figure 13. The fronds are allowed to rise to their normal position.



Figure 16. Area shown in Figure 5 after placement of mats.

allowed them to sink slowly to the bottom. The divers at the drop site were easily able to pull the mats to the general deployment location as they sank. Because delivery of materials to the site was weather dependent, calm weather was used to build stockpiles of folded mats and ballast on the sea-bed.

Deployment of the mats

Arrangement of the mats on the sea-bed was determined by Cebo UK, based on a wreck site plan

with contour details provided to them. Mats with 150 cm frond lengths were placed in the areas where the scour was deepest, with the shorter frond length mats being used in less severely scoured areas. While placing the mats over the top of the wreck may have provided more complete protection of the wreckage, this option was avoided in order that some of the wreck contents and the outline of the ship's hull would remain visible for the benefit of divers visiting the wreck under the permit system.

In preparation for deployment of the mats, a dive team measured in the locations of the mats and marked the corners of deployment areas with white fibreglass poles. This work was done in extremely poor visibility and it was only after the first four mats had been positioned that the visibility improved enough to reveal that a measurement error had caused them to be laid at the wrong angle to the wreck site. Figure 10 shows the layout of the Cegrass mats around the site. No action was taken to correct this error because the mats had already begun to collect sediment and would have required considerable effort to shift. It was also felt that this slight departure from plan would have a negligible effect on the overall efficiency of the system.

Diving on the *William Salthouse* is limited to a period of approximately one hour either side of the advertised time for slack water. Outside this period, tidal currents, often in excess of 6 knots, made efficient underwater work impossible.

For deployment, the folded mats were manoeuvred into position by teams of up to four divers (Fig. 11). Once in place the bottom half of the folded mat was anchored to the sea-bed by using heavy-duty nylon cable-ties to attach it to the chain links welded to the rail ballast sections. The mat was then unfolded (Fig. 12) and the ballasting completed. At this point the mats were also cable-tied to adjacent mats if possible. Once all ballasting and tying off was completed, the light twine used to hold the fronds down was cut and the frond allowed to rise to their normal position. (Fig. 13) Despite the care taken to avoid entanglement in the fronds it did occasionally occur and fronds were snapped off as a result. For this reason, a surface team was on stand-by to collect any dislodged material as it floated to the surface. This enabled re-use of the detached fronds and prevented pollution.

A total of 42 mats was deployed around the *William Salthouse* wreck site. Their deployment took approximately two weeks and was heavily reliant on the assistance of a large volunteer work-force. The overall cost of the project, excluding wages and the time contributed by volunteers was approximately A\$100 000. Funding for the project was from a special allocation made by the Victorian Government.

Results

Approximately one week after placement of the mats had been completed, approximately 10 to 15 centimetres of sediment was observed to have been deposited in all of the mats on the site (Figs 14 and 15). This rate of deposition continued until all of the scour holes in which the Cegrass was placed had been filled. Figures 5 and 16 show the same area of the wreck before and after placement of the Cegrass.

In the 2–3 month period immediately following the placement of the Cegrass, disturbance of the barrels and other artefacts in the centre of the wreck (where no mats

had been placed) appeared to continue. It was noted, however, that sediment was gradually being deposited in this area also. Light sheets of steel mesh were placed over the areas of the wreck where artefacts were exposed to prevent them being washed off the site by the current. The steel mesh provided a substrate for the establishment of marine life which appeared to accelerate the deposition of sediment at the centre of the wreck. At the time of writing, the steel mesh has almost completely corroded away and this area of the wreck is quite stable, but visible to visitors to the site.

After approximately six months, observations of the site indicated that the scouring of the wreck had been halted in all locations except for a deep hole around an iron object at the bow of the wreck. Although some sand had been deposited in the hole, channelling of the current around the iron object prevented sediment build-up. This localised problem was solved by filling the hole with sandbags and then recovering the area (*c.* 2 m²) with a small Cegrass mat. No further problem of this type was experienced, however, it was noted that, at the starboard bow of the wreck, failure to place the Cegrass mat hard up against the hull of the ship had allowed the formation of a narrow (*c.* 50 cm wide) scour channel between the hull and the edge of the mat. Again, this was a minor problem which was easily reversed by placing a section of Cegrass mat in the channel.

Close monitoring of the site continued up until 1993 when the site was re-opened for permit access by recreational divers.

At the time of writing, the site is still stable and no problems relating to erosion on the site have become evident. The ends of the Cegrass fronds are still visible at the surface of the dune which contains the wreck and have provided a secure substrate for the establishment of a wide variety of marine life.

Conclusions

Paucity of marine growth on the exposed sections of the *William Salthouse* wreck when it was first located by Bolton and Kennedy is a strong indication that the site had only recently been uncovered as a result of erosion of sediments. Without extensive qualitative data, it is not possible to determine whether or not the scouring of the site was compounded by interference by souvenir-hunting divers, archaeologists or recreational visitors.

With the benefit of hindsight we can observe the following:

1. The severity of the erosion of the *William Salthouse* wreck site was probably not recognised earlier because of the lack of qualitative monitoring of the site and, more importantly, experience in recognising potential problems of this nature.
2. If the severity of erosion had been recognised, less time may have been spent experimenting with small-scale solutions such as fences and hand-held dredging.

3. Dumping of spoil on the site may well have succeeded if expert advice had been sought on the type of spoil necessary to resist scouring by the strong currents which sweep the *William Salthouse*.

Nevertheless, the experience has led to a highly successful solution to the management of erosion on shipwrecks in similar situations. The historical and archaeological significance of the *William Salthouse* necessitated either complete excavation and recording of the site, and its contents, or stabilisation works, to ensure that the archaeological significance of the site was protected. The former option was precluded by the immense cost of such an undertaking. Opting for the latter option has assisted in the understanding of erosion processes affecting shipwrecks, and in the development of a more systematic approach to the management of similar problems in the future.

Presently, the site appears to be completely stable and has required no further intervention apart from the placing of another half-mat in a very deep hole which had not been completely filled. The top 15 to 20 cm of many of the fronds is still exposed and has been heavily colonised by marine organisms.

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Endnote

- ¹ The Maritime Heritage Unit (MHU) was previously known as the Historic Shipwrecks Unit (HSU) and more recently as the MHU (MHU). The present name (MHU) was adopted after the dissolution of the former Victoria Archaeological Survey and the subsequent formation of Heritage Victoria.

Shipwrecks sharks and shattered timbers—the *Shipwreck Atlas of New South Wales*

David Nutley

Heritage Branch, NSW Department of Urban Affairs & Planning, PO Box 3927, Sydney, NSW 2000

Background

The *Shipwreck Atlas of New South Wales* has been a serious attempt to systematically document all known shipwreck sites, (apart from many scuttled wrecks), on the New South Wales coast. It is a coast that faces east to the Pacific Ocean and the Tasman Sea and stretches from the Queensland border to the north and Victoria to the south.

The adjacent waters have accumulated some 2 000 shipwrecks in a period of just over 200 years with an estimated additional 300–400 wrecks in inland waterways. Only about 10% of these sites have been found to date. Many of the others simply disappeared at sea without trace, a reasonable number are likely to have been recycled by local shipbuilders and others are likely to have been small craft, totally destroyed on shallow reefs, pounded relentlessly by the southern Pacific Ocean or the Tasman Sea.

Most of the sites discovered to date, have been located accidentally—by divers swimming around reef areas, through the snagging of fishing nets, as the by-product of undersea mapping programs, or as an unfortunate result of dredging programs. The resting place of the remainder have come to light through historical research and dedicated searches using basic tools like human sight or more sophisticated remote sensing devices such as magnetometers or side scan sonars.

Why a Atlas of shipwrecks?

The concept of issuing an atlas of New South Wales shipwreck sites was first developed within the Maritime Archaeology Program of the Department of Planning in 1991.

Prior to developing the Atlas, the idea was discussed with a wide range of divers—instructors, shop proprietors, clubs and individuals. Invariably there was an enthusiastic response. It seemed that, at least among divers, this was a publication that would be in demand.

On the basis of these responses, the first edition of the Atlas became a reality.

This edition consisted of black and white prints of slightly reduced Hydrographic Office Charts. This was a cheap production but was well received, particularly by divers. Its size, however, was a problem. It did not fit any standard mailing envelope and dwarfed most coffee tables—let alone book sellers' shelves!

The purpose of the Atlas was to create a vehicle for communication exchange. A basic premise of the Department's Maritime Archaeology Program, since its inception in 1988, has been to ensure that the results of maritime archaeological research conducted by the Department were made publicly available. The Atlas was entirely consistent with this approach.

The charting of shipwreck sites is a valuable reference tool. For recreational divers it provides an indication of the location of shipwrecks in areas where they plan to visit. They can then contact a local diver shop or dive charter operator to obtain information on site conditions, how to get there and, most importantly, whether or not it is currently covered in sand! Local information sources can also provide advice on whether shore access is difficult.

Local communities and local council authorities can also use the Atlas to plan the development of shoreline interpretive signage—either as wreck trails or as stand-alone plaques. These have proved to be popular through their ability to provide visitors with an understanding of the events and maritime activities that helped form the history and character of today's landscape.

Planners and developers found the Atlas useful when considering dredging proposals, cable laying and offshore sand-mining proposals. Knowing the location of shipwreck sites that have been found to date and the general volume of other vessels lost in the area can help to guide initial plans rather than making last minute, expensive adjustments.

With the release of the first edition, the anticipated flow of information from divers and fishing operators was immediate. Numerous phone calls and visitations provided information on corrections on the reported location of wrecks and also on the location of additional wreck sites that did not appear in the Atlas.

The Second Edition

The result of this information flow, in conjunction with a considerable volume of research for the Department's shipwreck database and fieldwork by myself and Tim Smith (the other Departmental maritime archaeologist) meant that the first edition quickly went out of date—as well as going out of stock.

The Department then set about redesigning the Atlas, drawing upon a variety of skills within its information cartographic and heritage resources. The outcome was an enhanced publication that bore little resemblance to the first edition, apart from the basic philosophical concept. The prime necessity was to accommodate the fact that additional information would always need to be included as research progresses and as new sites are found. The solution was to have loose binding—the charts and cover boards held together with brass screw studs. The cover boards are themselves coated in plastic, appropriate for a book that may be used near water!

The new edition also aimed to be of interest to a wider audience. To achieve this, some of the many anecdotes, (tragic, bizarre, outlandish, numerous and heroic) were chosen from among thousands of newspaper references

used in researching the shipwreck histories along the coast. One of these anecdotes was chosen to relate to each charted section of the coast. In addition, other vessels losses, as yet unfound, were included to provide an indication of the level of shipping losses in that area at various periods of time.

The Atlas now comprises of three sections. Part 'A' is for special interest topic sheets. The initial sheet is a general introduction to maritime archaeology and historic shipwreck legislation. This topic sheet section will be added to periodically. At the time of writing, three additional sheets are under development. One provides descriptions of the types of anchors found on wreck sites along the New South Wales coast, another provides profiles of a range of vessel types included in the New South Wales shipwreck record, and the third sheet is a compilation of some of the rather fanciful or comic newspaper cartoon representations of the dangers faced by early salvage divers.

Part 'B' of the Atlas consists of 25 charted sections of the New South Wales coast with their accompanying anecdotes and list of unfound wrecks.

Part 'C' is an index of nearly 2 000 wrecks from the Department's shipwreck database. This allows readers to obtain basic information on each wreck and directs them to the official register, where available, from which additional information can be obtained.

Purchasers have the opportunity to register their acquisition of the Atlas in order to be notified of additional topic sheets or updated charts as these become available. From this list, it has also become evident that the buyers represent a much wider background than for the first edition. Being related to a specific State, most of the sales have been, as expected, in New South Wales although bookshop and education department purchases have been made in other Australian States including Victoria, South Australia and Queensland.

Where to Next?

In addition to building upon the level of information in the current charts and adding additional topic sheets, there is also potential for the Atlas to include information on the extensive inland river systems that once formed the major transport and communication network away from the coast. A study of the main stream of the Murray River along the New South Wales– Victorian border, located over 60 river boat wrecks. This study was conducted as a consultancy by Sarah Kenderdine for the Department of Planning in New South Wales and the Department of Development and Planning in Victoria (Kenderdine, 1995). In New South Wales, a further riverine study was commissioned in 1995 when Mike Richards was engaged to document, from historical and oral history sources, information on shipwrecks along the Clarence River on the New South Wales north coast (Richards, 1996). Further studies will provide a wealth of material from which inland shipwreck charts could be developed.

CDROM and the Internet provide additional challenges and opportunities. However, these developments require additional resources and it remains to be seen whether these can be justified when balanced against the need for continued field documentation, archival research, education programs and other management considerations.

The *Shipwreck Atlas of New South Wales* has drawn together the interests of shipwreck researchers, divers, people whose families have experienced shipwreck or near shipwreck, lovers of nautical history as well as those organisations who have responsibilities for recording, interpreting and managing historic shipwreck sites. It not only provides a visual orientation to the pattern and distribution of shipwreck sites, but provides the reader with a feeling for the experience of shipwreck itself.

This has been the success of the Atlas and the reason why its continued development is so rewarding.

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The shipwreck universe of the Northern Territory

Cosmas Coroneos

46 Gale Road, MAROUBRA NSW 2035

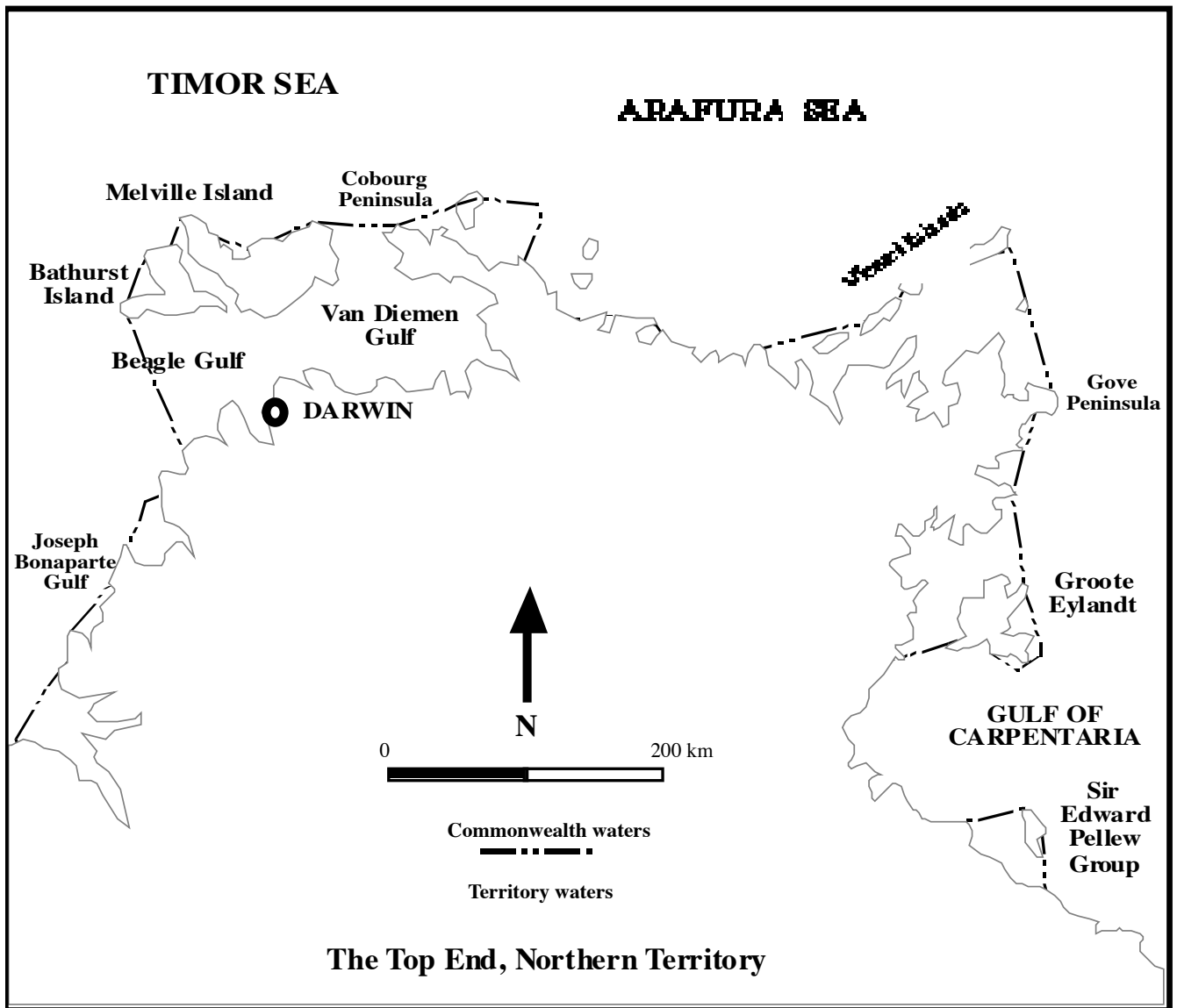


Figure 1. The Top End, Northern Territory.

In early 1996 the Maritime Archaeology and History Section, Museum and Art Gallery of the Northern Territory (MAGNT) undertook to update its records on wrecks in the Northern Territory. This culminated five months later in the creation of the Northern Territory Wrecks Database. This article utilises this new research and management tool to give a brief introduction to the history of the Northern Territory and its physical representation in the form of shipwrecks, or more broadly, submerged cultural resources.

The history of the Northern Territory for the purposes of this article has been divided into a

consecutive series of major economic and political eras or events. A summation of the wrecks taking place during these periods has been included to illustrate how the wreck resource reflects the major cultural trends of the region. This is of course just one way of manipulating and presenting the wreck resource. The method chosen was seen as the best way to introduce the Northern Territory and its wreck universe.

The article will conclude with a brief summary of the wreck resource and aspects of its significance in a national context. This will be followed by a discussion of some of the characteristics and

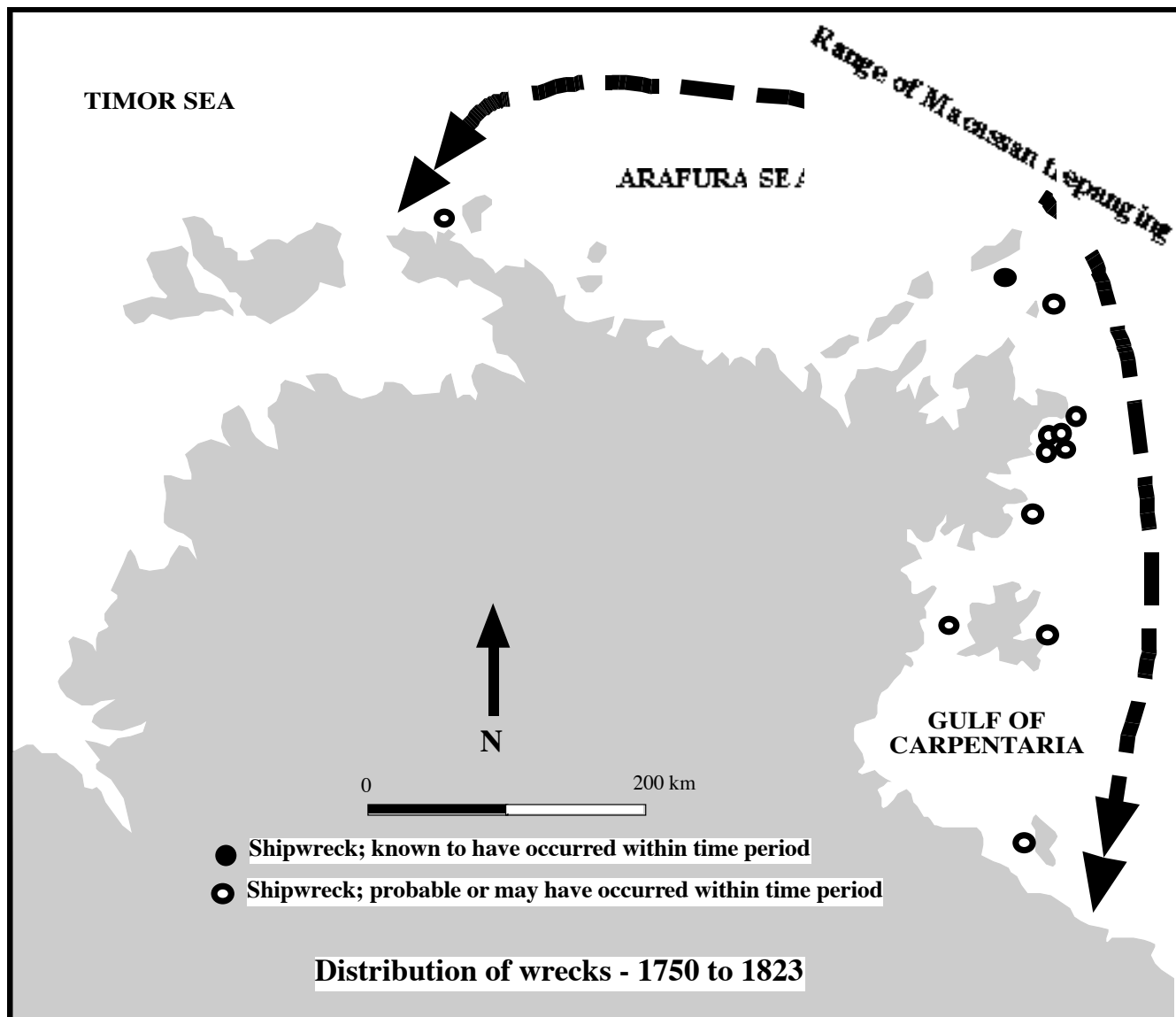


Figure 2. Distribution of wrecks—1750 to 1823.

considerations that are peculiar to the Northern Territory.

The Coastal environment (Figure 1)

The mainland coastline of the Northern Territory is 5 100 km long with a further 2 100 km of coast around the off-lying islands (*Year Book Australia*, 1991: 730). The continental shelf extends 140 km offshore. It is broad with a low gradient and never exceeds a depth of 200 m. Coral reefs are best developed on the extreme north coast and the off shore islands. The coastline is low-lying, with a combination of cliffs, rarely exceeding 20 m in height, indented bays, inlets and the estuaries of numerous rivers and creeks. Most of the shoreline is soft, that is, composed of unvegetated mud flats and mangrove swamps which cover an area of approximately 2

400 km². Long stretches of sandy beaches are also common.

In the winter months, the dry season, the region is dominated by the *South-East Trade Wind* which varies in direction between south and east (*Australia Pilot*, 1972: 15). Within 20 miles (32 km) of the coast, land and sea breezes are in effect, with winds of up to 15 kn shifting to the NE. Generally this wind is associated with fine weather.

The onset of the North-West or West Monsoon, wet season, is usually in December where NW to west winds spread from the west and north across the region (*Australia Pilot*, 1972: 16). This is followed with cloud, rain and frequent thunderstorms. It is particularly during this period and the following transitional period that the prevailing winds are liable to be upset by temporary

disturbances of clockwise winds accompanying tropical depressions.

Between the North-West or West Monsoon and the South-East Trade Wind twice annually there is a period of transition, lasting usually a few weeks. The period before the North-West or West Monsoon occurs sometime during October to December and the other after the North-West or West Monsoon takes place some time during March and April. The wind is unsteady in direction but often blows in the direction of the North-West Monsoon or the trade winds. It is generally light and even calm on the coast, usually at night. The land and sea breezes still occur, as well as the occasional squall. With the approach of the North-West or West Monsoon squalls occur at first at intervals of 4 to 5 days with the frequency increasing until they occur daily.

The occurrence of gale force winds, >28 kn, in the winter and spring months are infrequent and average less than 1%. In other months the frequency increases but rarely above 5% (*Australia Pilot*, 1972: 16). In the North-West or West Monsoon tropical storms evolve in the Arafura Sea and move in a SW direction along the coast. These storms, with gale force winds, cover an area varying in diameter from 20 to 150 miles (32–240 km). The clockwise rotating winds often reach 50 kn and occasionally gusting to 85 kn. The duration of these high winds does not usually last more than 12 hours (*Australia Pilot*, 1972:16).

Salinity for the region averages 34‰ in summer to 35‰ in the winter. (*Australia Pilot*, 1972: 12). However, it could be expected that the salinity will be less closer to shore in the summer months because of rain run off. As can be expected the mean sea surface temperature (°C) in summer is higher (29°C) than winter (24° to 25°C) (*Australia Pilot*, 1972: 12).

The consistent and dominant movement of swell in the summer months is from the west and north-west. In winter it is from the south to south-east (*Australia Pilot*, 1972: 12). The currents off the coast are highly variable, affected by the changing monsoon system. During the dry season the predominant direction of the current is WSW. In the wet season the direction is reversed, ENE (*Australia Pilot*, 1972: 13). Off shoots from this easterly flowing current reach into Joseph Bonaparte Gulf and the Gulf of Carpentaria where they swing around to weak clockwise directions.

The tidal stream generally runs east and south during the flood and west and north during the ebb (*Australia Pilot*, 1972: 13). This stream can achieve at times up to 4 kn especially in the approaches to Darwin. During the flood tide the tidal stream moves towards detached reefs from all directions and falls away during the ebb. The speed of the tidal currents increase in the channels through the reefs. The large tidal range along the north-western coast and the low gradient of the coastal lowlands results in some of the

larger rivers being affected by tides for more than 100 kilometres upstream from their mouths (*Year Book Australia*, 1991: 731).

Major cultural phases

Aboriginal occupation

Aboriginals have been living in the north coast since at least 50 000 b.p. (Flood, 1990: 17). The oscillating sea levels during the glacial and inter glacial periods over the last 100 000 years most likely maintained a pattern of alternating contact and isolation between the inhabitants of northern Australia and the Indonesian archipelago. The end of the last glacial approximately 8 000 b.p., resulted in the geographical and regular cultural severance between Aboriginals and the cultures across the Arafura and Timor seas until the last few centuries (Flood, 1990: 17).

The maritime activities of the coastal communities were confined to inshore spearing and netting marine animals in bark canoes. The operating range of these vessels would have been limited to a few kilometres offshore and probably not structurally capable to make long coastal journeys let alone travel across the Arafura and Timor seas.

The onset of regular seasonal visitation by the Macassans led to changes in the material culture of the north coast Aboriginals, more significantly than communities in Arnhem Land. One of these changes was the introduction of the dugout canoe based on the Macassan *lepa-lepa* (Mackintosh, 1976: 90). Superior in seaworthiness to the bark canoes, they allowed a more intensive exploitation of the local marine resources and a greater range of operations.

European exploration 1623–1818

The northern coast of Australia is the closest part of the continent to the densely populated Indonesian Archipelago. However the first known non-indigenous sighting of the Australian north coast took place in 1623 by the Dutchman, Van Coolsteerdt, in the *Arnhem*, over 100 years after the Europeans came into direct trading contact with the Indonesians and more than 700 years after Islamic penetration into the region (Schilder, 1989: 76). There would be no real contention in stating that the inhabitants of the archipelago would have known of the north Australian coast centuries before (Birningham, 1989: 1-2 for further discussion). The north-west monsoons could easily have led to Indonesian *perahus* being blown onto the coast as was documented in the nineteenth century (Mitchell, 1994: 42; Stokes, 1846: 328). The reasons for the absence of any information, at present, concerning the existence of the north coast of Australia prior to European discovery is most likely due to the lack of incentive in terms of natural resources or trade for regular visitation. This lack of interest also infected the Europeans who did not establish a permanent settlement on the coast for

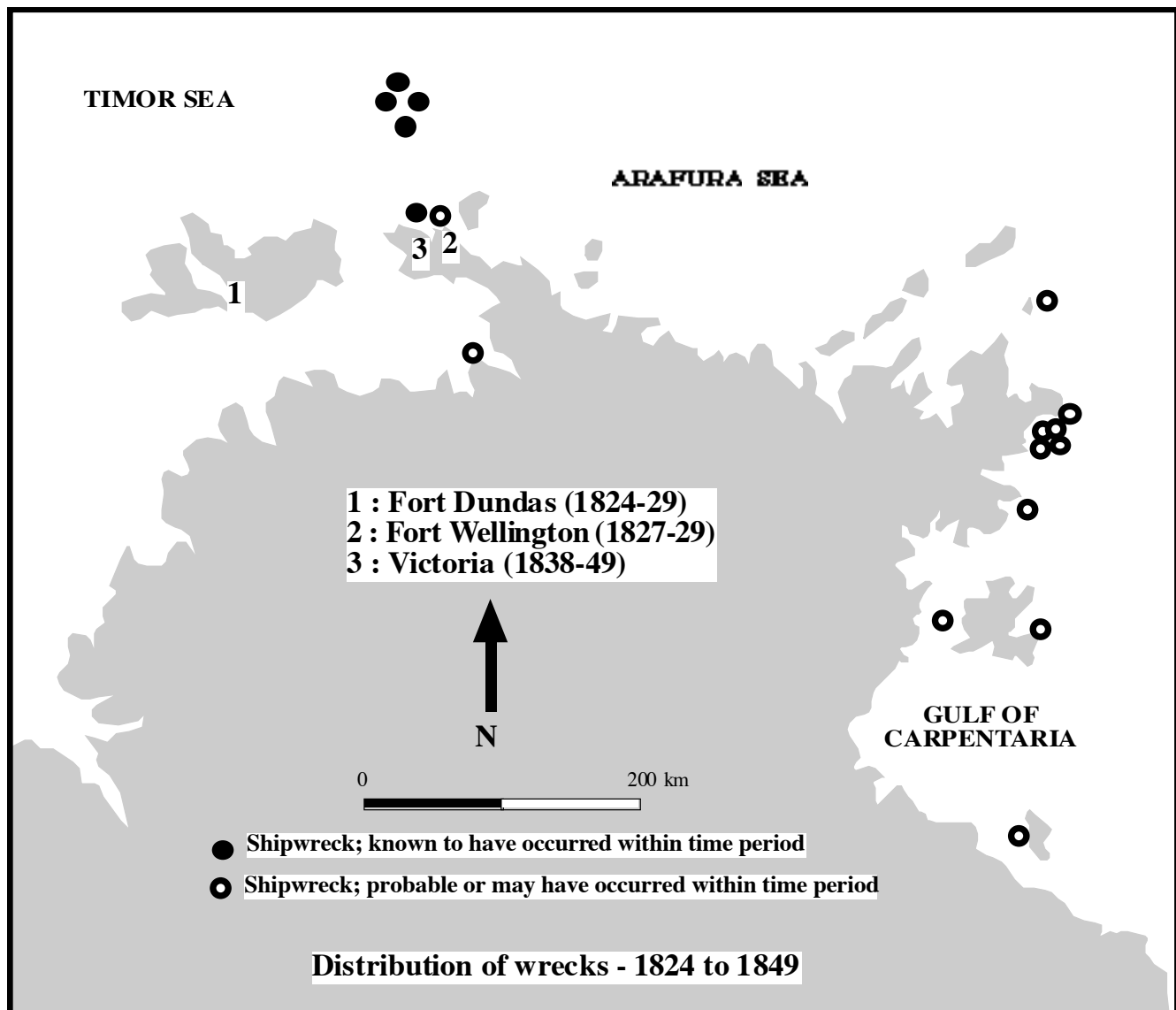


Figure 3. Distribution of wrecks—1824 to 1849.

another two centuries after their discovery.

Dutch visitation continued for the remainder of the seventeenth century; Peter Pieterszoon in 1636 and Abel Tasman in 1644, but with their curiosity satisfied they abandoned the coast (Schilder, 1976: 129–138; 181–187). The British developed an interest in the northern coast of Australia not long after the settlement of Sydney in 1788. In an effort to first define the extent of the continent they had annexed and to also assess the potential for trade and trade routes with the neighbouring Dutch colonies two expeditions were sent to chart the coast. In 1803, Mathew Flinders in the *Investigator* surveyed the Gulf of Carpentaria and eastern Arnhem Land. Fifteen years later, Phillip Parker King in the *Mermaid* completed the survey of the western half of the Northern Territory (Macknight, 1969: 48–72 and 104–122).

No wrecks of European vessels are known to have

taken place in the Northern Territory during this period.

The Macassans 1750–1823

If one looks at the history of the Northern Territory from a European perspective in the years from Van Coolsteerdt's first sighting to the establishment of Fort Dundas, in 1824, the impression given would be one of a region too poor in resources to attract attention. During the eighteenth century this attitude changed. It was at this time or perhaps earlier that perahus originating from the port of Macassar in southern Sulawesi were making regular visits to the north coast primarily in search of trepang (*bêche-de-mer*) for the Chinese market. The antiquity of the Macassan trepanging voyages to northern Australia is controversial with the first historical evidence for the industry dating back to 1754 (Mitchell, 1994: 42; Roberts, 1973: 148-149;

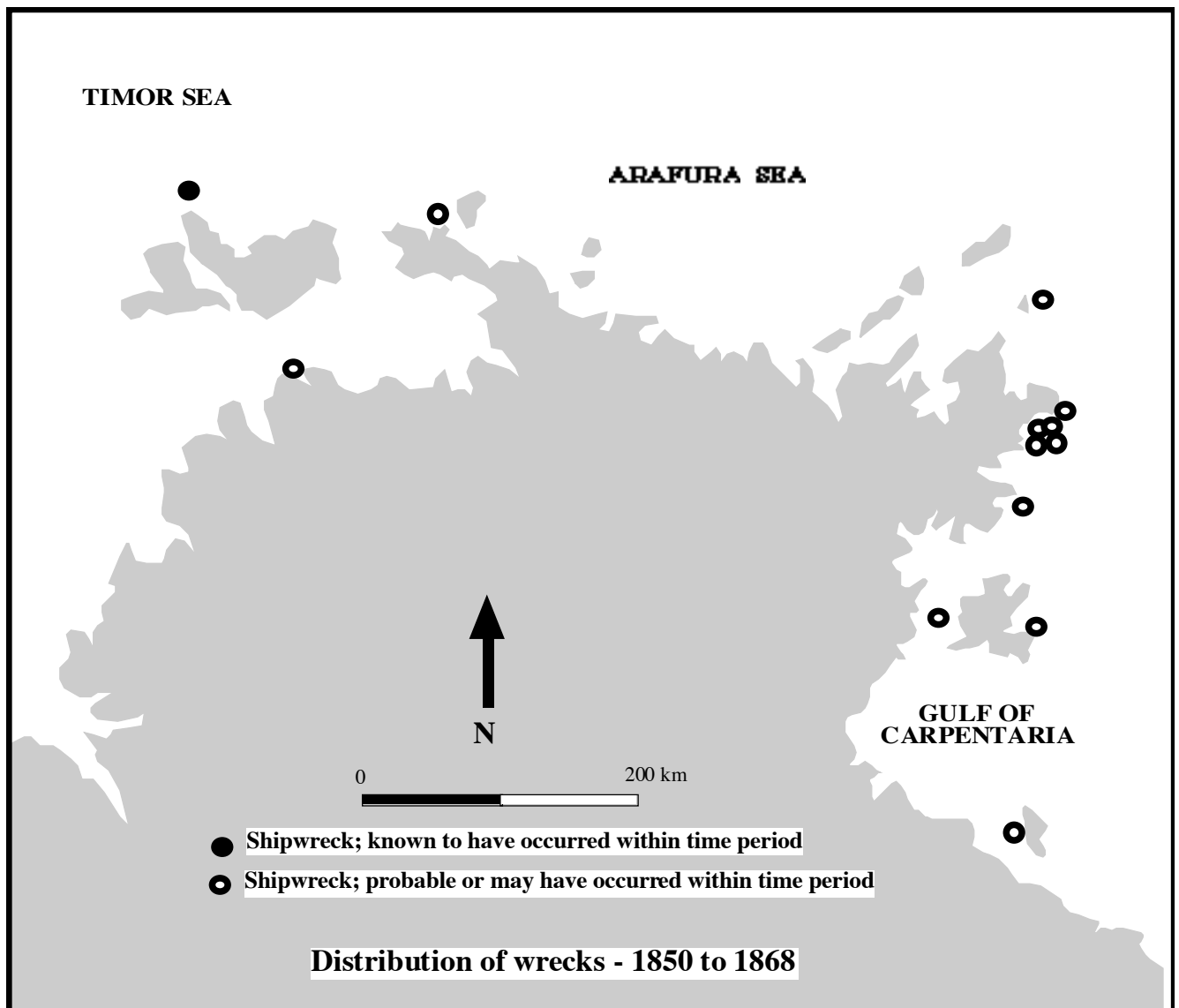


Figure 4. Distribution of wrecks—1850–1868.

Jack-Hinton, 1989). Radio carbon dates from some Macassan sites provide debatable evidence of visitation as early as AD 800 (Macknight, 1976: 158). The issue of the beginnings of regular Macassan voyages is beyond the scope of this paper and for the purposes of this article the mid eighteenth century will be taken as the start of the industry. It is interesting to note that the evidence in this debate is drawn from historical and terrestrial archaeological sources and as yet there has been no contribution from maritime archaeology.

Trepang, sea slug or *bêche-de-mer* is a holothurian that forms one of the five major groups of Echinoderms (Cannon & Silver, 1986). It is found in abundant numbers in the shallow mud flats of northern Australia. The animal was sought after as a delicacy by the Chinese. Fleets of Macassan *perahus* usually backed by capital provided by Chinese merchants descended onto the north Australian coast with the north westerly winds

in the wet season and departed with the south easterly winds of the dry season (Mulvany & Green, 1992: 167). A single fleet could be composed of 30 or more vessels and in some years up to 200 *perahus* amounting to over 2 000 men would be ranging the coastline from Cobourg Peninsula to the Sir Edward Pellew Group in south-eastern Arnhem Land (Mitchell, 1994: 42, 36; Mulvany & Green, 1992: 168, *Sydney Morning Herald* [SMH] 15 Oct. 1845; King, 1827).

All the vessels known to have been wrecked in this period are Macassan *perahus* (Fig. 2). Only one vessel, the wreck of a *perahu* sighted by Mathew Flinders on Marchinbar Island in 1814, was definitely lost in the period before European settlement. The remaining eleven wrecks have been obtained largely from oral sources which could not provide a precise wrecking date. These wrecks have been given a broad date range from 1750 to 1906, the complete period of the

Macassan trepanging industry. The location of these wrecks as can be expected stretch from Melville Island, being the landfall for the Macassan trepanging fleet, to East Arnhem Land.

The limpet ports 1824–1849

The presence of the Macassans on the north coast did not go unnoticed by the British, nor did the potential that they offered for trade. Between 1824 and 1849 three military outposts were established on the north coast, Fort Dundas (1824–29) on Bathurst Island, Fort Wellington (1827–29) and Victoria (1838–49) on Cobourgh Peninsula. The intention behind these settlements was to broadcast to other colonising powers the British intent of annexing the whole of the continent of Australia as well as to break into, economically, and bypass the Dutch-controlled Indonesian archipelago. This would be achieved by trading with the Macassans items of British manufacture in return for trepang and other products which could be in turn traded to the Chinese.

In short, these settlements, which never numbered more than 200 people at any one time, failed through a combination of being ill sited, in the case of Fort Dundas, and to some extent Victoria; poor leadership and administration, in the case of Fort Wellington; and, disease, as well as isolation, which afflicted all three settlements. The unsuitability of the soils for European-based crops, and the lack of free settlers and traders meant that the settlements had little to offer the Macassans in the way of trade. Stagnating and solely dependant for survival by sea, thus expensive to maintain, the settlements were eventually abandoned.

Only one European vessel, the *Orontes*, an ex-convict ship, was definitely lost during the quarter century that these settlements existed (Fig. 3). The other wreck, that of a two-masted vessel lost in Van Diemen Gulf, was reported to the Commandant of Victoria by Aborigines. A search party sent out to investigate found no trace of a wreck. The occurrence of one definite wreck during this period may seem surprising but this should be seen in the context of the nature of these settlements or more precisely military outposts. Firstly, these settlements never developed into centres of trade. Shipping volumes, therefore, were low and mainly confined to supply ships and naval vessels on station. Consequently the settlements never developed into ports with resulting infrastructure of small tonnage vessels such as lighters, barges and so on. The failure to develop or attract an entrepreneurial population of free settlers, as well as establishing satellite settlements meant that there were no, or few, individually owned vessels engaging in coastal trade or resource exploitation. In effect these settlements were very much introspective, static and confined. This is reflected in the shipwreck

record. The other four vessels are Macassan *perahus* which were lost in a storm outside of Port Essington in 1847.

Period of British abandonment 1850–1868

The north coast was left without a permanent British settlement for nearly twenty years until the north coast, renamed the Northern Territory, was annexed by the South Australian Government in 1863 (Powell, 1982: 74). The South Australians, eager to exploit the region through pastoralism, agriculture and free enterprise, very quickly began considering the establishment of a new settlement. After an abortive attempt at Escape Cliffs, Cape Hotham, the town of Palmerston was established, in 1868, at Port Darwin.

For the 80 years between the abandonment of Victoria to the establishment of Darwin only two wrecks are definitely known to have occurred (Fig. 4). One of these vessels, the *Magda*, was on *en route* from Geelong to Java when it strayed too close to Melville Island. The other vessel, the *Flying Dutchman* was supposedly wrecked near the Adelaide River, Van Diemen Gulf in 1851. Further research, however, is required to ascertain as to what it was doing there in the first place.

The settlement that stuck—Darwin 1869–1941

Unlike the earlier attempts to colonise the Northern Territory this new settlement was almost guaranteed a semblance of permanency and purpose. Darwin was to be the landfall for the undersea telegraph cable that was being laid from Singapore. The overland telegraph line at the same time was snaking northwards from Adelaide. When the two lines were connected, in 1871, Australia was linked to the rest of the British Empire by near instant communication. Darwin, in these early years, was populated by mostly public servants charged with maintaining this new communication system.

Coinciding with, and as a consequence of, the laying of the overland telegraph was the discovery of gold at Pine Creek, 100 km south of Darwin. This discovery provided the impetus for attracting more people and capital to the north and the development of Darwin as a port and commercial centre. The commencement of the railway line from Darwin to the goldfields 10 years later boosted the population and attracted more businesses. By the time the line was complete, in 1888, the population had increased to 8 000, of which 7000 were Chinese, but the population declined to 5 000 by 1890, remaining at that level until World War II (Powell, 1982: 97). The discovery of gold in the Kimberley and the expansion of pastoralism in that region opened up a sea connection with Darwin via Wyndham.

The population increase in the 1880s created a market and a lucrative export, gold, attracted shipping to Darwin. Most of this traffic did not stop in Darwin. Much of it, large mixed passenger and cargo steamships, was *en route* from ports in southern Australia

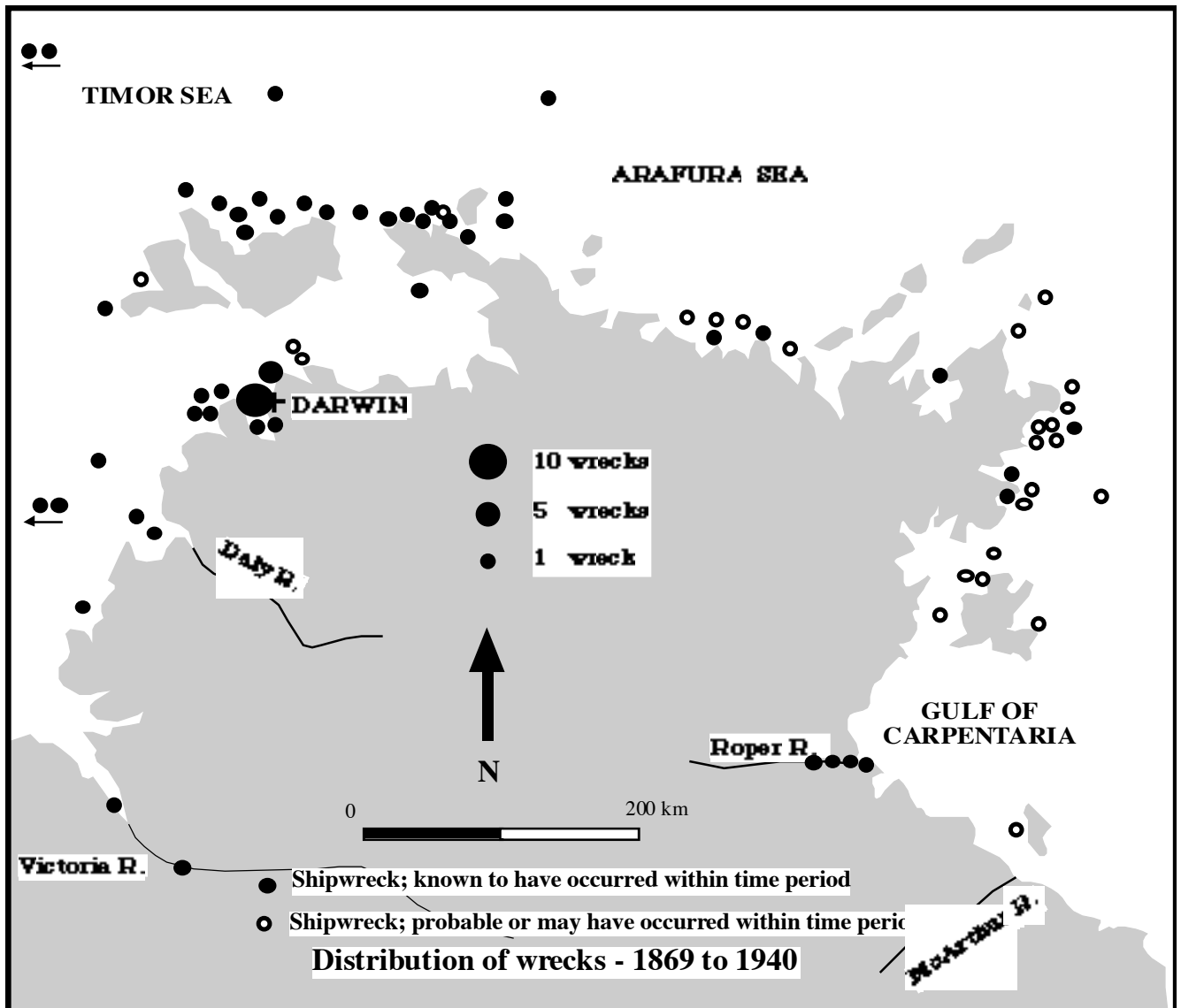


Figure 5. Distribution of wreck—1869 to 1940.

to destinations in south and east Asia, principally Singapore, Hong Kong and Japan. Darwin, up until the outbreak of World War II, totally relied on the sea for its material needs and exports. The increasing importance and size of Darwin as a port resulted in the growth of local small tonnage shipping which serviced the town and the immediate areas.

With Darwin being established as a secure long-term settlement and a port of call for major shipping lines it was inevitable that it would become a base for expansion, economic, territorial and spiritual, along the northern coast and its hinterland. Pastoral properties established around the Daly and Victoria Rivers were serviced by coastal vessels, mainly small tonnage steam vessels, from Darwin. To the east in the Gulf of Carpentaria, the Macarthur and Roper Rivers performed the same function as conduits for the export of livestock and produce. Though these river systems

lay in the economic sphere of north Queensland the region was still under the jurisdiction of the South Australian Government which occasioned coastal borne visitation from Darwin officials.

From the start of the twentieth century, Christian missionary societies established mission stations for Aborigines at the Daly River, Bathurst, Goulbourn, Elcho Islands, Millingimbi, Roper River, Yirrkala, Port Keats and Groote Eylandt. These missions relied mostly on their own vessels for supplies and communication.

The waters off the coast as well as acting as a line of communications between pastoral properties and missions, Darwin and onto the outside world were also exploited for their natural resources. Europeans, bolstered by the proximity of Darwin as a servicing centre, and an effective source of government support, began trepanning eventually forcing the Macassans out of the industry. Pearlring soon grew into a lucrative

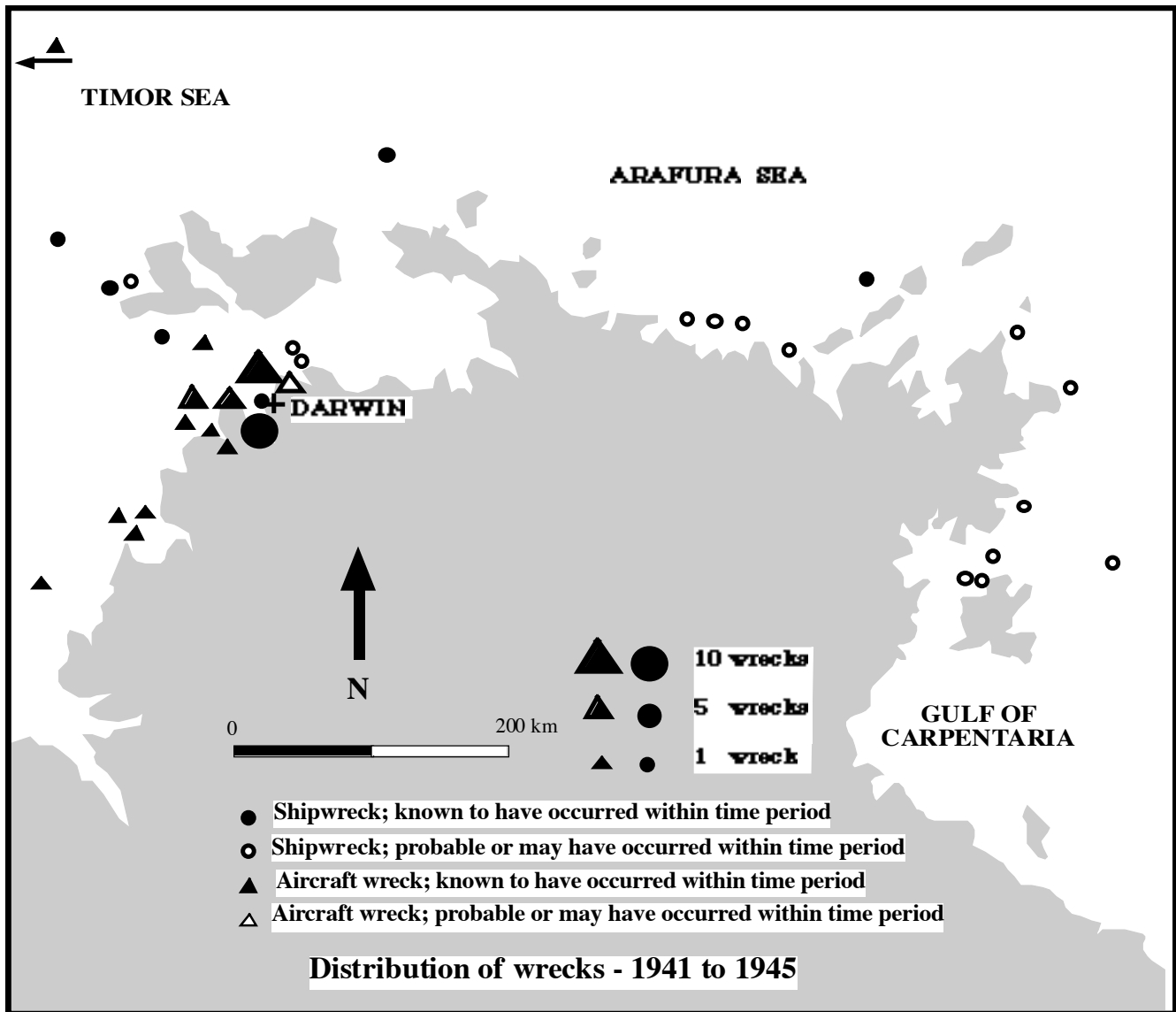


Figure 6. Distribution of wrecks—1941 to 1945.

industry with the increasing size of the pearling fleet based in Darwin eventually becoming dominated by the Japanese.

For all the increase in activity by the Europeans across the Northern Territory, Darwin remained the only port of consequence on the north coast until the 1960s. All this expansion however was not enough for the South Australian Government which saw the Northern Territory as giving back few returns for money spent. In 1911, the administration of the Northern Territory was transferred to the Commonwealth Government which infused new vigour, only to lead to a decline in development and growth almost a decade before the Great Depression. The development that did take place in during the 1920s and 30s was related to the defence of the north.

From 1869 onwards, there is a dramatic increase in the number of shipwrecks occurring in the Northern Territory (Fig. 5). In this period, 67 wreckings took place with at least another 30 possible occurrences. During this time the wrecks are surprisingly well distributed over the Northern Territory, considering that Darwin was the sole port and commercial centre for the region. This could reflect the excellence of Port Darwin and its approaches as a harbour while highlighting the dangers faced by vessels working close to shore in remote and new areas.

The majority, of the vessels lost in this period, 21 with another possible 11, were engaged in resource exploitation. Up until the end of the century these were almost exclusively Macassan perahus. The Macassan-based industry prospered throughout the eighteenth and for most of the nineteenth centuries. Towards the

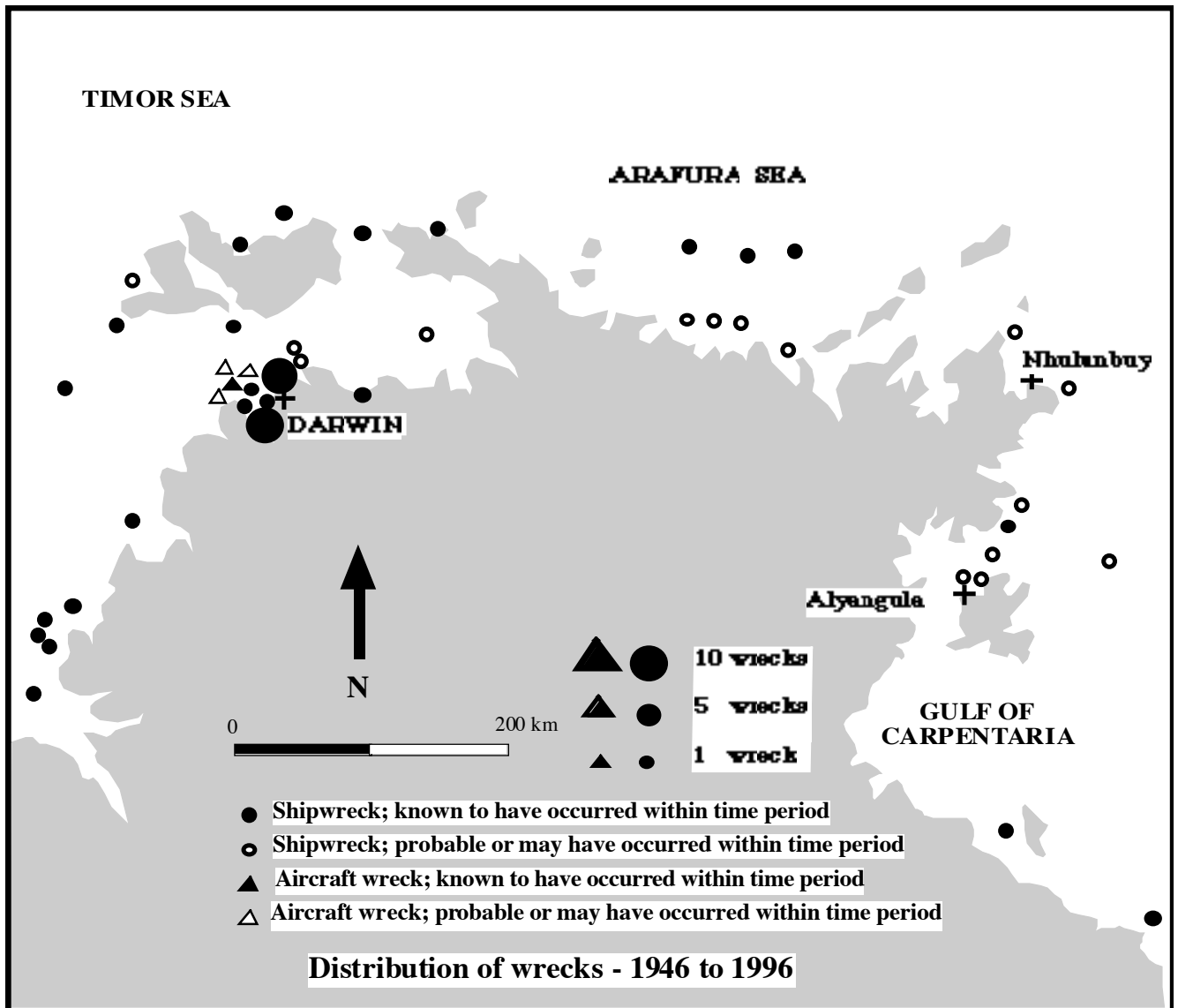


Figure 7. Distribution of wrecks—1946 to 1996.

end of the nineteenth century the number of vessels coming to Australia began to decline. The main reason for this was the increasing presence and influence of Europeans on the north coast. Europeans were attempting to enter the trepang market by undertaking the harvesting themselves. Though competition from the infant local industry did not affect the Macassans, the taxes and licenses imposed on them by the South Australian Government, in 1882 (Macknight, 1976: 117;118; Powell, 1982: 104). Fleet numbers fell, especially after 1899, when taxes increased. In 1906, the South Australian Government ceased to issue licenses to Macassan *perahus*. The last *perahu* to travel to the Northern Territory was in 1907 (Mitchell, 1994: 42). After the Macassan prohibition, vessels engaged in resource exploitation that were lost were pearling and European-operated *trepanging* luggers. With Darwin

becoming a regular port of call for shipping lines, and a supply centre for small satellite coastal settlements, the incidence of losses for cargo and passenger vessels increased, the most spectacular being the SS *Brisbane* (1874) and the SS *Australian* (1906).

World War II 1941-1945

The entry of Japan into Second World War came as no surprise to the Northern Territory. As early as 1924, oil storage facilities for the Royal Australian Navy (RAN) were built near the port; the numbers of military personnel increased steadily during the 1930s; and, in 1939, a submarine boom was stretched across the harbour (Powell, 1982: 178, 192). The surprise, however, was the rapidity, only two months after Pearl Harbour, of the Japanese attack. The first and largest raid on Darwin Harbour was carried out by 188 aircraft,

second only in scale to Pearl Harbour, on 19 February 1942 (McCarthy, 1992: 3). At the time, the harbour was full of war-commandeered supply ships and naval vessels from Australia, Britain and the United States. Eight vessels were sunk, four beached and eleven were left on fire or severely damaged. Darwin and the surrounding area was to endure approximately another 63 airborne attacks with the final raid taking place in November 1943 (Powell, 1982: 202). The war with the Japanese of course was not confined to Darwin Harbour; the eastern half of the Northern Territory also subjected to attacks, with vessels and aircraft being lost. By the end of hostilities, 45 vessels and aircraft are known to have been lost as a consequence of the War (Fig. 6).

The post-War era 1945–1996

With the end of the War, the Commonwealth Government moved quickly to rebuild and populate the city. By 1974 the population stood at 46 000 (Powell, 1982: 228). The Northern Territory during the 1950s and 60s experienced the same boom that was felt elsewhere in Australia. New mines were opening up in eastern Arnhem Land—bauxite at Nhulunbuy and manganese ore at Groote Eylandt (Alyangula)—which led to the creation of port facilities for ore carriers and supply vessels.

The exploitation of the marine resource also increased during the late 1960s with the establishment of the prawn fishery across the top of the Territory. Pearling continued but with more of an emphasis on pearling farms established at Bynoe Harbour and Cobourg Peninsula.

One of the effects of World War II on the maritime development of the Northern Territory was the completion of a sealed road from Darwin to Mount Isa. This, and the increased use of motor vehicles for transport, ended the Northern Territory's reliance on the sea. Air transportation also expanded transplanting the role that coastal shipping had as being the only means of effective communications with outlying coastal settlements. Unlike southern continental Australia, however, coastal shipping has not been totally supplanted as even today large parts of the Northern Territory are cut-off from vehicular access during the wet season.

The frequency of wrecks occurring in the 50 years since the end of World War II has not declined greatly (Fig. 7). The Northern Territory's continued, though diminished use of coastal shipping, which translates into shipwrecks; and catastrophic events such as Cyclone Tracy which accounts for 19 or 35% of the wrecks known to have definitely taken place in the period have also kept the wreck statistics high.

Unlike the period preceding World War II the majority of wreckings have taken place in and around Darwin Harbour. However, if the single night of destruction caused by Cyclone Tracy is taken away the

distribution across the Northern Territory is more even. Furthermore, most of the wrecks occurring in Darwin Harbour since 1974 have been deliberately scuttled as artificial reefs. Many of these are south and east Asian refugee boats, another feature of the wreck resource of Darwin Harbour.

Of the known functions of the vessels lost during this period most, 19, were engaged in transportation of passengers and cargo, reflecting the important connection with the sea as a communication and supply route. The continued use of the sea as a commercial resource is illustrated in the number of vessels, 10, lost across the north coast, the majority of these being trawlers engaged in prawning.

Summary of wrecks in Northern Territory

In the recently completed Northern Territory Wrecks Database Project, 203 submerged cultural features have been entered. One hundred and sixty-four vessels and 36 aircraft are known to have been lost in Northern Territory waters. As more archival research is undertaken, this figure is very likely to rise. A final estimate for the Northern Territory would be difficult to determine. The long period of visitation of Macassans to this coast prior to sustained European settlement after 1869 no doubt resulted in many more wrecks that documented are through European records and oral sources. The Northern Territory Wrecks Database has on record 27 *perahu* wrecks. Between 1882 to 1906 eleven *perahus* were recorded as being wrecked or missing in the Northern Territory (Macknight, 1976: 115, 135–6). As a loose estimate, if this figure is extrapolated for the whole period of Macassan visitation, which for at least 150, years it is possible that 75 or more *perahus* could be wrecked in the Northern Territory.

The frequency of recorded wreckings increases dramatically after the settling of Darwin. As may be expected, this is a result of the steady increase in population, settlements and economic activity along the coast. Clusters of vessels wrecked within short time periods are a characteristic feature of the wreck resource with singular catastrophic events such as the initial bombing of Darwin and Cyclone Tracy accounting for 29 vessels lost in two separate events. The figure increases to 54 (27% of the total) vessels and aircraft if the whole period of the war in the north is included. The majority of wrecks, 74, have taken place in the Darwin Harbour area.

Of the 203 known submerged cultural features 125 are situated in Territory waters, 15 in Commonwealth waters while the legal jurisdiction of the remaining 63 is unclear. Eleven wrecks have been inspected with the locations of another 35 known.

Considerations for maritime archaeological work in the Northern Territory

There are some aspects peculiar to the Northern

Territory that impact on the undertaking of maritime archaeological work. First and foremost are the constraints imposed by the physical environment in which most of the wrecks are located: the nature of the coast, low visibility and strong tidal currents. The low visibility results from the proximity of mangrove swamps. Diving in rivers, creeks and the edges of mangrove swamps is not an option as the threat of crocodiles is real. During the wet season, water visibility can drop further due to rain run off. Crocodiles also tend to venture out into open water during this season. The tidal range, greater than 6 m in places, limits diving to the neap tides.

These challenging conditions are not the rule for the Northern Territory. The conditions described above are very applicable for the Darwin region where, as mentioned above, most of the wrecks are located. In the 1995 field trip to Cobourg Peninsula more benign conditions were experienced. The tidal range and therefore current, was not as great as Darwin Harbour while diving in some locations provided 10 m and greater visibility. The same situation is said to apply for diving around the Nhulunbuy and Groote Eylandt regions.

The stable seasonal weather patterns are a great bonus. For 6 months of the year south easterly winds can be guaranteed almost every day with their intensity and those of the afternoon sea breezes being the variables to consider. The situation is reversed in the wet season. Generally the best time to conduct fieldwork is the beginning and end of the dry season when periods of calm are likely to occur. Another advantage is the absence of ocean swell that makes working close in shore in southern Australia difficult.

Another noticeable aspect is the limited number of divers and the centres from which they operate. Darwin, Nhulunbuy and Groote Eylandt are the only places where dive shops and clubs operate. Their range of operations are confined by the lack of roads and distance. The dive shops in Darwin find it more cost effective to run packaged dive charters out of Indonesia than to dive in localities a few hundred kilometres from Darwin. The low numbers of local divers and limited locations for diving in the Northern Territory means that maritime archaeologists are deprived of a vital information source concerning the location and condition of wrecks.

A critical consideration for maritime archaeological work in the Northern Territory is that land access to most of the coastline requires permission from the traditional owners. Bathurst and Melville Islands, Cobourg Peninsula, Arnhem Land and Groote Eylandt are run by local land councils. The issue of whether jurisdiction continues into adjacent sea areas is not resolved but it would be extremely unwise not to seek permission before undertaking fieldwork. The continued occupation of much of the Northern

Territory coastline by the traditional owners is an exciting aspect for maritime archaeology in the Northern Territory. There can be no comparison in the retention of knowledge with regards to shipwreck events and exact locations in these coastal communities with European communities in southern Australia. Many of the accounts of wrecked Macassan perahus have been obtained by anthropologists and terrestrial archaeologists who either lacked the means or were disinclined to investigate further. Any future shipwreck inspection work in the areas mentioned above will have limited success or end in failure unless there is cooperation with the traditional owners.

Conclusion

Though every wreck has its own inherent significance, two themes, which embody many Northern Territory wrecks, stand out and are of immense interest for the Northern Territory as well as the rest of Australia. The first of these is the presence of Macassan wrecks. The Macassan experience in Australia is significant not only because it predates the period of European settlement, but also in the manner in which contact and relationships with the indigenous inhabitants differed to that of the European settlers. To this date no *perahu* wreck has been located though rumours abound. The difficulties of locating a Macassan wreck cannot be overstated but the effort in the end would be worthwhile.

The World War II wrecks of Darwin Harbour are an underestimated resource within Australia. Within a small area one can dive on at least ten sites associated with World War II. Their degree of preservation is surprising, especially the Catalinas. The salvage operations by Japanese contractors in the 1950s on many of the shipwrecks in the harbour have in some cases enhanced the diving experience. Allowed only to remove the hulls above the mud line this has exposed the cargo, such as motor bikes, bren carriers and trucks, that some of the vessels were carrying for clear and safe inspection. This suite of wrecks are unique in an Australian context. Though the archaeological potential of these remains are limited these wrecks provide an excellent opportunity for promoting shipwrecks and Australia's heritage to the public.

Acknowledgements

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Archaeological investigations of the Catalina wreck sites in East Arm, Darwin Harbour

Silvano Jung

13 Houston Street, Larrakeyah, NT 0820

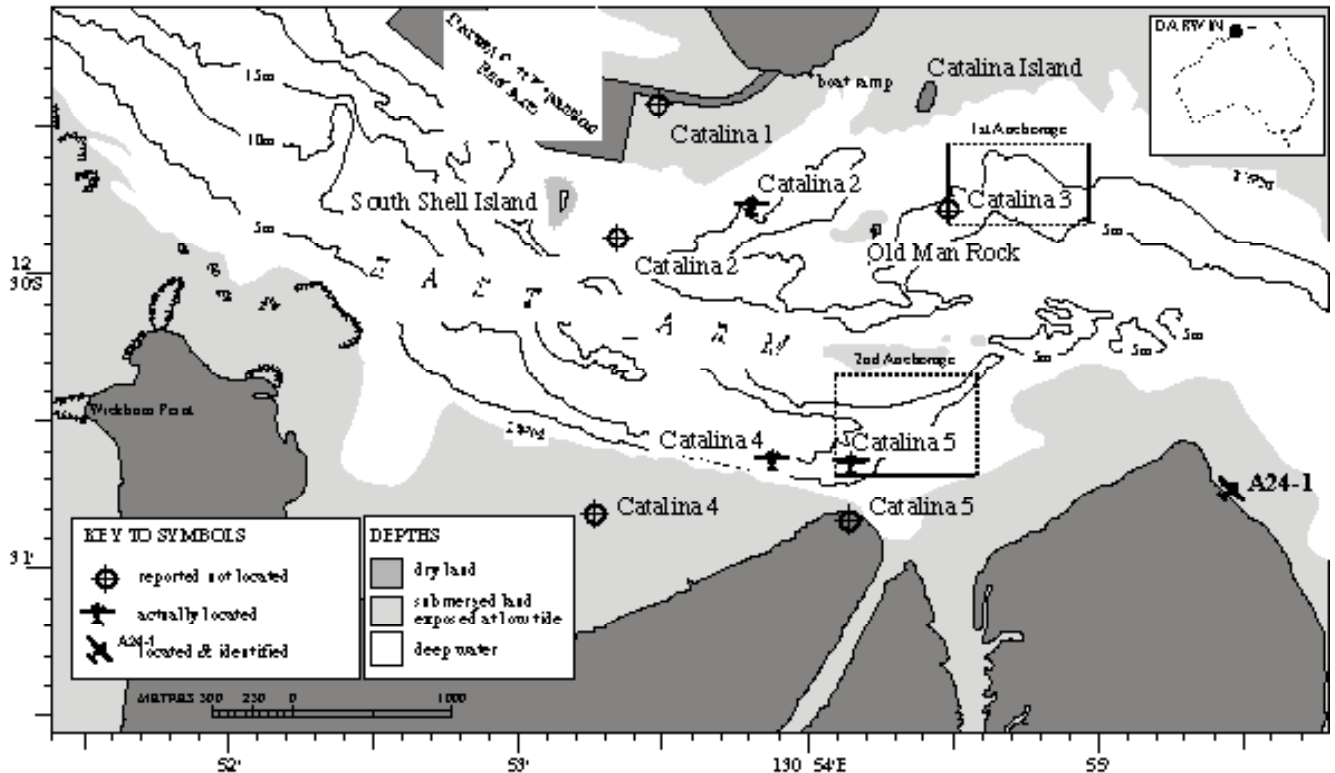


Figure 1. Site location chart of the Catalina flying boat wreck sites in East Arm, Darwin Harbour. Positions marked as ‘reported not located’ are taken from DPIF (1992). The other locations are GPS readings taken by MAGNT except for A24-1 which was plotted from chart (After Admiralty Chart Aus 28, 1995). Also shown are the areas of WW II Catalina anchorages where planes were moored for arming and refuelling purposes (Harron, 1943).

Introduction

Wreck inspections carried out by the Maritime Archaeology and History Section, Museum and Art Gallery of the Northern Territory (MAGNT) in 1995 were aimed at verifying a number of reported World War II (WW II) Catalina flying boat wreck sites in East Arm, Darwin Harbour. The origin of these reports is a publication called *Wrecks in Darwin Waters* produced by a high school teacher (Lewis, 1992), which mentions the positions of five Catalina wreck sites. However, Lewis’ locations of these sites is questionable. He does not conclusively identify the Catalina wreck sites he refers to, except for one Royal Australian Air Force (RAAF) Catalina known as A24-1.

This study provides information on where four of the six Catalina wreck sites are actually located as determined by the MAGNT wreck inspections. Focus is then turned towards establishing a predictive model which identifies

diagnostic variables that illustrate the different Catalina models wrecked in Darwin Harbour. It is argued that determining the Catalina model at each wreck site will identify which aircraft are United States Navy (USN) and which are RAAF. Other factors that could identify each wreck site are also examined, such as evidence for how each aircraft was lost. Examination of the wreck site data that records the loss event would help to determine whether a plane had crashed or whether it had been destroyed while moored.

Two examples of the PB4Y-1 model were lost in Darwin Harbour and these planes 22-P-4 (BUAERNO 1214) and 22-P-8 (BUAERNO 1233 or 1238) (James, A., 1997, pers. comm. 15 May, Wagner, R., 1997, pers. comm. 5 May) However, the third US Navy plane which was 22-P-41, an ex-Royal Netherlands Air Force plane which was PB4Y-5, an all together different looking aircraft from PB4Y-1. These three planes belonged to Patrol Wing

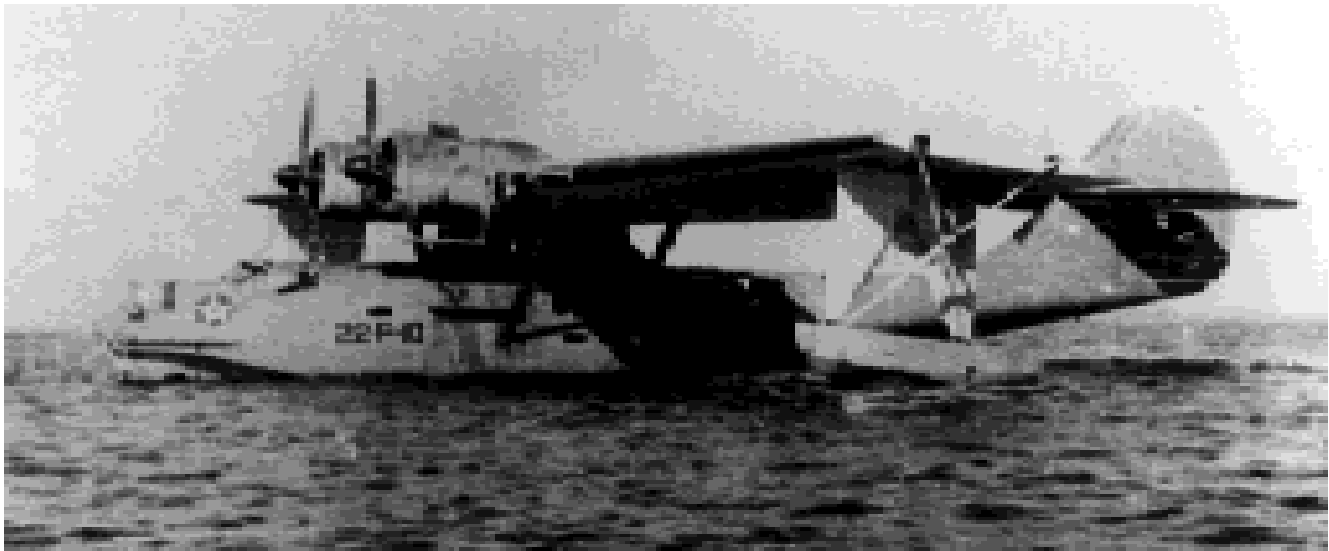


Figure 2. US Navy 22-P-10 from PATWING 10 which had flown to Derby from Darwin shortly before the first Japanese air raid. Note the spinners or air screws on the propellers that were distinctive to this model Catalina (Duncan Jenkins Collection PH106/9, Northern Territory Library).

10 (PATWING 10). The US Navy planes were strafed at their moorings during the first Japanese air raid on Darwin on 19 of February 1942. The RAAF lost one PB5Y-5 (A24-1), one PB5Y-5A (A24-69) and two PB2B-1s (A24-205 and A24-206) in 1945 as a result of accident rather than enemy action. Once again, there were marked diagnostic changes in the appearance between each of the models mentioned. Therefore, if the model of each wreck site can be determined, the identity of some of the planes can be established. Other features or factors that distinguish A24-205 from A24-206, both PB2B-1s, will need to be examined. These are discussed, concluding that further underwater archaeological research is required to test the identification hypothesis.

Previous reports and publications

A publication produced for anglers by the Department of Primary Industries and Fisheries (DPIF, 1992:10–11) called *Darwin's artificial reefs* provided chart plotted latitude and longitude co-ordinates for five Catalina wreck sites, co-inciding with four of Lewis' locations. However, two differences in this publication, compared with Lewis (1992) are the addition of a site position called 'Catalina 5' and an omission of A24-1. The two publications (Lewis 1992 and DPIF, 1992) are generally similar; both mention the reported locations of the wreck sites and neither verify that cultural material is actually found on those locations. Therefore, an archaeological field survey of East Arm previously has not been done. The MAGNT Catalina wreck inspections, that are reported on in this paper, are the archaeological appraisals of the extent of the submerged cultural material in the East Arm.

Darwin Port expansion—East Arm. The draft Environmental Impact Statement

The Draft Environmental Impact Statement (Acer Vaughan, 1995: 91, 92, 101) for the new port development in East Arm uses Catalina positions given by Lewis (1992) and DPIF (1992) in their report. However, one reported wreck site, 'Catalina 1' has never been located and it is now suggested that it was confused with the position of the nearby site of 'Catalina 2' (see Fig. 1) (Coulter, B. 1996, pers. comm., 1 November). By inference, the environmental impact statement did not ground truth the location for this wreck site because it still included the reported location of 'Catalina 1' in its findings and recommendations, even though nothing is now said to have been found at that location (Acer Vaughan, 1995: 90–91). Furthermore, according to Lewis (1997, pers. comm, 9 April) the Royal Australian Navy Dive Team 11 did do a survey of the area where 'Catalina 1' was reported to be as a training exercise, but found nothing.

Environmental Assessment Report—aims and results

In the Environmental Assessment Report and Recommendations for the Darwin Port Expansion—East Arm (Environment Protection Unit [EPU]), mention is made of the remains of the East Arm Flying Boat Base and Lugger Maintenance Section, but the sunken Catalinas are only briefly referred to (EPU 1994: 18). The reference to these submerged aircraft wrecks is in the Appendix: 'Undertakings by the Proponent'. The undertaking in regard to these sites is that: 'Assistance will be provided for the salvaging and relocation of the two Catalina Flying Boat wrecks in the port construction area' (EPU 1994). The two wreck sites which are referred are

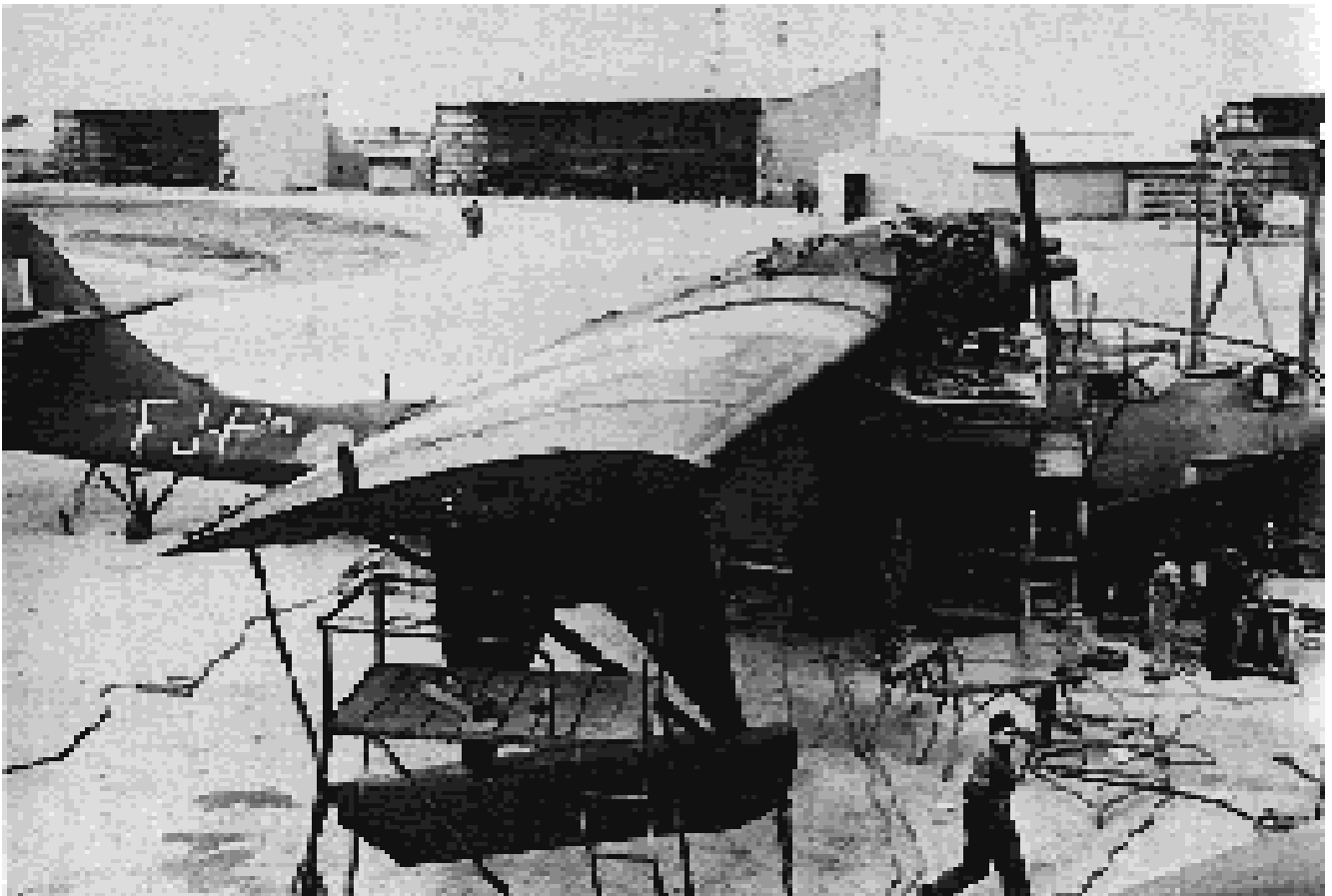


Figure 3. '...A24-69 undergoes modification from amphibian to flying boat at Lake Boga, during August 1944. This aircraft was the first PB5A received in the country' (Vincent 1981: 66).

'Catalina 1' and 'Catalina 2' (see Fig. 1). As mentioned above, the existence of 'Catalina 1' has not been verified but a small salvage operation was carried out at the site of 'Catalina 2'.

In response to the EPU's recommendation, the Royal Australian Navy and the Darwin Aviation Museum raised one engine off the wreck site but left the remainder of the aircraft in the East Arm (Figs. 5–6, 15). The EPU's recommendation to raise the aircraft wreck site completely and relocate it to another part of the harbour was not feasible. The engine raised from the site was then destined for display at the Darwin Aviation Museum, but it is still undergoing rudimentary conservation at the Aviation Museum's Garden Hill workshop (Chandler, 1994; Lewis, 1995: 26).

MAGNT previous studies

More recently, museum reports by Clark and Jung (1995) and Jung (1996) have verified the locations of some of the Catalina wreck sites, but have included the Lewis and DPIF positions for those sites whose locations have not been verified to date. These two reports have also postulated how some of the sites could be identified, but they need further verification in order to affirm this. In retrospect then, it is evident that a cycle of

misinformation has developed that perpetuates historical inaccuracies as to where the Catalina wreck sites are located and which plane is which. This situation needs to be changed by surveying the Catalina sites using a systematic methodology that is verifiable; to date this has not been done. The research presented in this paper is a start in this direction, in that it provides verifiable information to where some of the Catalinas are actually located and looks at the available evidence that suggests how they could be identified.

Locations of the Catalinas in East Arm

Four reported Catalina wreck site locations were inspected during the 1995 field season. These were: 'Catalina 2', 'Catalina 4', 'Catalina 5' and A24-1 (Fig. 1). Time and resources did not allow visits to the other reported wreck site, 'Catalina 3'. The sites inspected by the Museum occur at the northern shores of East Arm, bounded to the west by South Shell Island, and bounded to the east by Old Man Rock as well as along the southern shores of East Arm.

The locations of 'Catalina 2', 'Catalina 4' and 'Catalina 5' were recorded using between 25 to 50 GPS (Global Positioning System) readings which were averaged to produce the latitudes and longitudes listed in Table 1.

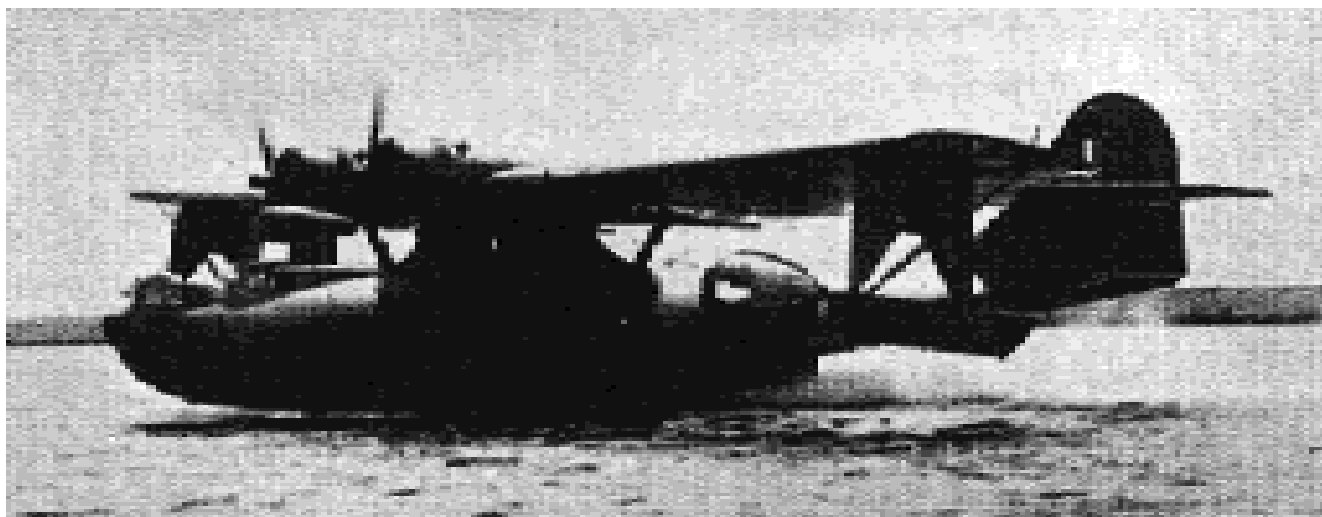


Figure 4. 'A24-206 taxis across Lake Boga prior to delivery to No. 43 Squadron' (Vincent 1981: 117). Note the radome mounted above the cockpit.

The location for A24-1 was derived by chart only. The GPS locations given in Table 1 were obtained using a hand-held Magellan 2000 GPS which is only accurate to about 100 metres. One site, 'Catalina 4', is currently marked with a buoy. A24-1 is perhaps the easiest site to re-locate because it is on a mud bank on the edge of mangroves in East Arm and is exposed at low tide.

Environmental description

The Northern Territory city of Darwin is located in the tropics which experiences two defined seasonal changes known as the Wet Season (October to May) and the Dry Season (June to September). The region experiences tropical cyclones during the Wet Season that have occasionally hit Darwin with destructive force.

Darwin Harbour is split up by three peninsulas of land which form the West Arm, Middle Arm and East Arm water courses. Like most of the intertidal zone in the harbour, East Arm consists of mud flats with mangrove populations growing along the high-tide line (Hanley, 1988: 135).

Three Islands occur in East Arm. These are North Shell, South Shell and Catalina Islands (exposed at high tide). Old Man Rock is a pinnacle that also becomes submerged at high tide and this is marked with a navigation beacon together with South Shell Island. North Shell Island has recently been covered over and incorporated into a land backed wharf, which began construction in 1995.

The sub-tidal environment in East Arm is composed of fine sands and mud with a scour zone of gravel in channels which are flushed by fast flowing tidal streams (Hanley 1988: 135). Darwin experiences tidal variations of up to eight metres resulting in strong currents. Underwater visibility in the Dry Season is between 0 to 5 metres. Wet Season run-off, however, reduces visibility even further, but corals manage to survive, as well as sponges and ascidians in the murky waters. The located wreck sites also form important artificial reefs that attract a diversity of fish species such as golden snapper, jew fish, moon fish, estuary cod, Spanish flag and coral trout (DPIF, 1992: 10–11).

| SITE NAME | LATITUDE (South) | LONGITUDE (East) |
|------------------|------------------|------------------|
| Catalina 1 | 12° 29.45' | 130° 53.50' |
| Catalina 2 (GPS) | 12° 29.76' | 130° 53.81' |
| Catalina 3 | 12° 29.80' | 130° 54.50' |
| Catalina 4 (GPS) | 12° 30.63' | 130° 53.88' |
| Catalina 5 (GPS) | 12° 30.64' | 130° 54.16' |
| A24-1 | 12° 30.74' | 130° 55.46' |

Table 1. Location co-ordinates for the six reported Catalina wreck sites in East Arm.

Catalina specifications—diagnostic features between models

The American flying boat was at the end of its production by 1939 as it was obsolete. However, England's urgent need for aeroplanes as a result of War being declared with Germany boosted the American aviation manufacturing industry. The Americans called their flying boats 'PBY' (Patrol Bomber/Consolidated [Y is the code for 'Consolidated']) in recognition of their multi-purpose role ranging from air-sea rescue, coastal surveillance and offensive capabilities. It was because aircraft such as these that the English needed so badly, that an initial order of 106 planes was sent to Consolidated Aircraft Company's factory in San Diego, California on the day War was declared (Wilson, 1991: 16). This huge demand for the aircraft spurred on further production that meant the rebirth of the flying boat, some of which are still flying today as water bombers and survey aircraft (Wilson 1991: 12). The English subsequently renamed the PBY as the 'Catalina' after the idyllic island called Santa Catalina near San Diego. The Americans then abbreviated the name further to 'Cat' (Knott, 1981:9).

The change from PBY-4 to PBY-5

Two examples of the early PBY-4 models (22-P-4 and 22-P-8) are wrecked in the harbour. A photograph of another one of the US Navy Catalinas, 22-P-10, which belonged to PATWING 10, shows that it is a PBY-4 model (Fig. 2). This particular plane was not lost in Darwin Harbour, but it illustrates that PATWING 10 did have PBY-4 models in Darwin. These models had sliding hatches on either side of the fuselage that covered the waist gunner's position. They also had propeller spinners and rounded tail surfaces. As a result, although James (1997) and Wagner (1997) do not cite primary references, their opinion that the two PBY-4 models are wrecked in Darwin Harbour is valid since there were PBY-4s operating from Darwin.

These PBY-4s were meant to be the last model of Catalina built, but Commonwealth orders for more flying boats resulted in new model productions (Wilson 1991: 16). First of the new models was the PBY-5 which featured observation blisters on either side of the fuselage and changes to the tail surfaces as well as the change to more powerful Pratt and Whitney engines (Fig. 7. See also Appendix 1). In Darwin Harbour, there is record of two of this model having been lost, Wing Commander Keith Bolithos' A24-1 and the ex-Dutch plane from the US Navy mentioned previously. The RAAF also lost later model Catalinas in the harbour. These were one PBY-5A and two PB2B-1s; the latter being Canadian built.

Diagnostic features of the PBY-5A

The PBY-5 was purely a flying boat, but the PBY-5A was an amphibious aircraft, delivered to the RAAF with an undercarriage enabling it to land on water as well as on an airstrip. The PBY-5 flying boat had to have beaching



Figure 5. A Catalina engine said to have been recovered off 'Catalina 2' by 'the salvage team' (Candler 1994).

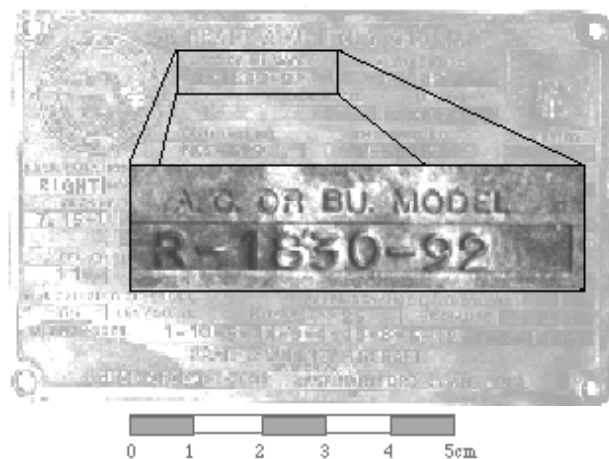


Figure 6. Close-up shot of the engine number on the manufacturer's engine plate said to have been removed from the Catalina engine in Figure 5.

gear fitted to enable it to come out of the water onto a ramp. The beaching gear also had to be removed before flight once the aircraft was back in the water. However, the convenience of being amphibious was not suitable for a military aircraft which could not afford the space and additional weight of the undercarriage. In World War II the Catalinas had to fly sorties to far-away targets. Every bit of space was needed as well as the need to keep the aircraft as light as possible. The flying boat was lighter and could travel further with a heavy bomb load than the PBY-5A. Consequently, the RAAF converted many of these amphibious aircraft to flying boats known officially as PBY-5A(M) (i.e. modified). The conversion involved removing the amphibious gear and installing an auxiliary power unit in the port wheel well and food lockers in the starboard wheel well (Vincent 1981: 66). A24-69 was one of the first of this model in the country (Fig. 3).

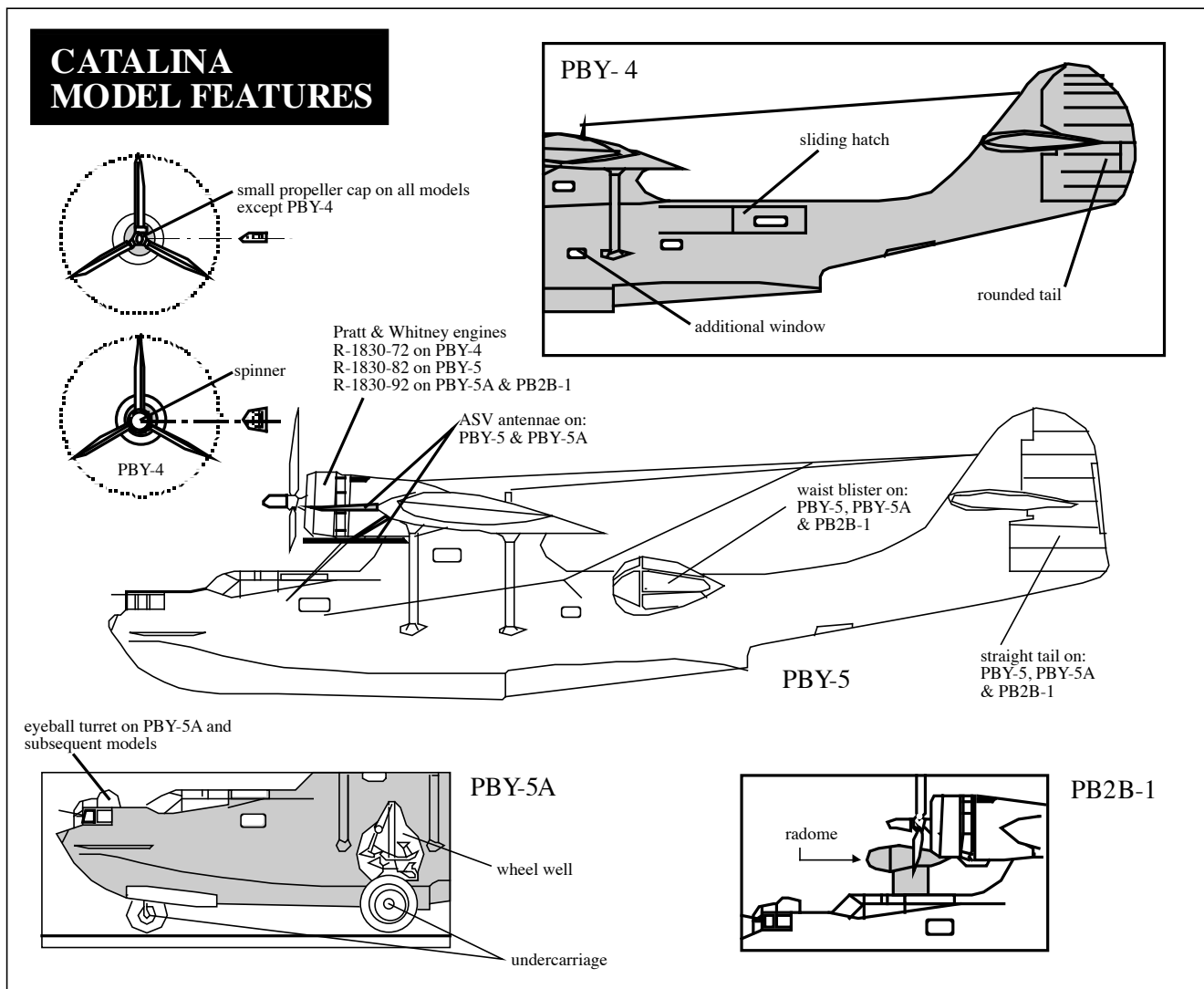


Figure 7. Catalina line drawings showing the main differences between the models sunk in Darwin Harbour (Knott 1981: 138; Knott 1979: 177).

Another distinguishing feature of the PBY-5A model was that it was the first to incorporate the ‘eyeball’ turret that held twin 0.30-inch machine guns instead of the single gun in previous turrets (Wilson 1991: 19). Subsequent military model Catalinas had these turrets including the PB2B-1s.

Cat eyes—diagnostic features of the Catalina RADAR

The Patrol Bomber/Boeing (PB2B-1), otherwise known as the ‘200 series’ was one of the later model Catalinas lost in Darwin Harbour by the RAAF. The most distinguishing feature for this aircraft was

...the radome mounted dish driven by an electric motor which replaced the mass of aerials on the earlier PBY-5 and 5A models (Vincent 1981: 77).

Figure 4 shows A24-206 at Lake Boga with the radome mounted on top of the cockpit (see also Fig. 7).

The concept of the RADAR had been developed further by the Americans after the British had used it successfully in the Battle of Britain, by installing the first operational ASV (Air-To-Surface Vessel) RADAR on board USN Martin PBM-1 Mariners for anti-submarine patrols. By 1942, the ASV radars were being installed in PBY Catalinas which effectively enabled the aircraft to see in the dark (Knott 1981: 90–91). These early ASV RADAR were primitive in comparison to the new radome which was fitted to the PB2B-1. The radome operated much like the turning radar bar that can be seen on surface vessels today, except that it was enclosed in a foot ball shaped housing that made the unit aerodynamic.

Catalina engines

Knowing the various types of Pratt and Whitney engines is of some help in identifying the different Catalina models lost in the Harbour. The early PBY-4s had Pratt and Whitney R-1830-72 Twin Row Wasp engines which

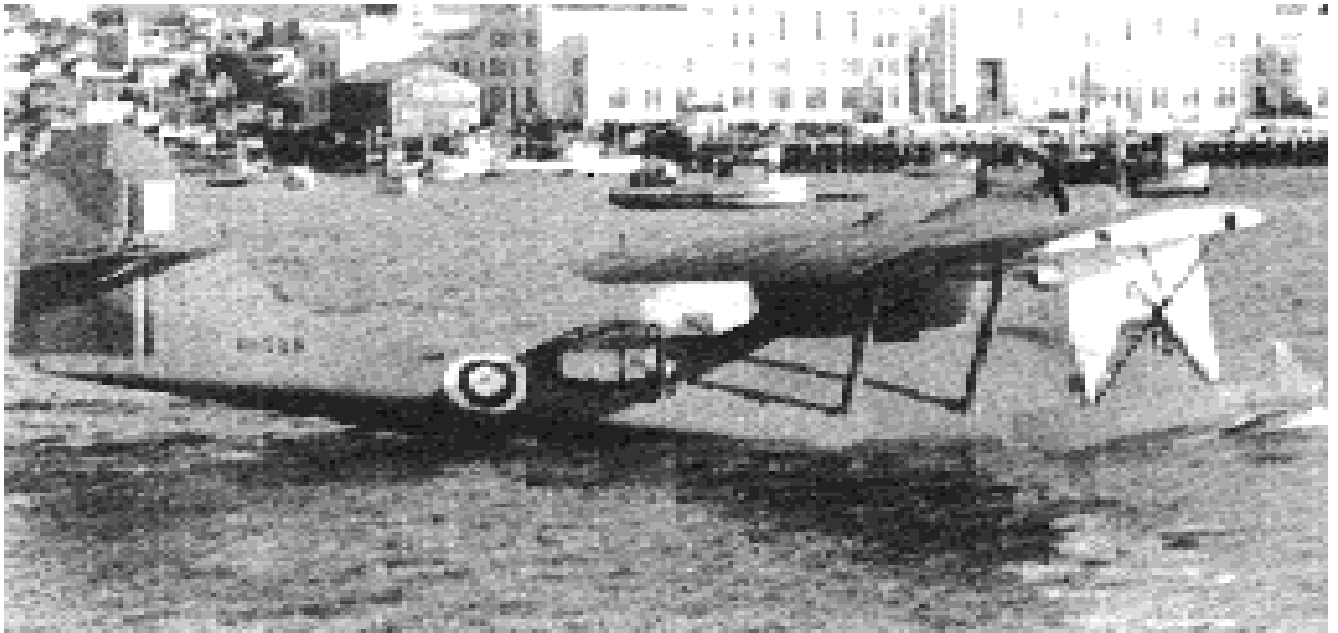


Figure 8. 'The RAAF's first Catalina, A24-1, pictured at San Diego in early 1941 and still wearing its Royal Air Force serial number, AH534. For the delivery flight to Australia it was allocated the civilian registration VH-AFA' (Wilson 1991: 22)

had propeller spinners or air screws. This model was the only one which had propeller spinners that made the propeller mounting more aerodynamic (Wilson 1991: 16). They may have been dropped from latter models to help keep production costs down (Fig. 2 see also Fig. 7). The PBY-5 and PBY-5A had more powerful Pratt and Whitney R-1830-82. The latter model PB2B-1's also had Pratt and Whitney engines, but these were the latter and increasingly powerful Pratt and Whitney R-1830-92 Twin Row Wasp engines (Appendix 1).

However, it may be too tenuous to assert that the different engines can actually indicate which model aircraft they were mounted on. The long sorties flown by these aircraft during the War took their toll on machinery necessitating engine changes. An engine specification plate said to have been recovered off an engine from 'Catalina 2' shows that this aircraft was fitted with R-1830-92 engines (Fig. 6). As these were a later model engine, it seems that this aircraft did undergo at least one engine change.

Engines are bulky and dense hence they survive quite well at an underwater aircraft wreck site, whereas other, more fragile parts of the aircraft such as the wings, tail surfaces and fuselage are more likely to break-up. This differential preservation of aircraft elements is repeated at other underwater aircraft wreck sites where fuselage does not survive. For example, an investigation of a Liberator bomber in the Marshall Islands shows that wings and engines have survived, but the fuselage has not (Spennemann, 1996). This is further demonstrated by the two other inspected Catalina wreck sites in Darwin Harbour that still had their engines ('Catalina 4' and 'Catalina 5'), but were missing parts of their wings and fuselages.

Summary of Catalina service history

There were five USN Catalinas in Darwin Harbour in February 1942. These planes were all from PATWING which was involved in tracking the advancing Japanese forces moving south through the Macassar Straits. Little is currently known of their service history except that they were reinforcements from Patrol Squadron VP-22. PATWING 10 originally comprised of Squadrons VP-101 and 102, but an additional 12 PBYS from Squadron VP-22, as well as another five handed over by the Royal Netherlands Air Force, brought the total number of aircraft in PATWING 10 to 45 (Knott 1981: 57). This occurred in January 1942. Soon after PATWING 10 was sent to oppose the Japanese landings at Manado, north Sulawesi (Knott 1981: 50–51).

The first Catalina delivered to the RAAF was A24-1. This aircraft was meant for the Royal Air Force (RAF) as part of their initial order for flying boats from Consolidated (Fig. 8). The first registration number for this aircraft was, therefore, a RAF number: AH534. However, the RAAF flying boat order was not ready by the time the Australians arrived to pick-up their aircraft. The Australian and British Governments then came to an agreement whereby the RAF would give one of its Catalinas to Australia on the understanding that the RAAF would then give its first production scheduled flying boat from Consolidated to the RAF (Wilson 1991: 22).

By this stage of the War, America was still neutral and as a result, the delivery flight of A24-1 to Australia had to be made with civilian registration letters VH-AFA and flown by Qantas crews who were part of the Qantas Long Range Operations Division (Vincent, 1981: 12; Wilson,

1991: 22). The delivery flights of the first 18 Catalinas to Australia by Qantas pilots represented achievements in long distance flights that were pioneering in aviation history. For instance, starting from San Diego on 25 January 1941 and arriving at Sydney five days later, the delivery flight of A24-1 was only the third time the Pacific had been crossed by air (Wilson 1991: 22). This demonstrated the aircraft's long range capability, which was to prove throughout the War as the aeroplane's greatest asset. The longest leg of the delivery flight was from San Diego to Honolulu, a distance of 2 371 nautical miles (4 392 km) which required almost a full day in the air (Wilson 1991: 22).

The aircraft was received at Rose Bay, Sydney, on 2 February 1941 (Riddle, 1992: 11). A24-1 was used thereafter for sea plane training in New South Wales until significant Catalina losses required it to be brought into front line service (Riddle, 1992: 8). On 14 March 1941 the aircraft was issued to No. 11 Squadron at Port Moresby. Upon arrival at Port Moresby, Captain Sims, who had flown the aircraft to Port Moresby from Australia, commenced the operations of carrying RAAF personnel and equipment to the AOB's (Advanced Operational Bases) and continued patrolling Australia's outer defence perimeter. The aircraft remained in service until 2 September 1941, when it returned to Rathmines New South Wales for engine changes (Riddle, 1992: 11).

A24-1 was attached to No. 20 Squadron at the time of its loss. This Squadron began their move from Cairns to Darwin in June 1944 after having flown a variety of sorties from Cairns to targets such as Buin, Faisi, Tonolei, Buka, Kahili, Kavieng, Bouganville and Rabaul (Riddle, 1992: 28–48). One of the most spectacular successes of A24-1 was when it sighted a Japanese convoy on 6 January 1943. In command of A24-1 was Captain David Vernon who describes the attack on one of the vessels in the convoy the 5 447 ton *Nichiryu Maru*, a troop ship carrying between 600 and 700 troops. The vessel exploded with the loss of all aboard except for six men who were later seen in a whale boat (Riddle, 1992: 38; Vincent 1981: 30).

By mid 1944 Nos 20 and 43 Squadrons (the latter from Karumba) had completed their move to Darwin. The Squadrons were then involved in mine laying operations under the direction of No. 76 Wing based at Doctor's Gully, Darwin (Vincent, 1981: 67). Mine laying, bombing and torpedo operations continued later on around the Philippines and South China Seas until the end of the War with Japan on 15 August 1945. Catalina operations, however, continued afterwards when A24-1 and several other aircraft from Rathmines flew to Singapore, taking blood plasma, penicillin, surgical equipment and quinine to return with Australian prisoners of war (POW). It was while operating in this role that Catalina A24-1 crashed on take-off and was abandoned on a mud bank in East Arm.

A24-69 could have been repatriating POWs from Singapore, much like A24-1, as these two planes were

both lost shortly after the War. Reference to it having taken part in an air raid on Malang airfield when the RAAF Catalinas had reverted to their bombing role to harass Japanese airfields in the Indies is all the examined references record of its war-time service (Vincent, 1981: 81). Perhaps the greatest historical interest concerning this aircraft is that No. 43 Squadron was the first unit to operate all three PBV-5, PBV-5A and PBV-5A(M) models (Fig. 3). Its PBV-5As were officially the strength of No. 6 Communications Unit but attached to No. 43 Squadron for air sea rescue duties (Vincent, 1981: 66).

Even less information exists about what A24-205 and 206 (Fig. 4) were doing before their loss. One assumption is that A24-206 was involved in anti-submarine duties on account of it being loaded-up with depth charges. Further archival research is required to reconstruct their service histories.

Historical account of loss

On the morning of 19 February 1942, one hundred and eight-eight aircraft from four Japanese carriers in the south Timor Sea and from the air strip at Kendari in Indonesia, launched the first air raid on Darwin. Their mission was to destroy Allied shipping, aircraft and airfields as well as other targets in town (McCarthy, 1992: 1, 3). On the water that day were three USN Catalinas, moored close to the 1 190 ton US Navy seaplane tender *William B. Preston* (AVD-7), a converted destroyer and the coal hulk *Kelat* (Aviation Historical Society [AHS], 1992: 15; Vincent, 1981: 40). These planes had the USN registration numbers 22-P-4, 22-P-8 and 22-P-41. The other two planes in PATWING 10, but which were not destroyed in Darwin Harbour, were numbers 22-P-10 and 22-P-18 (Lewis, 1992: 42). Earlier that morning, 22-P-10 (Fig. 2) had flown to Derby and 22-P-18, flown by Lieutenant Thomas Moorer and his eight crew, had been sent out on patrol (AHS, 1992: 14; Lewis, 1992: 43; Knott, 1981: 59; Messimer, 1985: 246).

While flying towards their target, nine Japanese fighters came across Lieutenant Moorer's Catalina 22-P-18. The Catalina was shot down near the northern tip of Bathurst Island, becoming the first USN Catalina to be destroyed that day. The remaining three Catalinas of PATWING 10 (22-P-4, 22-P-8 and 22-P-41) were strafed and sunk at their moorings in Darwin Harbour (AHS, 1992: 14-16). The air crews abandoned their moored aircraft as soon as it was realised that a numerically superior force was attacking them and tried to make it to the *William B. Preston* or to shore. Plane No. 22-P-41 was apparently the last to be destroyed:

During this time both planes and personnel were subjected to many strafing attacks. Fortunately none of the men were wounded. When plane number 41 remained afloat after four strafing attacks it was blown up by bombs dropped by a 'Jap plane' (Lewis, 1992: 42).

| RAAF Number | Model | Previous Identity | Delivered | Disposal/Remarks |
|-------------|--------|--------------------------------|-----------|---|
| A24-1 | PBY-5 | RAF AH534 Civilian Reg. VH-AFA | 02/41 | Lost on take off from East Arm, Darwin 30/8/45 |
| A24-69 | PBY-5A | USN 34056 | 12/43 | Caught fire while moored East Arm 14/12/45 |
| A24-205 | PB2B-1 | USN 44224 RAF JX614 | 01/45 | Crashed on take off and sank East Arm 9/8/45 |
| A24-206 | PB2B-1 | USN 44217 RAF JX611 | 02/45 | Destroyed after explosion of depth charges East Arm 20/6/45 |

Table 2. Historical data of the four RAAF Catalinas lost in East Arm, Darwin Harbour (Vincent, 1981: 107, 111, 116; Wilson, 1991: 63, 64).

Despite 63 further air raids on Darwin by the Japanese (AHS, 1992: 78-79), there were no further Catalina losses in the harbour until 1945, when four from the RAAF were lost (Table 2). In 1994 Andrew McMillan interviewed Catalina veterans and recorded their version of events on two of the four RAAF Catalinas lost. These accounts are the only recorded interviews with the witnesses of the RAAF losses. While under the command of Wing Commander Keith Bolitho, A24-1 crashed during take-off and sank on 30 August 1945. Jim Rodgers, gives an account of the loss:

Our aircraft are overloaded sir. We can't possibly go like this. I pointed out to them that they weren't over loaded and Keith decided he'd show them that everything was alright and he promptly started bouncing his aeroplane. But he had a theory that if you didn't fly after your third bounce you weren't going to fly at all. And he's up about fifty feet in the air and he pulled his donks (engines) off and goes bang on the bottom and the whole bloody hull on the bottom just caves in (McMillan 1994a).

The aircraft sank in shallow water in three minutes. Alic Emslie, No. 20 Squadron leader, goes on to say what was salvaged:

And he sunk out in the area there and we got the crash boats out and we got them off alright, but the aeroplane was nearly under, and all their cargo was on board... Anyway we got the panniers out of the thing and that night we managed to beach the aeroplane and I put the doctor and my Squadron Leader duty officer on to make sure this was salvaged properly, and they got down there and the doctor said 'Oh these instruments are buggered, they've been under salt water'. And all the airmen were hopping in and souveniring them, and I had to get the bloody things back. The army were pretty annoyed about it all. I got 'em back, the blokes were pretty good (McMillan 1994a).

The aircraft has been on the same mud bank since it was beached after the accident. The other Catalinas, as far as it is known, were never beached for salvage, but left *in situ* where they were lost.

The following is a transcript of an interview with

Alic Emslie who witnessed the accidental explosion of a depth charge which destroyed A24-206:

We'd just been out on a job in it and when we came back and landed and they'd refuelled it and we were almost to the jetty when we heard this terrific crunch. They'd been loading depth charges on it and they had two on one side, they were fitting one to the other side when some clown in the cockpit pressed the release button and dropped the depth charges off. Of course when they went down and reached their depth, up they went. One dropped straight through the bomb scow. It killed I think three fellows on the bomb scow and then others were concussed in the water, a couple drowned (McMillan 1994b).

Vincent (1981: 122) lists 2 armourers killed, LAC R. L. Graham and Cpl W. A. Strang. These men are interred in the Adelaide River War Cemetery.

MAGNT Catalina wreck inspections

Four of the six reported Catalina wreck sites in East Arm were visited during the 1995 field season to verify their locations using GPS and to record information on the cultural material remaining. From March until November 1995 MAGNT archaeologists visited the wreck sites of 'Catalina 4', 'Catalina 5', 'Catalina 2' and A24-1. Using SCUBA, sketches of 'Catalina 4' and 'Catalina 5' were drawn illustrating the conditions of these two wreck sites. Their dives also documented the port wing, engine and forward section of the fuselage of 'Catalina 4' with photography and underwater video. The wreck sites of 'Catalina 2' and A24-1 were not recorded as intensely, but a GPS position for 'Catalina 2' was obtained and A24-1 was visited, but not surveyed.

'Catalina 5'

One of the first Museum dives on the Catalinas was the wreck site of 'Catalina 5'. Cosmos Coroneos, Paul Clark and Rob Smith dived the wreck on 5 March 1995. A site sketch was produced during the wreck inspections (Fig. 9) that shows an extensively damaged aircraft with some structure still remaining.

The site lies on a silt bottom at a depth of 9 to 12 metres. The port wing is upside down on top of the starboard wing. The port engine sits inside the cockpit. The starboard engine is located under the port wing next to the fuselage. One of the propellers of the starboard engine appears to protrude through the port wing. The tail section, although not seen, is apparently 40 metres off site (Weiss, 1996).

'Catalina 4'

On 20 of August 1995 'Catalina 4' (Fig. 10) was visited by Coroneos, Clark and Didier Rouer. A further two site inspections were done on 5 October (Coroneos and Bob Ramsey) and on 16 November (Clark and Rouer). An underwater video camera and a Nikonos 5 camera

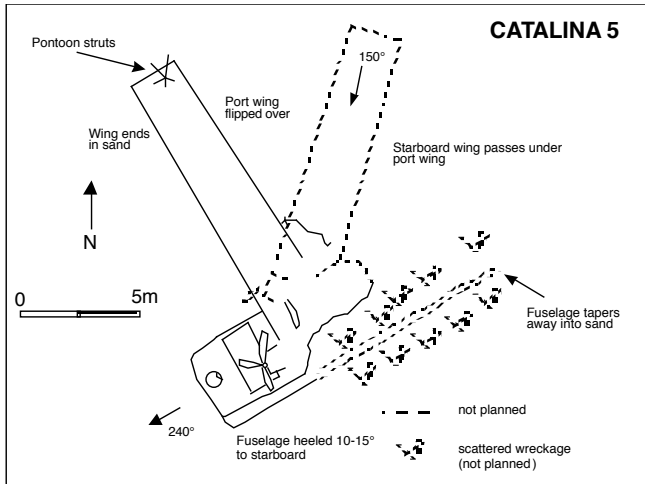


Figure 9. Sketch plan of 'Catalina 5' in East Arm, Darwin Harbour (Drawing by C. Coroneos and P. Clark 1995).



Figure 11. Photo showing large hole in the port wing of 'Catalina 4'. Scale in 20 cms (Photo: Bob Ramsey 1995).

is cracked. There is also a large hole in the centre of the wing where the metallic skin appears to have been peeled back (Fig. 11).

The port wing sits upright and is supported off the bottom by the pontoon strut. However, the pontoon that would have been attached to the strut, was not located. The port wing is still attached to the fuselage. The starboard wing was not located.

Both 14 cylinder engines are still on site, although they have collapsed from their mounts. The starboard engine is turned around and faces towards where the tail would have been. The port engine is buried in sediments with only one propeller visible. However, all three propeller blades are visible on the starboard engine. On the starboard engine propeller is a small diameter propeller cap, but no spinner or air screw which indicates that the wreck site is not of a USN PBY-4 (see Catalina engines).

A gunner's turret is recognisable by the circular opening on top of the nose. The glass of the gun turret itself is gone, leaving empty spaces between the turret struts. Furthermore, there was no evidence of the machine guns fitted inside the turret, but ammunition was seen strewn about the site. The cockpit is visible behind the gun turret and is distinguished by a large opening just above the point where the port wing joins the fuselage. The cockpit frame structure with glass is gone. The aft section of the fuselage, together with the tail, was not found.

'Catalina 2'

The second dive on 5 March was done on one of the Catalinas reported to be between South Shell Island and Old Man Rock at a depth between 12 to 14 metres. This was the wreck site of Catalina 2', which had been worked over by sports divers, the Royal Australian Navy and the Darwin Aviation Museum. The wreck inspection involved two divers (Coroneos and Smith) going down to see if there was a Catalina at this reported location. Since it was the second dive of the day on the same bottles, they were running out of air, but what they saw briefly was the scattered remains of a Catalina (Coroneos, C. 1996 pers. comm., 1 November).

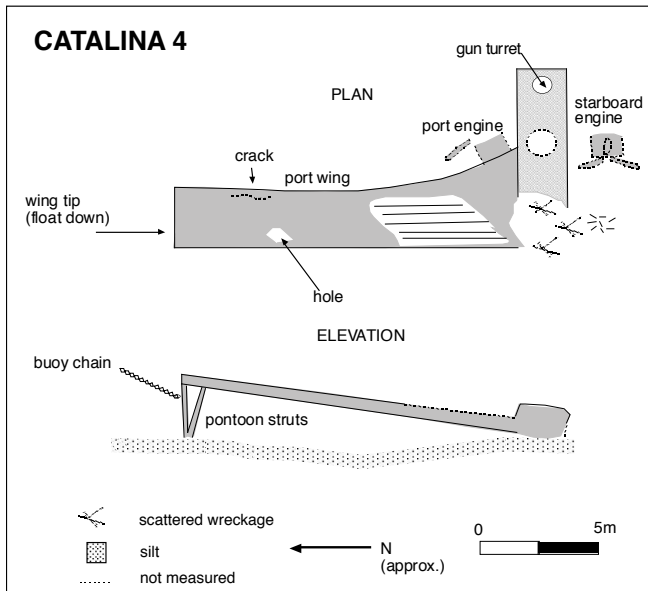


Figure 10. Sketch plan of 'Catalina 4' in East Arm, Darwin Harbour (Drawing by C. Coroneos, B. Ramsey and D. Rouer 1995).

where taken down on the second wreck inspection to record an image of the wreck.

This wreck site is at a depth of 12 to 14 metres and is currently marked on the surface by two buoys, one tied to the other sharing the single buoy chain that goes down to the wreck. The buoy chain is attached to the port wing pontoon strut which is in the 'down' position. These pontoons were folded flush with the wing tip once the aircraft was in flight and operated by the flight engineer who sat just below the middle of the wings. The port wing is approximately 15 metres long by 2.4 to 4.2 metres wide. The ailerons, on the western facing edge of the wing are missing. The wing is well preserved towards the tip but deteriorates towards the fuselage, with the skin missing and the air frames visible. At one point, at the centre of the wing, the leading edge

| Catalina Model | PBY-4 | PBY-5 | PBY-5A | PB2B-1 |
|-----------------------|-----------------|-----------------|---------------|-------------------|
| Aircraft lost | 22-P-4 & 22-P-8 | A24-1 & 22-P-41 | A24-69 | A24-205 & A24-206 |
| Engines | R-1830-72 | R-1830-82 | R-1830-92 | R-1830-92 |
| Radar antennae | ASV | ASV | ASV | Radome |
| Wheel wells | No | No | Yes | No |
| Tail surfaces | Rounded | Squared | Squared | Squared |
| Propeller spinners | Yes | No | No | No |
| Turrets | Circular | Circular | Eyeball | Eyeball |
| Waist blisters | No | Yes | Yes | Yes |
| Sliding hatch | Yes | No | No | No |

Table 3. Variable list of diagnostic Catalina model features.

A24-1

The last Catalina wreck site to be inspected on 16 November by Clark, Jung and Rouer was A24-1, stranded upon a mud bank at Middle Arm (Figs. 12 and 13). The site was located from a dinghy during the high tide which enabled a close approach. This wreck site is of the first Catalina received by the RAAF and it survived relatively well until Cyclone Tracy devastated Darwin on Christmas Day 1974. Most of the aircraft elements are still at the site, but are now scattered and structure is much less intact. The starboard wing could be seen above water with evidence of an engine mount. The engines were not seen because the site was flooding during the Museum visit. The wings themselves are no longer attached to the fuselage. The port wing was submerged, but just visible below the surface. Another recognisable feature was the forward gunners' turret.

Discussion

How can the Catalina wreck sites be identified?

'Catalina 4' sits upright on the muddy floor in East Arm, suggesting that it was stationary or moored at the time of its loss and that it settled into its final resting place. There is also the presence of a large hole in the port wing which could have resulted from an explosion. The damage evident on 'Catalina 4' suggests that it is A24-206 which was destroyed by the accidental explosion of a depth charge that it was being loaded-up with at the time of its loss. However, it is difficult to be positive about this, because the damaging process to an aircraft floating on the water by a depth charge dropping through a bomb scow and exploding some distance below the water is not well understood. In this case, if the damage seen on 'Catalina 4' was caused by an explosion, the damage was not so extensive as to blow the aircraft to pieces, but only put a hole in the wing and damage the hull. More collaborative evidence is needed to indicate that the damage seen on 'Catalina 2' was produced by a depth

charge explosion, rather than by post-depositional factors such as anglers' boat anchors going through the wing.

Another clue to the 'Catalina 4s' identification is an account by Hal Healy, who was one of the Catalina crews that remembers the depth charge explosion which destroyed A24-206. He describes the bomb scow that was sunk with A24-206 as 'a flat bottomed timber barge with an engine' (McMillan 1994c). This not only substantiates how the aircraft was lost, but also what other cultural material is associated with the loss (Fig. 14). This bomb scow may have survived in association with A24-206.

The wreck site of 'Catalina 4' has as yet not been looked at with the aim of finding out its identity. The Museum's visit to this site aimed to verify the location and to record what cultural material remained. It is now necessary to re-visit the site with the aim of proving that it is a PB2B-1.

Further cultural material is said to have been raised from 'Catalina 2' by the Darwin Sub Aqua Club which suggests that this is another RAAF aircraft, A24-69 (Weiss, R. 1996 pers. comm., 7 October). A manufacturer's specification plate, said to be one of the artefacts recovered from 'Catalina 2' (Fig. 15), is for a PBY-5A model Catalina. Historical records show that the only Catalina of this model lost in East Arm was A24-69. However, it is not possible to affirm this because the specification plate was removed without recording it *in situ*. The Museum inspection of 'Catalina 2' determined the wreck site's actual location, but did not have enough time to record any of the surviving cultural material that could help identify the site.

The wreck site of 'Catalina 5' appears to be that of an aeroplane which had crash landed on the water on account of the extent of the damage and spread of remains at the site, but only further surveying to relocate these other sections of the aircraft would help verify how the aircraft was lost. The only other plane to have crashed on take-off in Darwin Harbour apart from A24-1, was

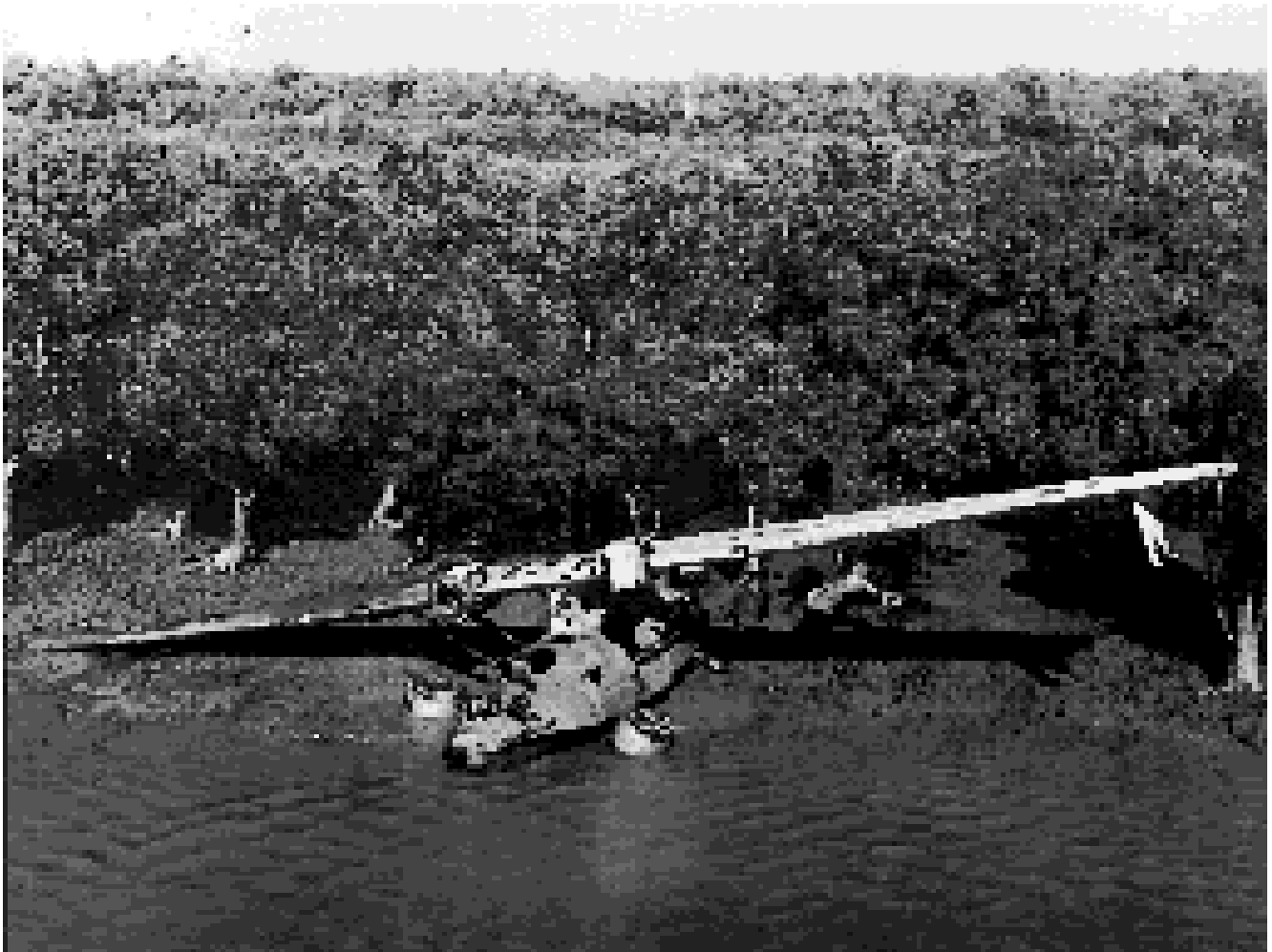


Figure 12. Remains of A24-1 abandoned in mangroves in East Arm, Darwin 1974 (Photo: Darwin Aviation Museum).

A24-205, a PB2B-1 model the same as A24-206. Further examination of the site is needed to find the radome that distinguished this particular model from the PB2Bs.

Historical accounts for the loss of A24-1 indicated that it was the only aircraft to be beached after its take-off crash. This explains why this is the most confidently identified Catalina wreck site because it has always been exposed on the mud bank where it lies today, whereas over time, the identity of the other aircraft became confused beneath the murky waters in East Arm.

Summarised in Table 3 is a list of variables mentioned previously under the ‘Catalina Specifications’ heading. This information can be used as a tool for helping distinguish between various models of Catalinas. However, in Darwin Harbour, archaeologists investigating the Catalina wreck sites must also be aware of how each aircraft was lost because evidence for their wrecking events can help to indicate how the wreck sites could be identified. For instance, there are two PB2B-1’s in Darwin Harbour. If the radome is located on both sites, another method is necessary to identify which wreck site is of A24-205 or A24-206. This study has suggested how ‘Catalina 4’ and ‘Catalina 5’ may have been lost, but now requires an appraisal of how the model variables

listed in Table 3 could substantiate their identification.

Catalina wreck site depositional theory

It is known that one Catalina wreck site is that of a RAAF aircraft, A24-1. Given that the other three wreck sites inspected by the Museum are possibly RAAF aircraft as well, then the reported wreck sites of ‘Catalina 3’



Figure 13. A24-1, exposed at low tide on mud bank in East Arm, Darwin Harbour (Photo: P. Clark 1995).



Figure 14. Armourers loading a Catalina in Darwin Harbour from a bomb scow, perhaps similar to the one sunk with A24-206 (Vincent 1981: 48).

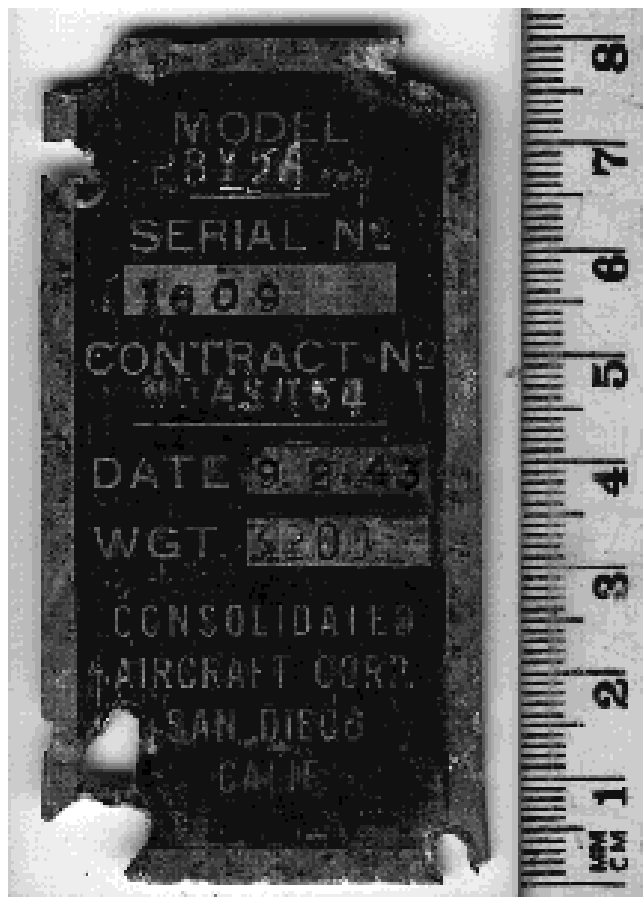


Figure 15. Aircraft identification plate said to have been recovered from 'Catalina 2' (Photo: S. Jung).

must be USN as there were only four RAAF Catalinas recorded to have been lost. However, the USN Catalinas were not sunk in East Arm. A map produced by the AHS shows an approximate position for where the three USN Catalinas were moored during the first Japanese air raid on Darwin. These aircraft were moored in deeper water alongside their sea plane tender USS *William B. Preston* in Darwin Harbour (Fig 16).

Since all of the located Catalina wreck sites occur in East Arm, the USN wreck sites cannot be *in situ*. These planes must have been removed from where they sank and moved to East Arm for salvage at the flying boat base. Therefore, what is represented by the Catalina wreck sites in East Arm is a 'dump' of aircraft rather than wreck sites that are *in situ*. However, this depositional theory cannot be said to apply to the assumed RAAF wreck site locations where evidence suggests that they are *in situ* (e.g. see 'Catalina 4').

Administrative Commander Major Harron provides a map suggesting the positions for where the anti-aircraft guns should be set-up in East Arm for the defence of the flying boat base (refer Fig. 1). On this map, Harron also records the locations of the Catalina anchorages which seems to coincide with where two of the located wreck sites occur. Assuming that the wreck site of 'Catalina 4' is that of A24-206, the wreck lies close to the second anchorage area where it would have been moored for armouring and refuelling purposes (see Fig. 1). The site, as mentioned previously, also has settled upright into its current position which seems to concur with how the

aircraft was lost i.e. by accidental depth charge explosion and not broken-up as a result of a crash.

In Darwin Harbour, five Catalinas are recorded to have been lost during WW II and two shortly after the War during the same year, in 1945. Since only four sites have been verified, there is still three more Catalina wreck sites that are not located. To test this depositional theory, the other missing Catalinas need to be located. If these unlocated sites are found in East Arm as well, this would support the argument that not all of Catalinas lost in Darwin Harbour are *in situ*. For instance, we know that the three USN Catalinas were moored along side the *William B. Preston*. Catalina crews tried to make it to the *William, B. Preston* after their aircraft were destroyed. Large ships could not moor in East Arm because of the shallow water and as a result they were moored further towards the middle of the harbour. Therefore, if the USN Catalinas are found in East Arm, they must have been raised and brought there for salvage after they were sunk.

Conclusions and further research

The submerged WW II Catalinas in Darwin Harbour present a unique archaeological puzzle. Seven Catalinas in total were recorded to have been lost, but only four have been located. Determining their identity now

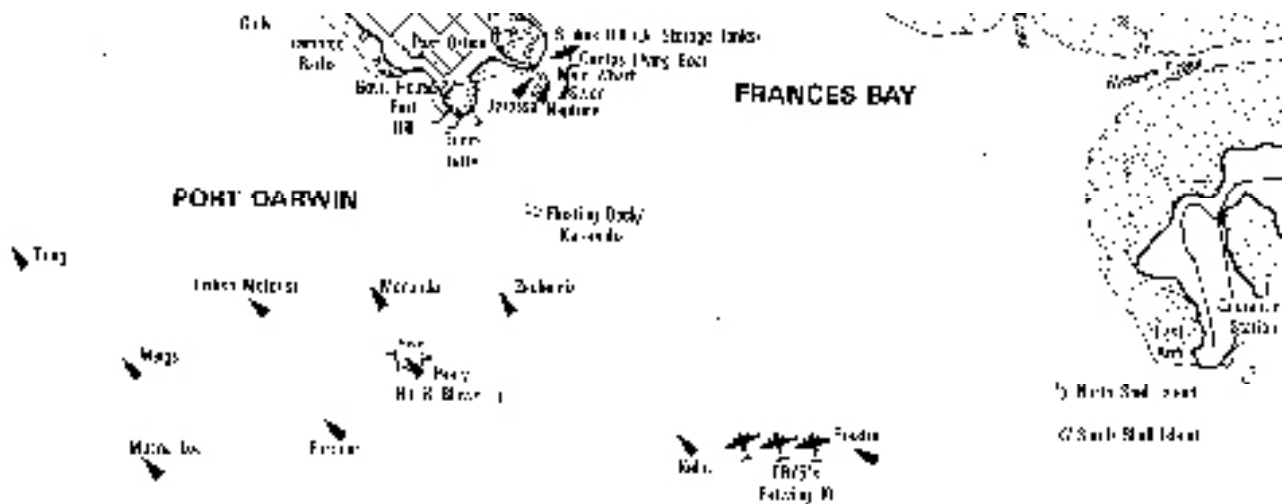


Figure 16. Map showing the approximate location of shipping and flying boats prior to the first Japanese air raid on Darwin Harbour (AHS 1991:15).

poses a problem because of the lack of contextual site evidence. Previous studies have focussed on the recovery of artefacts from only one located site and this was done without regard for archaeological context. The other located Catalina sites in East Arm are still a relatively unknown entity, both in terms of where they are located and how they are identified.

This study is the first archaeological appraisal of what the current understanding of these sites represents. A predictive model has been developed that is based upon identifying the different models of Catalinas that were recorded to have been lost. Since certain models have been shown to have diagnostic features, recording those features on the wreck sites today would identify the sites because it is known that certain planes were specially one model. This methodology is a step in predicting the Catalina identifications. Archaeologist now need to follow-up collaborative evidence and to record site features that are diagnostic of the Catalina models lost in Darwin Harbour as well as taking into account what evidence remains of how they were lost.

There is a belief in the community that any cultural material that lies on the bottom of Darwin Harbour should be raised before divers 'bash' a wreck site (Voss, 1996). This process has gone unchecked and is happening in Darwin Harbour today without archaeological considerations (Jung, 1996b). The Catalina wreck sites are currently not protected by legislation; nothing can be done to stop the unscientific recovery of artefacts until such time as the Catalina wreck sites are nominated and declared 'Historic Places' under the Northern Territory *Heritage Conservation Act 1991*.

These sites are worth protecting as they are both archaeologically and historically significant. They represent a unique Australian and American chapter in the air war with Japan and, as a result, are significant internationally as well as nationally. The three USN planes still belong to the United States Government,

therefore management plans regarding these sites must incorporate support of the American Government, since the Darwin Catalinas are part of their history and identity. The Darwin Catalinas have never been given the recognition they deserve, for these machines carried men that risked their lives in the defence of this country and should be protected as testaments to their efforts.

It is also important that the artefacts raised by sports divers are measured and documented, so as to keep a record of what has been raised (Appendix 2). Although raised without contextual information, such artefacts could still contribute to our understanding of the cultural material in Darwin Harbour. Ultimately, research data on artefact collections in public hands should be incorporated into the Northern Territory Shipwreck Database (NTSD) which aims to build a centralised resource tool for both public and government research inquires. This information service is currently available over the Internet for shipwrecks in the Northern Territory via the National Shipwreck Database, Western Australian Maritime Museum. Something similar should be done to include submerged aircraft wrecks to create a more comprehensive database of all submerged material culture sites and relics.

The Darwin Catalinas are not the only submerged Catalinas in Australian waters today. In Western Australia there are eight Catalinas in Roebuck Bay which were lost during a Japanese air raid on 3 March 1942. Furthermore, near Rottnest Island four Qantas aircraft which operated the Nedlands (on Perth's Swan River) to Koggala Lake (in southern Ceylon) run during the war, were scuttled in November 1945 as a result of the Lend Lease agreement which prohibited civilian use of military aircraft (Wilson, 1991: 58–59). Another one of these Qantas aircraft was scuttled off Sydney later in March 1946 (Wilson, 1991: 59).

However, the locations for the Broome Catalina wrecks have not been verified (McCarthy, M. 1996

pers. comm., 10 November). The four Catalinas at Rottneest Island and the one off Sydney are known by name: G-AGID *Vega Star*, G-AGFM 'Altair Star', G-AGID 'Rigel Star', G-AGIE *Antares Star* and G-AGKS *Spica Star* (the Sydney wreck) (Wilson, 1991: 58). This paper has implications for the overall study of sunken Catalina wrecks around Australia. The Rottneest Island wrecks, if they are ever discovered (they lie in about 200 metres of water), will need an appraisal of how each wreck could be identified. The Broome wrecks are a similarly unknown entity and archaeologists investigating these sites will also be faced with the problem of how to identify individual Catalinas from a group of flying boats lost in the same area.

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Appendix 1. Specifications of the four types of Catalinas lost in East Arm.

| Model | PBY-4 | PBY-5 | PBY-5A | PB2B-1 |
|----------------------|--|--|--|---|
| Aircraft lost | (USN?) | (A24-1) | (A24-69) | (A24-205, 206) |
| Wingspan (ft) | | 104 | 104 | |
| Length (ft-in) | | 63-10 | 63-10 | |
| Height (ft-in) | | 18-10 | 20-2 | |
| Wing area (sq ft) | | 14 000 | 14 000 | |
| Gross weight (lbs) | | 31 800 | 34 000 | |
| Power plant (2) | R-8230-72 Twin Row Wasps | R-1830-82 Twin Row Wasps | R-1830-92 Twin Row Wasps | R-8230-92 Twin Row Wasps |
| Engine make | Pratt and Whitney | Pratt and Whitney | Pratt and Whitney | Pratt and Whitney |
| Propellers | Hamilton Standard constant speed and feathering | Hamilton Standard constant speed and feathering | Hamilton Standard constant speed and feathering | Hamilton Standard constant speed and feathering |
| Manufacturer | Consolidated Aircraft | Consolidated Aircraft | Consolidated Aircraft | Boeing Aircraft |
| Place built | San Diego | San Diego | San Diego | Vancouver |
| State/Province | California | California | California | British Columbia |
| Country | USA | USA | USA | Canada |
| Horse Power | | 1 200 | 1 200 | |
| Maximum speed (mph) | | 195 | 180 | |
| Cruising speed (mph) | | 110 | 117 | |
| Ceiling (ft) | | 18 000 | 15 000 | |
| Range (ml) | | 2 850 | 2 550 | |
| Crew | 8 | 9 | 9 | 9 |
| Armament | <p>OFFENSIVE</p> <p>four 500lb (227 kg) or 1 000 lb (454 kg) bombs or four 325 lb (147 kg) depth charges or two torpedos on underwing hard points</p> <p>DEFENSIVE</p> <p>two 0.30 in Browning machine guns, one in bow turret with 1 000 rounds, one in tunnel position with 500 rounds. One 0.50 in Browning machine gun in each waist position (2) with 800 rounds per gun.</p> | <p>OFFENSIVE</p> <p>four 500 lb (227kg) or 1 000 lb (454 kg) bombs or four 325 lb (147 kg) depth charges or two torpedos on underwing hard points</p> <p>DEFENSIVE</p> <p>four 0.50 in Browning machine guns, one in bow turret with 1 000 rounds, one in tunnel position with 500 rounds, one in each waist position (2) with 800 rounds per gun.</p> | <p>OFFENSIVE</p> <p>four 500 lb (227 kg) or two 1 000 lb (454 kg) bombs or four 325lb (147kg) depth charges or two torpedos on underwing hard points</p> <p>DEFENSIVE</p> <p>two 0.30 in Browning machine gun in bow eyeball turret with 500 rounds each. One 0.50 in Browning machine gun in tunnel position with 500 rounds, one in each waist position (2) with 800 rounds per gun.</p> | <p>OFFENSIVE</p> <p>four 500 lb (227 kg) or two 1 000 lb (454 kg) bombs or four 325 lb (147 kg) depth charges or two torpedos on underwing hard points</p> <p>DEFENSIVE</p> <p>four 0.30 in Browning machine gun in bow eyeball turret with 500 rounds each. One 0.50 in Browning machine gun in tunnel position with 500 rounds, one in each waist position (2) with 800 rounds per gun.</p> |

Table 3. Variable list of diagnostic Catalina model features.

Appendix 2. Recovered Catalina folding anchors from A24-206

The Catalina wreck sites are visited regularly by Darwin dive charter operators who have been bringing up folding anchors from the wreck sites. Three folding aircraft anchors so-far are said to have been recovered from within this wreck site (Hoise, T., 1995, pers. comm., November). One of the anchors recovered by Hoise in 1991 was loaned to MAGNT and displayed in the Boat Shed Gallery. The artefact has since been returned, but a description was recorded (Figs. 17, 18, 20).

The folding Catalina anchor has a locking mechanism at its base that cannot be unlocked unless specific outward pressure is applied to the locking cleat (Fig. 19). The photo shows the top tripping palm locked by the locking cleat. This cleat snaps into the notched end of the shaft, holding the folding elements of the anchor open. The flukes must be extended first for the locating lugs to fit into the locked position. The lower tripping palm has yet to be extended so as to show the locating lugs.

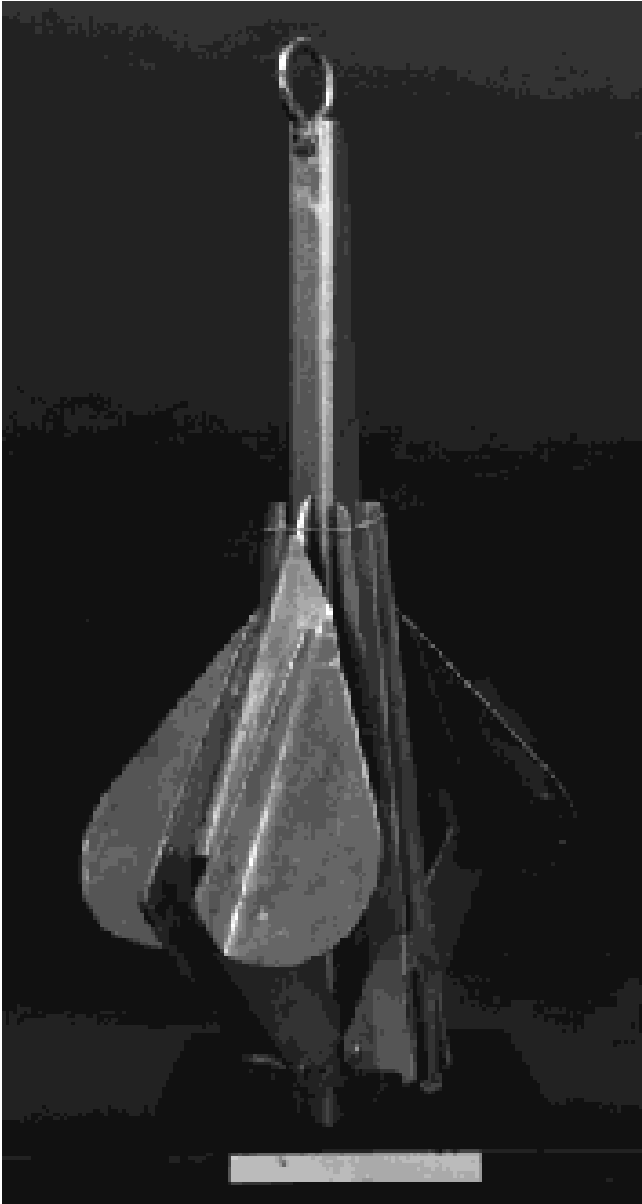


Figure 17. Catalina folding anchor in the folded position. Scale in 20 cms.

Anchor Dimensions

| | |
|--|---------------------|
| Overall height..... | 905 mm |
| Overall width between flukes..... | 785 mm (417 folded) |
| Overall width between tripping palms.. | 995 mm (210 folded) |
| Fluke span..... | 312 mm |
| Fluke height..... | 340 mm |
| Total weight | 14.5 kg |

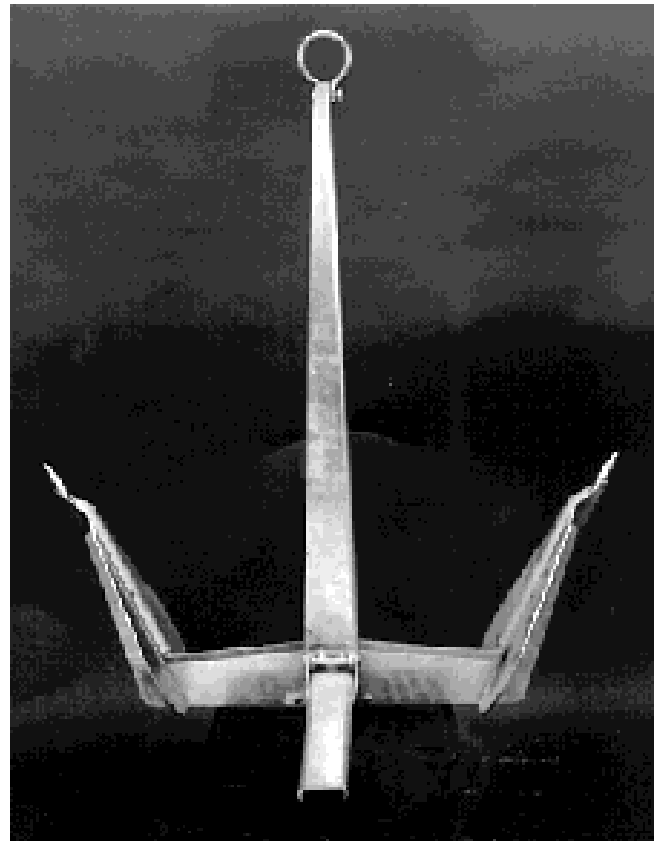


Figure 18. Catalina folding anchor in the extended position.

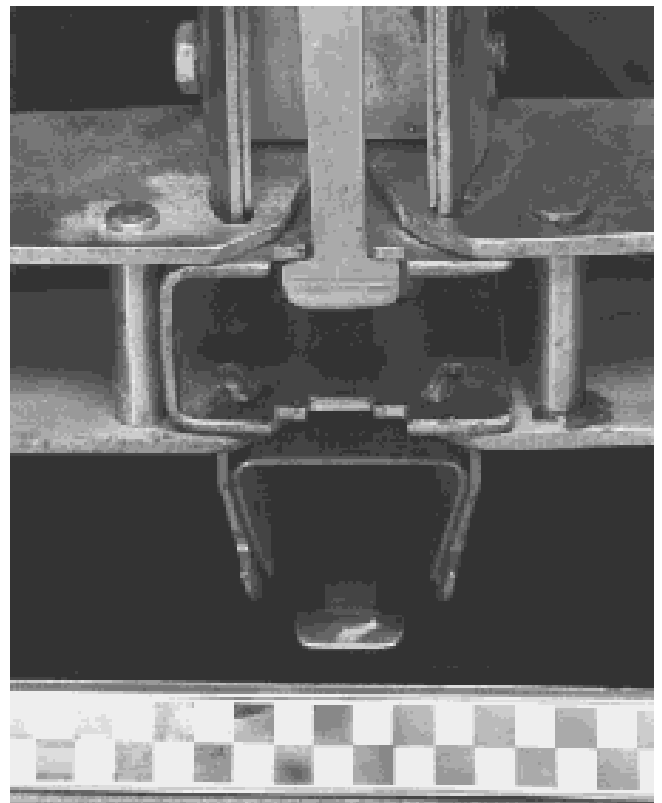


Figure 19. Close-up at the base of the Catalina folding anchor showing the locking operation (scale in cm).

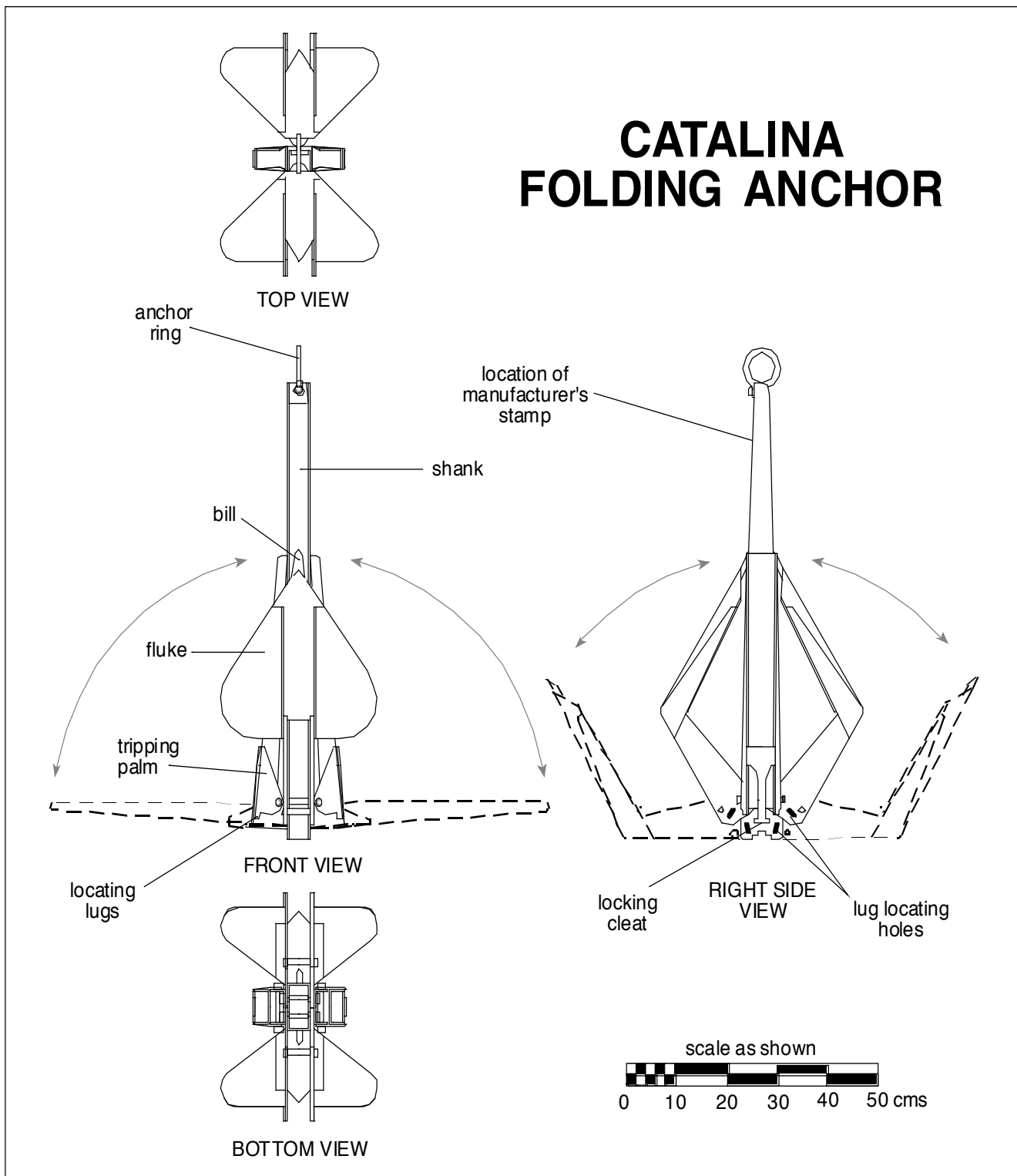


Figure 20. Line drawing of Catalina folding anchor said to have been recovered from 'Catalina 4'.

The development of an integrated approach to field archaeology in the UK and the role of the Archaeological Diving Unit (ADU)

Ian Oxley

Archaeological Diving Unit, University of St Andrews, St Andrews, Fife, United Kingdom KY16 9AJ

Introduction

In field archaeology in the UK there is no clear division between period based archaeology (such as historic or prehistoric archaeology). Despite this seeming advantage in comparison to the development of archaeology in other countries, we have experienced difficulties in achieving an acceptable level of integration between terrestrial and submerged archaeology in all its forms—marine, nautical, underwater and maritime.

However, the Archaeological Diving Unit (ADU) has for over a decade, on a contract basis, had a significant role in promoting such integration and reducing the influence of treasure hunting and inappropriate salvage of archaeological and historic remains. The existence of the ADU has had a significant role in achieving a level of integration in the UK and, at the close of its tenth year of fieldwork, it is an appropriate time to review this role.

In attempting such a review, this paper will refer to many topics of current concern in archaeology—professional accreditation, individual and corporate ethics, the perception of the discipline in the eyes of the public and industry, the perceived value of archaeology, relationships with sport divers, and diving safety on archaeological sites for both professionals and amateurs.

Barriers to integration

Research frameworks and agendas

There is clearly a requirement for submerged archaeology to be included in general trends in archaeology as a whole. The emphasis now is on obtaining good information about the nature, extent and significance of the archaeological resource and minimising the damage to it, but at the same time allowing legitimate development to progress where appropriate.

However the pendulum can swing too far so that too many of the resources available for archaeology are spent on 'development driven' fieldwork. It is recognised that such work should not be isolated from the objectives of archaeological research in general but that cultural resource management professionals require reference points which will enable them to assess the implications of particular development projects in relation to overall research aims and objectives.

At the moment there is no comprehensive research framework on a national or regional scale, and none which take into account the steadily growing interest in the archaeology of inter-tidal and marine zones. However, English Heritage are contributing to the debate by helping to identify current needs and facilitating the identification of solutions (Olivier, 1996). It is hoped that through the

efforts of the Maritime Affairs Group of the Institute of Field Archaeologists (see below) the interests of the maritime and marine archaeological communities can be included in such initiatives.

The development of marine archaeology in the UK

The uncontrolled treasure hunting on wreck sites in the late 1960s and early 1970s prompted the enactment of the *Protection of Wrecks Act 1973* and the beginnings of modern marine archaeology in the UK (Baldwin, 1994). In the 1970s, licensed excavations took place on designated Historic Wreck Sites to varying standards ranging from large projects such as that culminating in the raising of the remains of the *Mary Rose* to small, totally amateur, long-running excavations. Sadly most of the latter remain essentially unpublished and even the definitive publication of the *Mary Rose* excavations is still forthcoming. Such very large projects are unlikely to be repeatable in the near future in the UK due to the changed economic situation. They may also be viewed as an inappropriate use of limited resources in the light of our general ignorance about the nature of the overall submerged resource.

Until recently marine archaeology in the UK could be characterised by relatively poor data collection—where it has been done it could be said to be of variable and questionable worth—we only have to look at the quality and extent of the information which is available to assist decision making in the management of the forty designated Historic Wreck Sites of the UK. Few of these sites have site plans carried out to an acceptable standard, and only poor or incomplete records of artefacts recovered exist even though the *Protection of Wrecks Act* has been in place since 1973.

A different approach in the mid- to late-1980s involved less intrusive, smaller scale investigations which have no intention to recover hull structures or large numbers of artefacts (with their attendant conservation implications) (Watson & Gale, 1990). Increasing government monitoring and regulation of work on designated Historic Wreck Sites, partly due to the input of the Archaeological Diving Unit, has led to a general reduction of activity on those sites and a shift away from artefact recovery to survey.

In the 1990s a new philosophy has emerged. Rather than excavation being the principal activity with the public forming the main audience, now the conservation ethic is firmly established with much more pre-disturbance or non-intrusive survey work taking place—the first duty of archaeologists being not to excavate deposits but to conserve them and to protect them against the



Figure 1. Map of the UK designated Historic Wreck Sites as of September 1996, also showing the limits of the UK Territorial Waters (shaded).

impacts of development (Oxley, 1994). In general, two distinct areas of field investigation can be identified—shipwreck research which is largely directed towards post-Medieval vessels (essentially carried out by avocational archaeological groups) and inter-tidal research on prehistoric and Early Medieval sites (sponsored by local authority archaeologists) (Firth, 1995b).

Lack of awareness

There clearly remains a widespread ignorance of, and often deliberate disregard for, the law and contemporary heritage management values amongst the general public. In a sense there still remains a time-lag in the UK in the integration of marine archaeology into field archaeology in general. In contrast, in parts of mainland Europe an increasing number of examples of the routine application of scientific archaeological techniques to material derived from marine or nautical archaeological projects can be seen. Such projects are not regarded as exotic or fundamentally different from land archaeology (Robinson & Aaby, 1994).

It has still proved remarkably difficult for the marine archaeological community to break down commonly held misconceptions such as:

- ‘fortunes’ can be made by exploiting ‘treasure’ ships under the sea despite sound evidence to the contrary (Throckmorton, 1990; Von der Porten, 1994);
- the (erroneous) belief that ‘finders-keepers’ applies underwater (see Receiver of Wreck below);
- that it is somehow brave and courageous to go diving and that anyone who does so deserves to profit from what they find;
- that ‘if I don’t lift this object then some other (less responsible) person almost certainly will’.

Submerged field archaeology in the UK

There is a distinct lack of guidance on information sources and good practice. Currently there are no integrated controls which are sympathetic to archaeological material underwater and Government seems unwilling to review statutory provisions.

The increase in development pressure on the marine zone is the primary factor which has created the need for the clarification and definition of standards for archaeological activities, such as field evaluation. This problem is becoming increasingly acute as developers are made aware of (and begin to accept) their responsibilities (Oxley, 1995b).

There is no established corpus of knowledge detailing the nature, quality and extent of the marine archaeological resource and there is no obvious network of sources of archaeological advice available to assist developers and curators.

The number of organisations involved in coastal and marine management

The current legislation and statutory requirements for the marine zone indicate that inadequate consideration is given to archaeological concerns in procedures controlling offshore development yet the UK Government’s response (DoE, 1992) to coastal zone management proposals stated that it was not persuaded that extension of local planning controls seaward was necessarily the best approach, nor did it accept the suggestions for National Coastal Zone Units, Regional Groups or a hierarchy of Coastal Zone Management Plans. Instead, the Government proposed that local authorities take the lead in preparing management plans and liaison with local bodies.

The current planning and management framework of the coastal and marine zones is characterised by the inordinately large number of organisations with powers or responsibilities. They include landowners, port and harbour authorities, the Crown Estate Commissioners, regional water companies, the Environment Agency, over twenty Government departments and agencies, and county, district and metropolitan local authorities. A review of coastal management and the division of powers and responsibilities amongst the many bodies involved is given in *Coastal planning and management: a review* (DOE, 1993). Further, *The management of archaeology underwater* (Firth, 1993) describes submerged archaeological remains and their place in the management of the coast and offshore areas, and *Archaeology and coastal zone management* (Firth, 1995a) highlights the possibilities of an integrating coastal and underwater archaeology into the more general concerns of coastal zone management.

Sectoral responsibilities

Various government departments are responsible for near- and off-shore zones but only in relation to their areas of interest. In terms of maritime archaeology generally, the Department of National Heritage (DNH) takes responsibility in England, whereas in Scotland and Wales this subject area is administered by the Scottish and Welsh Offices respectively. However, in Northern Ireland in 1992 the then Environment Service of the Department of Environment (NI) entered an agency agreement with the DNH to carry out administrative functions in relation to the *Protection of Wrecks Act*. The *Protection of Wrecks Act 1973* is administered in England and Northern Ireland by the Secretary of State for the Department of National Heritage (DNH) and by the equivalent bodies in Scotland (Historic Scotland) and Wales (Cadw). The contrast is that the heritage organisation for England, English Heritage, is currently unable to be involved in maritime archaeology because of the geographical limits imposed when the organisation was established—it cannot operate below the Low Water Mark.

The Department of the Environment has responsibility for designating Marine Nature Reserves, Ramsar and

Special Protection Areas (for bird habitat preservation). It also co-ordinates the Government View Procedure (see description below) for marine aggregate exploitation and oil and gas extraction. The Department of Transport administers the provisions of the various Merchant Shipping Acts which affect ownership, salvage and the reporting of material removed for the sea-bed in UK territorial waters. The Department of Trade and Industry has responsibility for the licensing of oil and gas exploration, appraisal and development. Such licensing includes requirements for Environmental Assessments which include paying attention to archaeological resources. Similar responsibilities are held by the equivalent departments in Wales, Scotland and Northern Ireland.

Another example of potential confusion and/or conflict of interest is the role of the Crown Estates Commissioners (CEC) who are responsible for maintaining and enhancing the value of the Crown Estate (which includes most of the inter-tidal areas and the whole of the sea-bed out to the 12 mile territorial limit) but at the same time they are encouraged to exploit this resource such as the issuing of licences to operators in the maritime aggregate industry.

Physical limits of jurisdiction

The jurisdiction of local planning authorities usually ends at the low-water mark yet increasingly local authorities with coastal responsibilities are recognising that many of their activities have effects beyond the coast edge. Some have initiated maritime Sites and Monuments Registers (SMRs) and carried out surveys of coastal archaeology which acknowledge marine sites (Northumberland County Council n.d.). One interesting example is where Cleveland County Council, North Yorkshire County Council, and North York Moors National Park recently completed a study of a section of coast from Seaham to Whitby. The objectives of the project were: to identify and access sources of data at local level; enhance data in the SMRs and the Royal Commission on the Historic Monuments of England's National Archaeological Record-Maritime; contribute towards the development of methodologies of compilation and enhancement of inventories in the marine zone; and raise the awareness of potential of maritime archaeology in the North East of England. The project succeeded in identifying 2 243 archaeological sites (Buglass, 1994).

Lack of reporting procedures

There are no formal mechanisms for information on new finds to be relayed to the relevant local and national sites and monuments inventories and to appropriate archaeological bodies. Chance discoveries by divers and others normally go unreported and thus valuable information is lost to the archaeological community. The principal reason for this unsatisfactory situation is that there is no statutory requirement to report information

about marine finds and sites to archaeological authorities or museums.

Contingency plans have recently been developed by some local authorities prompted by the realisation of the considerable cost implications if a find of major archaeological significance is made accidentally on their coast or in neighbouring coastal waters (Allen, 1995). Many local authorities, recognising the inadequacies of conventional finds reporting relating to marine finds, have developed proposals for co-operation between local museums, local archaeological bodies, the Receiver of Wreck and the national recording and inventory facilities (Highland Regional Council, 1995).

Coastal Management Plans

The UK Governments preference is for coastal management plans which are to encourage more broadly-based initiatives within a multi-agency approach usually led by local authorities. Depending upon the particular issues to be addressed, these plans are normally expected to cover areas comprising several local authorities, serving to provide a sharing information between all parties, and input to statutory development plans and other agency programmes. However, the interests of archaeology are not comprehensively or even consistently taken into account.

Management plans and conservation policies provide an important opportunity to include land and submerged archaeological sites in the management of the coastal zone. Management plans represent County and Local authority policy towards topics such as coastal zones and Heritage Coasts. They are non-statutory documents but have support in statutory structure and local plans. These management plans, for conservation purposes, are being developed for coastal areas, Heritage Coasts and fragile estuarine environments, all which have competing commercial, industrial, nature and historical interests. Development of management plans demand a co-operative effort to include concerns of many groups with an interest in the coastal zone—something which requires a positive response from archaeologists.

Estuary and Firth Management Plans

Estuaries are important and threatened areas often combining sensitive wildlife areas with busy, commercial ports. Estuary management plans provide a future framework in which activities can take place without damaging the natural, cultural and economic resource. To aid in the development of such plans, English Nature began its Estuaries Initiative in 1992 and its recommendations recognise submerged archaeological sites as well as land archaeology and includes them as a resource to be considered in the formulation of management plans.

In a similar way Scottish Natural Heritage has initiated Focus on Firths, a Scotland-wide initiative to provide integrated management of the natural resources of selected Firths (e.g. the Moray, Clyde, Solway and Forth).

The initiative will review and analyse various aspects of each Firth's environment, its uses and activities, identify issues and create draft objectives for its future management.

Heritage Coasts

The Heritage Coast designation is a non-statutory designation which aims to focus attention on the management needs of stretches of undeveloped coast, where the relationships between landscape and nature conservation, sport, recreation, tourism, pollution and water quality issues are interlocking and distinctive (Countryside Commission, 1991). The objective of Heritage Coast policy is to protect the natural beauty, including marine flora and fauna, and their heritage features (including archaeology), enhance public enjoyment, maintain and improve the environmental health of inshore waters, and take account of economic needs such as agriculture and fishing.

Documents produced as part of the process of developing a management plan for the North Yorkshire and Cleveland Heritage Coast give equal coverage to the archaeological heritage (North Yorkshire and Cleveland Heritage Coast Steering Group, 1993) and Issue 10 of Heritage Coast was devoted specifically to coastal archaeology (Heritage Coast Forum, 1993).

Inconsistencies in legislation

Archaeological sites of any type underwater in the UK are not protected unless there has been specific legal protection. There are relatively few pieces of legislation with direct relevance to archaeology underwater and their implementation are often complex, misunderstood, and subject to variations in interpretation. It is probable that the current legislation has proved a significant barrier to integration as separate legislation is currently applied to shipwreck sites and there is no provision for comprehensive portable antiquities legislation which has equal application regardless of the environment in which the find was discovered.

'Wreck' recovered from the sea from UK Territorial waters (including material of archaeological and historic value) is subject to the provisions of Part IX of *The Merchant Shipping Acts 1894* (Receiver of Wreck, 1994). Wreck includes a ship, aircraft, or hovercraft, parts of these, their cargo and equipment. The Receiver of Wreck, located within The Coastguard Agency, is responsible for the administration of the Acts on the behalf of the Department of Transport. All material must be reported to the Receiver who will then determine if it can be considered as wreck or not. This includes material recovered from sites designated under the *Protection of Wreck Act 1973*. The Receiver of Wreck will investigate ownership of the wreck items and the owner has one year to come forward and prove title to the property. During this statutory period the finder may be allowed to hold the material on behalf of the Receiver of Wreck. The Receiver must be satisfied that the finder has sufficient expertise and resources to



Figure 2. An ADU diver carrying out survey using a helmet-mounted video camera on the surviving, deadwood structure of the Church Rocks site (courtesy of Department of National Heritage and ADU).

provide adequate conservation facilities to ensure that the material does not deteriorate.

Wreck recovered from within UK waters which remains unclaimed at the end of the one year statutory period, becomes the property of the Crown and the Receiver of Wreck is required to dispose of it. This may be through sale or auction, although in many instances the finder will be allowed to keep items of unclaimed wreck in place of a salvage award.

Parts of the *Merchant Shipping Acts* were designed in the 19th century specifically to control problems relating to the salvage of commercial material and to protect the rights of owners whose property was lost at sea or wrecked on the coast of the UK. The Receiver is committed to try, wherever practical, to offer items of historic wreck to institutions where they will remain accessible to the public (e.g. offered to Government registered museums first). For the purposes of the MSA historic wreck is defined as items over 100 years old. The system still requires that

| NO. | SITE NAME | DATE | TYPE | LOCATION |
|-----|-----------------------------|------------|-----------------------|-----------------|
| 1 | Cattewater Wreck | 1500–1550 | armed merchantman? | Plymouth |
| 2 | <i>Mary Rose</i> | 1545 | warship | Solent |
| 3 | <i>Grace Dieu</i> | 1439 | warship | Hamble River |
| 4 | <i>Amsterdam</i> | 1749 | Dutch East Indiaman | Hastings |
| 5 | <i>Mary</i> | 1675 | Royal Yacht | Anglesey |
| 6 | <i>Assurance/Pomone</i> | 1738/1811 | warships | Isle of Wight |
| 7 | <i>Anne</i> | 1690 | warship | Near Hastings |
| 8 | Tearing Ledge | 1707 | warship | Isles of Scilly |
| 9 | Rill Cove | early C17 | armed merchantman? | Lizard |
| 10 | S. Edinburgh Channel | late C18 | merchantman | Thames Estuary |
| 11 | Church Rocks | C16 | warship? | Teignmouth |
| 12 | Pwll Fanog | medieval | slate carrier? | Menai Strait |
| 13 | Moor Sand | c. 1000 BC | artefact scatter | Salcombe |
| 14 | <i>Coronation</i> (Inshore) | 1691 | warship | Plymouth |
| 15 | <i>Kennermerland</i> | 1664 | Dutch East Indiaman | Shetland |
| 16 | Langdon Bay | c. 1100 BC | artefact scatter | Dover |
| 17 | Tal-Y-Bont | 1600–1650 | armed merchantman? | Barmouth |
| 18 | <i>Stirling Castle</i> | 1703 | warship | Kent |
| 19 | <i>Invincible</i> | 1758 | warship | Solent |
| 20 | Bartholomew Ledge | C16 | armed merchantman | Isles of Scilly |
| 21 | <i>Northumberland</i> | 1703 | warship | Kent |
| 22 | <i>Restoration</i> | 1703 | warship | Kent |
| 23 | <i>St Anthony</i> | 1527 | merchantman | Lizard |
| 24 | <i>Schiedam</i> | 1684 | merchantman | Lizard |
| 25 | Brighton Marina | c. 1600 | warship? | Brighton |
| 26 | Yarmouth Roads | c. 1600 | armed merchantman | Isles of Wight |
| 27 | Studland Bay | c. 1500 | armed merchantman | Dorset |
| 28 | <i>Admiral Gardner</i> | 1809 | English East Indiaman | Kent |
| 29 | <i>Hazardous</i> | 1706 | warship | Bracklesham |
| 30 | <i>Coronation</i> | 1691 | warship | Plymouth |
| 31 | <i>Iona II</i> | 1864 | paddle steamer | Lundy |
| 32 | Gull Rock | C15/16 | artefact scatter | Lundy |
| 33 | <i>Wrangles Palais</i> | 1687 | warship | Shetland |
| 34 | Erme Estuary | C17–C18 | armed vessel | South Devon |
| 35 | The Smalls | c. 1100 | sword guard findspot | South Wales |
| 36 | Duart Point | 1653 | warship | Sound of Mull |
| 37 | <i>Dartmouth</i> | 1690 | warship | Sound of Mull |
| 38 | <i>Girona</i> | 1588 | warship | Ulster |
| 39 | <i>Royal Anne</i> | 1721 | warship | Lizard |
| 40 | Erme Ingot Site | unknown | artefact scatter | South Devon |
| 41 | Dunwich Bank | ?C16 | warship? | Suffolk |
| 42 | <i>Resurgam</i> | 1880 | steam submarine | Liverpool Bay |

Table 1. List of designated Historic Shipwreck Sites as of September 1996. Numbers relate to the positions on the UK map (Figure 1).

items are raised from the sea-bed. In the past this has served to encourage uncontrolled disturbance of the burial environments of sites.

The MSA should act as a mechanism for reporting and recording of archaeological finds but to date this has not been fully developed (Firth, 1993). The requirement to report to the Receiver comes as a requirement of salvage. If nothing is recovered there is no obligation to report the location of the wreck. Thus the Act does not provide for the reporting of archaeological remains *per se*, nor for its preservation *in situ*, and it does not cover inland waters.

The *Protection of Wrecks Act 1973* (PWA, 1973) is used to control activities on areas of sea-bed which contain important sites. Anyone can apply for a licence to investigate a designated site but they must have accredited archaeological advice. Under this Act wreck sites of archaeological, historical or artistic interest are designated and a restricted area around the wreck established where activities such as diving, excavation, deposition of materials, and salvage are prohibited, except where a licence is issued (with appropriate restrictions) by the DNH or equivalent body. Advice on designation is provided by the Secretary of State for National Heritage's Advisory Committee on Historic Wreck Sites (ACHWS) a non-governmental body composed of individuals with interests and expertise in the marine zone and DNH provides secretarial support to the ACHWS. For a further discussion of the PWA and its relation to the MSA see Oxley (1995a).

Once designated a notice is published in *Notices to Mariners* and the designated area is marked on Admiralty Charts (subject to periodic revision). Some sites which are situated close to shore have notices warning of the restricted area placed nearby. Offshore sites may be marked with an Historic Wreck buoy.

There is no specific age limit for designating a wreck nor any reference in the PWA 1973 to 'national' importance but the sites must be located within the 12 mile territorial limit and in tidal waters. Currently most of the designated wrecks are post-medieval with the majority located in the South and South West coasts of England. There are 42 designated Historic Wreck Sites in total, 4 in Scotland, 5 in Wales, 32 in England and 1 in Northern Ireland (Fig. 1 and Table 1). The distribution reflects more the historically favoured areas for sport diving rather than maritime activity in the past. A guide to the designated Historic Wreck Sites, provided by the ADU (1994) is available on the World Wide Web (http://www.st-andrews.ac.uk/~www_shir/deswrecks.html).

Only in February 1996 has the Department of National Heritage produced a full colour leaflet and poster promoting the *Protection of Wrecks Act 1973* and the designated Historic Wreck Sites of the UK.

A further piece of legislation, *The Ancient Monuments and Archaeological Areas Act 1979*, can be applied within UK territorial waters as it contains a general provision for the scheduling of monuments in the territorial sea and it

also refers specifically to vessels. However, to date it has never been applied to wholly submerged sites probably because it was developed primarily for land sites with the assumption that they can be readily identified, positioned and defined. In Northern Ireland *The Historic Monuments and Archaeological Objects (NI) Order 1995* provides for the protection of all archaeological sites and objects including those on the foreshore and the sea-bed.

Finally *The Protection of Military Remains Act 1986* provides for the protection of remains of military aircraft and vessels that have crashed, sunk or been stranded (this includes any associated human remains). Wreckage of ships have to be designated as a 'protected place' by Government and then it becomes an offence to tamper with, damage, move, remove or unearth it or enter the interior. Divers are allowed to visit such sites provided that no damage results.

The development and influence of the Archaeological Diving Unit (ADU)

Introduction

For the last decade there has been a fixed point of advice, technical assistance and expertise available to those Government organisations responsible for shipwreck archaeology in the UK in the form of the ADU. The existence of the Unit has influenced the development of an integrated approach to archaeology by demonstrating sound professional practice and accreditation; and displaying and defending a policy in a consistent manner against activities such as treasure hunting and treasure salvage. The Unit has taken pains to develop good working relationships with a wide range of individuals and organisations (e.g. universities, museums and local authorities) within archaeology and related disciplines. Unit members have served as officers of influential organisations like the Institute of Field Archaeologists, the Nautical Archaeology Society and the Joint Nautical Archaeology Policy Committee.

The ADU is contracted to the UK Government to collect information for, and give advice to, the Department of National Heritage and the Home Country heritage bodies who administer heritage legislation relating to wrecks—Historic Scotland, Cadw and the Environment and Heritage Service of the Department of Environment (Northern Ireland)—but not English Heritage. Formed in 1986 the staff of the Unit has gradually increased from one full-time and two part-time (only four months of the year) to four full-time and one part-time (six months). Consistency of approach and practice has been maintained under the direction of Martin Dean, the founder of the Unit.

Balancing its relationship with the general public against its contractual obligations to Government the ADU has often found itself in the position of being the public face of Government's historic wreck policy, particularly in relation to recreational divers.

The functions of the Unit include:

- the investigation and assessment of new sites proposed for designation under the PWA 1973;
- the monitoring of survey and excavation work carried out under license on existing designated sites;
- advising existing licensees and archaeological directors/advisors;
- the assessment of threats (man-made and natural) to existing designated sites.

Territorial remit

The area of operation of the Unit is substantial—the whole of the UK territorial waters out to the 12 nautical mile territorial limit and including all rivers, estuaries and sea lochs up to the limit of tidal influence. This area approximates to 80 000 square miles and it can be visualised if it is remembered that the landmass of England is about 93 000 square miles. Therefore the area of sea-bed that the ADU is expected to be able to assess sites in equates to roughly three quarters of the landmass of England.

Working practice

The current configuration of the ADU comprises four full-time archaeologists together with one part-time during the summer field season. All are academically qualified in archaeology and have substantial practical experience of marine archaeological sites. All ADU members are trained to surface supplied air commercial diving standards and at least four of the team have Diver Medical Technician qualifications. The ADUs diving support vessel carries surface supply breathing system and a transportable decompression chamber in the form of a hyperbaric stretcher.

The Unit has an active policy of keeping aware and up-to-date with new technology in marine surveying and related disciplines, for example investing in DGPS equipment to improve site location, video imaging for site recording (see Fig. 2) and diving safety. Research is also undertaken into methodologies to improve marine site management such as site stabilisation and monitoring (Oxley, 1992).

The work of the ADU has enabled the Advisory Committee on Historic Wreck Sites to take a more proactive stance in its advice to Government and to give greater weight to the quality of its advice (Saunders, 1994) and it has promoted integration in the areas outlined as follows.

Consultation

A continuing role throughout the history of the ADU has been the provision of advice and information on marine archaeology and often underwater archaeology in general. The Unit has also provided comment on development proposals, minerals extraction applications and shoreline management plans.

Receiver of Wreck

The ADU has provided advice and support to the Receiver of Wreck whose remit has changed in recent years in that

one individual now carries out this function for the whole of the UK. Previously, the responsibility for dealing with wreck was invested in regional HM Customs Officers with the consequent problems of consistency and reporting. Efforts that the Receiver has made recently to treat historic wreck sympathetically (Receiver of Wreck, 1994) have been encouraged by the ADU and this policy has resulted in a significant increase in the numbers of sites and finds being reported.

Joint Nautical Archaeology Policy Committee

The ADU has contributed to the work of this important lobby group, made up of individuals from the Association of County Archaeological Officers, Hampshire and Wight Trust for Maritime Archaeology, the Maritime Affairs Group of the Institute of Field Archaeologists, National Maritime Museum, National Museum of Wales, National Trust, Nautical Archaeology Society, Scottish Trust for Underwater Archaeology, Society for Nautical Research. The JNAPC has published policy documents aimed at influencing government such as *Heritage at Sea* (JNAPC, 1989) and *Still at Sea* (JNAPC, 1993). Key areas for improvement were identified including the extension of the areas of responsibility of all the UK Home Country Royal Commissions on historical and archaeological monuments to include territorial waters, and they stressed the need for better information on the nature and extent of marine archaeological heritage in order to inform planning decisions, and the provision of adequate training and education opportunities for recreational divers.

A further important product of the JNAPC is the *Code of Practice for Seabed Developers* (JNAPC, 1995) which sets out recommended procedures for consultation and co-operation between sea-bed developers and archaeologists, providing a framework within which concerns for the maritime archaeological heritage and the interests of other sea users can be reconciled.

Health and Safety Executive (HSE) regulation of diving at work for the purposes of archaeology

The Diving at Work Regulations (1981) and its later amendments are due to be replaced by new legislation undergoing a consultative process. The ADU is actively involved in proposals to change the Governments health and safety Regulations in relation to diving at work, lobbying to improve the safety of archaeological diving. The ADU is the only established archaeological team which operates under the existing Regulations without recourse to Exemption certificates. The latter provisions currently allow diving mainly for the purposes of archaeology to be exempt from many parts of the existing Regulations which were designed more to protect the diver in industrial situations rather than in archaeology. The proposed new regulations will seek to allow archaeologists to dive safely without having to conform to the safeguards necessary for divers working in offshore oil production environments.

The essence of both the existing and proposed regulations is that where people are involved in archaeological diving operations they must be 'competent' to undertake the task. Those diving will also require Health and Safety Executive approved certificates of medical fitness and first-aid training, as well as diving qualifications appropriate to the environment of the diving operation (lake, river or sea etc.) and the equipment to be used. The diving operation must be carried out under the auspices of a diving contractor registered annually with the HSE. Organisations paying (or giving expenses) to recreational divers for archaeological work underwater are likely to be in breach of both the existing and the proposed regulations. The divers themselves would also be in breach of the regulations.

The basic regulations will be supported by codes of practice written for specific areas of the diving industry by those actively involved in each area. The *Code of Practice for Scientific and Archaeological Diving* will eventually be approved by HSE and it is anticipated that the new regulations will be in place in 1997.

Promoting integration

On the positive side we have seen examples of a steady 'creeping down the foreshore into the sea' from the point of view of heritage management such as the Langstone Harbour Project which advocates a 'seamless' approach to survey on land, in the inter-tidal zone and underwater. This Project also indicates the advantages of combined research programmes, in this case between a County archaeological body (Hampshire County Council), a university (Department of Geography at Portsmouth), an archaeological unit (Wessex Archaeology) and a trust (Hampshire and Isle of Wight Trust for Maritime Archaeology) with part-funding by the Department of National Heritage (Allen *et al.*, 1993).

The overall lack of consistency with terrestrial archaeology is being replaced by a slowly growing appreciation for the philosophy that, particularly in the case of sites which cross the environmental boundary of the coast edge, a 'seamless' approach can be shown to be more profitable. For an example of an integrated approach to coastal management see Gilman *et al.* (1995).

Marine conservation

In the UK important advances have been made in developing a management plan for the Marine Nature Reserve situated around the island of Lundy in the Bristol Channel. Two sites designated under the *Protection of Wrecks Act 1973* (and therefore monitored by the ADU) lie within the Marine Nature Reserve boundaries and English Nature acknowledge the importance of integrating the management of the archaeological heritage with that of other heritage interests (English Nature, 1993a). Within the Lundy Marine Nature Reserve a zoning scheme has been adopted to show people where they can undertake activities with minimal impact on

the wildlife or conflict with other users of the Reserve (English Nature, 1993b). The brochure detailing the scheme includes the restrictions for the two designated sites required under the 1973 Act. An assessment of the archaeological resource within the Reserve has been carried out which highlights the benefits to be gained by including the culture heritage in the future management of the Marine Reserve including resource protection issues (controlling access), resource management (managing archaeological remains in situ, encouraging reporting of finds) and interpretation (interpretative display boards) (Robertson, 1995).

National and local sites and monuments inventories (SMRs)

Research initiatives suggest that there may be over 500 000 documented wreck sites in the UK and initial work on maritime sites in England alone has generated over 30 000 references. The latter information has been generated as part of the Royal Commission on the Historical Monuments of England—Maritime Record, an inventory of maritime sites to include shipwrecks and areas of archaeological importance within a coastal limit of twelve nautical miles and with a cut-off date of 1945. It was developed out of a one-year pilot study in cooperation with the Isle of Wight and Hampshire County Councils resulting in the creation of the Isle of Wight Maritime Sites and Monuments Register. From this a prototype record a data-standard for a national inventory was developed and appropriate sources of information identified.

On a national scale similar initiatives have been undertaken in Northern Ireland by the Historic Buildings and Monuments Branch, Department of the Environment (NI) and the respective Royal Commissions in Wales and Scotland.

All counties or regions in the UK and other planning authorities which operate on a regional basis outside the local authority frameworks (e.g. National Park Authorities) should maintain up-to-date archaeological sites and monument registers. Such registers are usually initiated so that as complete a record as possible of such sites is available to make informed management decisions for example when reviewing development proposals the implications for archaeological material can be more accurately measured.

Maritime SMRs have been established in some English counties and at least two Scottish Regions (Fife and Highland) in order to add sites situated in marine environments to the inventories. However, there are still many coastal areas which do not include submerged sites in their records.

Institute of Field Archaeologists (IFA)

A recent development in field archaeology in the UK is the emergence of the Institute of Field Archaeologists (IFA) which was formed in 1982 to advance the practice of field archaeology and allied disciplines by promoting professional standards and ethics for the conservation,

management and study of the archaeological resource.

All IFA members agree to abide by a *Code of Conduct* (IFA, 1988), *Codes of Approved Practice* (IFA, 1990) and the other By-laws of the Institute, and as such they can be identified as persons professing specific standards of competence, responsibility and ethical behaviour in the pursuit of archaeological work. The *Codes* indicate the general standard of conduct to which members of the Institute are expected to adhere, failing which its governing body may judge them guilty of conduct unbecoming to a member of the Institute and may reprimand, suspend or expel them. One often contentious provision is the recommendation that archaeological excavations should be definitively published within ten years. Being a member of the IFA provides a clear recognition of an individual's archaeological competence and experience.

The ADU has been heavily involved (both corporately and as individuals) with the IFA and many of its special interest groups and working parties—serving as officers on Council, providing specialist advice, and developing the Areas of Competence (including Underwater Archaeology). Most of the archaeologists currently active in marine archaeology in the UK are members of the IFA. Members of the Unit have been involved in the production of an IFA Technical Paper so that all field archaeologists can be made aware of the possible methods for approaching and investigating marine sites (Oxley & O'Regan, 1996). It is also hoped that other individuals and organisations, whose activities and responsibilities relate to and affect the marine archaeology of this country (including heritage managers and those involved in tourism), will also benefit from this initiative.

There is a Maritime Affairs Special Interest Group within the Institute for all those members interested in the archaeology of water transport and related activities; submerged settlements and landscapes; and underwater archaeology. The Maritime Affairs Group, together with the IFA as a whole, has played a significant role in raising awareness about the fragility and importance of the underwater archaeological resource, and in particular furthering the integration of the interests of underwater archaeologists into mainstream archaeology.

The IFA has also taken a lead role in setting and maintaining standards, particularly for the archaeological activities which usually occur in advance of development projects likely to destroy or impact archaeological remains. The IFAs Standards initiative seeks to define best practice for the execution of archaeological activities such as desk base assessment, evaluation, excavation, buildings recording and watching briefs. The Standards apply to all environments and refer to all archaeological field investigations (whether prompted by research, environmental assessment, sites and monuments/inventory validation and enhancement, or local/national resource management requirements). The ADU has contributed to the drafting of the Standards ensuring that the implications of archaeological activities in

submerged environments are considered. For example, making it clear that such operations must be carried by archaeologists with the appropriate diving qualifications and such work must be under the auspices of a registered diving contractor.

The IFA has recently passed a Bye-law under which archaeological organisations can be registered, the aim being to ensure that organisations operate in accordance with the *Code of Conduct* of the Institute. It requires that the archaeological operations of an IFA-registered archaeological organisation are carried out only by, or under, the responsibility of a suitably experienced corporate Member of the Institute holding the senior archaeological post in the organisation. This initiative is likely to have a profound effect on the development of contract archaeology units and organisations, a number of which have begun to carry out work in submerged environments.

Nautical Archaeology Society

The Nautical Archaeology Society (NAS) is active in promoting the aims and goals of archaeology and it has been successful in developing a structured training programme in the principles and techniques of archaeology underwater. The stated aims of the Society are to advance education in nautical archaeology at all levels; to improve standards of conservation; recording and publication; and to encourage the participation of the public (Dean *et al.* 1992). To this end the NAS publishes the *International Journal of Nautical Archaeology*, the principal international journal for disciplines of underwater archaeology, and a quarterly newsletter entitled *Nautical Archaeology*.

The NAS Training programme was instigated, developed and managed by a succession of professional marine archaeologists in the early 1980s (including two future ADU members). It represents an agreed syllabus and standard for the teaching of nautical/underwater archaeological principles and techniques. A Training Pack is available which enables the courses to be held worldwide to the same standard thus fostering consistency and paving the way for exchange visits and opening up projects world-wide. Training can be started in one country and followed up in another.

Archaeology underwater as a career in the UK

Most practising field archaeologists claiming a specialism in marine or maritime aspects have a first degree in archaeology (or closely related subjects). This is in contrast to the days of the *Mary Rose* project in the early Eighties when few had formal academic qualifications. Some practitioners had no degree, having progressed up the career ladder through experience alone.

Such alternative career paths still exist although they are less common. The entry regulations for a professional association like the Institute of Field Archaeologists recognise that although a degree in archaeology might

be a basic requirement of membership, alternative routes exist for those with other qualifications, or indeed without formal academic training at all.

A recommended career path would be to obtain a degree in Archaeology or closely related subject and then to progress to a maritime heritage postgraduate course, perhaps focusing on a particular interest for a dissertation topic at Masters level. At the same time, due to the increasing regulation of diving safety, it would appear to be more cost effective to take a Health and Safety Executive approved diving course (in SCUBA or Surface Supplied Diving) as this is a requirement for diving at work, as opposed to beginning diver training as a recreational diver then having to spend time and money to gain HSE certification at a later date. All of the recent recruits to the ADU have had to pay for their own HSE Part III Surface Supplied Diving qualifications in order to be employed by the Unit.

Graduate and postgraduate opportunities

The recent general trend in UK universities as far as maritime studies and marine archaeology is concerned is for appointments to be made at lecturer level to enable specialist modules to be offered as part of general archaeology first degrees. In addition, postgraduate (MA and MSc) programmes have recently been initiated at the Universities of Southampton and Liverpool to add to those already available at Bristol and St Andrews. All the taught Masters courses have similar core units, generally one on aspects of Maritime Culture or Heritage Studies, and a second on Archaeology Underwater field techniques.

The Scottish Institute of Maritime Studies (SIMS) at the University of St Andrews

SIMS has a long track record in submerged archaeology teaching and research offering a taught Postgraduate Diploma in Maritime Studies together with M.Litt, M.Phil, Ph.D. research degrees. Since the formation of the Unit the ADU has contributed to the teaching programmes and all the practical activities of the SIMS. A seawater training facility has been developed in a redundant sea bathing pool at Cellardyke where four iron cannons have been placed for purposes of in-water survey training in a sheltered environment, as an experimental facility for testing corrosion potential measurement and other management strategies for marine archaeological sites such as cathodic protection, re-burial and *in situ* stabilisation.

In common with other university departments in the UK, SIMS has become involved in archaeological contract work including desk-based assessments in advance of local sewer outfall construction. Other SIMS projects include the UK National Historic Ships Database funded by the Department of National Heritage, and the Duart Point Historic Shipwreck Project. St Andrews also has strong links with NAS Training Programme and courses have been offered here for more than nine years (largely organised and taught by ADU members). SIMS currently hosts the

Scottish NAS Training Organiser, a part-time post funded by the heritage body in Scotland, Historic Scotland.

Finally a relatively new SIMS initiative, generated by an ADU member (this author), is represented by Maritime Fife an inter-disciplinary research project incorporating a maritime sites database (an adaptation of the local authority Sites and Monuments Register), funded by a consortium of District Authorities and the Regional Council. The aim of Maritime Fife is to research and record archaeological sites whether they are situated on the coast edge, foreshore, inter-tidal area or sea-bed around the Fife coast. The information will be derived from a variety of sources including archival research, oral testimony and site survey. Project members also disseminate information in public lectures, museum displays and school visits. Maritime Fife serves as a focus for local maritime archaeological and historical studies, and it is a point of contact for anyone to enquire about any aspect of Fife's maritime past.

Conclusions

It is a time of rapid change in the field of marine archaeology in the UK and it is believed that the Archaeological Diving Unit has contributed to the campaign to establish a more appropriate treatment and management of the marine archaeological resource especially in relation to our shipwreck heritage.

The Unit has consistently maintained that it should be explicitly recognised that archaeological evidence and sites exist beneath the sea within our Territorial Waters and they it must be managed effectively for the benefit of present and future generations. This heritage resource should be considered, in the first instance, independently of present day environmental boundaries or historically-derived administrative boundaries. It is a significant part of the whole resource and should be recognised as such throughout government and society.

To achieve these aims of effective management a number of requirements are necessary: sustained and comprehensive research into the nature, extent, condition and potential of the resource; **all** national and local sites and monument inventories must be adapted to include marine sites; development control procedures in the marine zone must be at least equivalent to those on land; and planning policy guidance should apply explicitly to archaeology within the full extent of UK Territorial Limits.

On a positive note there has been steady progress in raising awareness about maritime and marine archaeology in the UK, and slow progress in integrating submerged archaeology with terrestrial field archaeology. Notable improvements include the introduction of maritime site records into the national sites and monument inventories of England, Scotland, Wales and Northern Ireland, together with an increasing number of local authorities adding marine sites to their local databases. The most recent landmark is the consultation document *Protecting Our Heritage*, (DNH, 1996), which indicates the UK

Governments intention to make the heritage body for England, English Heritage, responsible for archaeological sites situated below the Low Water Mark in England.

Although we are seeing more integrated coastal and marine heritage projects (particularly at a county and regional level) and a slow increase in the employment opportunities for archaeologists with qualifications and experience in maritime heritage management, there is no room for complacency. Unfortunately in the current economic climate most projects have only short-term funding and thus job opportunities are usually limited to short-term contracts.

Therefore the current trends are to be encouraged not the least because more people are able to appreciate their maritime past, and the ways in which they can become involved in the investigation and study of all aspects of their marine and maritime archaeological heritage. It is hoped that the Archaeological Diving Unit can continue to contribute to these trends and as we approach the renewal of the ADU contract we can take some comfort from the Government's statement that, in maritime archaeology, it 'considers a single source of professional field advice to be helpful and it intends to seek a power for English Heritage to place and manage such a contract and related activities on behalf of the UK authorities' (DNH, 1996: 48).

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Addresses

Institute of Field Archaeologists, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom (tel/fax +44 161 275 2304).

Joint Nautical Archaeology Policy Committee, c/o Maritime Section, National Monuments Record Centre, Royal Commission on the Historical Monuments of England, Kemble Drive, Swindon SN2 2GZ, United Kingdom (tel +44 1793 414600, fax +44 1793 414 606).

Nautical Archaeology Society, Training, 19 College Road, HM Naval Base, Portsmouth, Hants. PO1 3LJ, United Kingdom (tel/fax +44 1705 818419).

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Low Cost 'Z's'

John Riley

PO Box 52, Bondi, New South Wales 2026

Introduction

Horizontal measurements (X-Y) on deep sites pose no difficulty to the diver. However, vertical measurements (Z) do. Bottom time at 50 to 60 metres is limited and constructing a grid in the open ocean would be time consuming to erect and keep in good order. The use of an air bubble inside a clear plastic tube is also impractical in low visibility, swell and currents and needs the help of a second trained diver. Divers also have to carry and operate more equipment. This paper describes a simple method of measuring 'Z' coordinates at depth.

Equipment

A diver using the standard dive equipment required to dive to depths of 50–60 metres, is already equipped to make vertical measurements to an accuracy of ± 10 cm.

The Apollo Sun Fish dive watch gives time, bottom time, current depth and maximum depth, and can display a dive log of the last five dives, including surface intervals. The Aladin Pro Dive Computer has all the above functions and also computes and displays decompression times required to surface safely.

Both units measure in whole feet or in metres and tenths of metres. The Apollo Sun Fish can be converted from Imperial to metric measurements underwater. The Aladin Pro comes in metric or Imperial and cannot be changed.

Both units can be worn on the diver's wrist, attached to a hand-held slate or as part of a combo boot along with contents gauge at the end of the high pressure hose.

Method

The method of use is simple. Descending onto site, the diver places the measuring device on a datum point and records the depth on a site plan carried below on a slate. Further depths can then be recorded around the site and marked on the plan. Before surfacing, the depth at the datum point is measured and recorded again> these measurements can be justified to the master datum on the surface to compare previous work on site. Accuracy of 10 cm can be obtained on high profile sites using this method.,

In shallow water, when dive times are much longer, the water depths may vary with tides. The datum depth then changes with the tide. Frequent trips back to the datum will give measurements that can be adjusted more accurately.

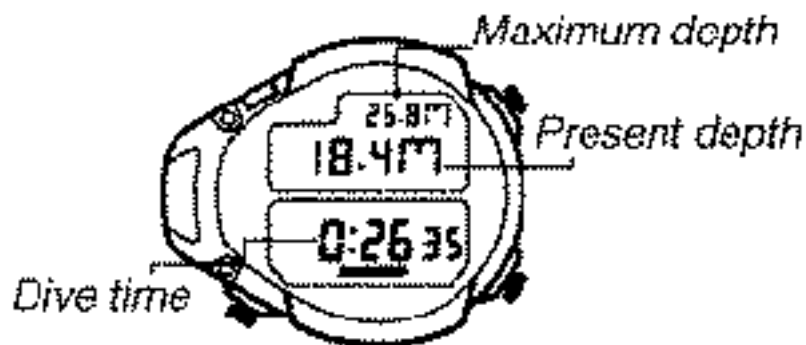


Figure 1. Information displayed on Apollo Sunfish at depth.

Estimating depth of cover on screw steamship wrecks powered by inverted, compound, triple expansion and quadruple expansion engines

John Riley

PO Box 52, Bondi, New South Wales 2026

Introduction

This paper briefly describes a method developed by the author for estimating the depth of cover on screw steamship wrecks powered by inverted, compound, triple expansion and quadruple expansion engines. The term ‘inverted’ is the old expression for the now used vertical engine.

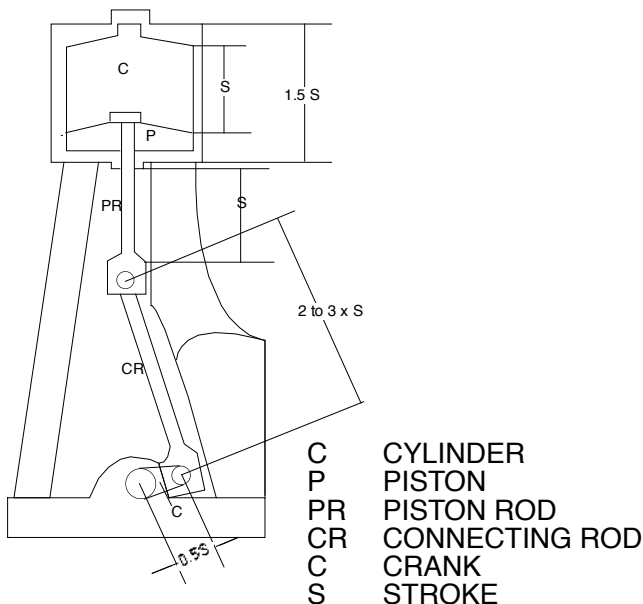


Figure 1. Endsection of typical inverted (vertical) steam engine (John Riley, 1996).

Method

The method of measurement is based on the principle that the relationship of the stroke of a steam engine is proportional to its height. The longer the stroke, the taller the engine.

Figure 1 shows the end section of a typical inverted steam engine. *Lloyd's Register of Shipping* gives the cylinder size and stroke in inches, for example:

SS OAKLAND

T. 3CY. 12", 19" AND 32"–24"

This abbreviation reads Triple expansion engine of three cylinders. High pressure cylinder 12 inches

diameter. Intermediate cylinder 19 inches in diameter. Low pressure cylinder 32 inches in diameter. The stroke is recorded as 24 inches.

- The pistons are enclosed in cylinders tall enough to allow the piston to travel 24 inches, this is called the ‘stroke’.
- The clearance of the piston rod running through the bottom of the cylinder cover must be at least that of the stroke.
- The connecting rod connecting the piston rod and crank is traditionally between two and three times the stroke. This avoids too large an angle from the centre line of thrust at 1/2 stroke (i.e. piston midway up or down the cylinder).
- The crank on the propeller shaft is half that of the stroke to allow the piston to travel the full stroke.

By adding:

Piston stroke 1 + piston rod clearance 1 + connecting rod 3 + crank 1/2 = 5 1/2 x stroke.

Add to this the thickness of the cylinder head covers, piston thickness and stuffing boxes at another 1/2 stroke, the total engine height with the connecting rod at 3 x stroke is 6 x stroke.

From *Lloyd's Register*, the stated stroke for the SS *Oakland* is 24 inches. Therefore, height of engine is 24 inches x 6 = 12 feet (3.6 m).

If the stroke is not known, the height of the engine can be estimated by multiplying the cylinder height (1 1/2 stroke) by 4, i.e. 36" x 4 = 12 feet (3.6 m).

A variable in the above calculations is the length of the connecting rod (from 2–3 x length of stroke). By using 3 x stroke, the maximum depth is calculated.

Results

On a series of engines tested with this theory, the average was: Height = 5.7 x stroke.

Therefore, a quick estimate of 6 x stroke is easy to remember and calculate. If the stroke is not known, the total engine height is 4 x height of the cylinders.

Example 1—SS *Emu*

Figure 2 is a photograph of a compound steam engine buried to the cylinder head on a sandy beach. The engine is upright and expected to be still attached to the hull of the vessel. The vessel has been identified as the wreck of the SS *Emu*. The shipping register records the stroke

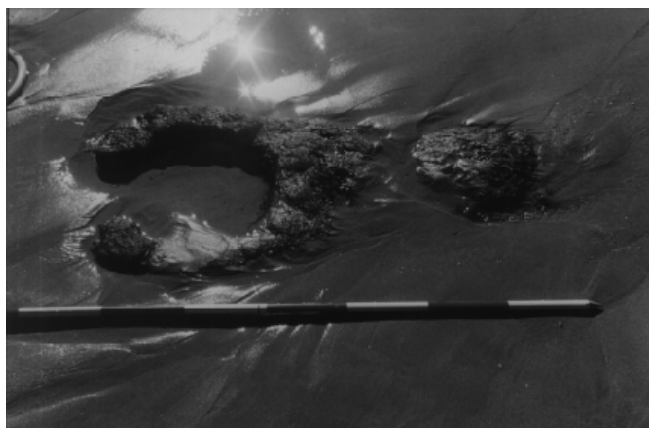


Figure 2. Compound steam engine from the SS *Emu* buried to the cylinder head (Photo: Tim Smith).



Figure 3. Cylinders of a triple expansion engine of the SS *Oakland* (Photo: John Riley).

at 10 inches, therefore engine height is 10 inches x 6 = 60 inches (1.5 m).

The hull will be exposed after clearing away 1.5 metres of cover. Knowing this, the correct lengths and amount of equipment can be brought to the site for any excavation work.

Fieldwork confirmed depth of cover on site to be as estimated.

Example 2—SS *Oakland*

Figure 3 shows the cylinders of a triple expansion engine of the SS *Oakland*. The sand level is just below the bottom cylinder cover. If the stroke is not known, the cylinder height can be measured and multiplied by 4 to give engine height. Deduct the exposed height of the engine and the depth of cover is known.

Comparison of engine size

The following table (Fig. 4) gives the comparative engine sizes for the SS *Emu*, SS *Oakland*, SS *Catterthun* and SS *Yongala*.

References

Lloyd's Register of Shipping.

| Ship | Stroke | Engine Height | |
|----------------------|--------|---------------|--------|
| | | Feet | Metres |
| SS <i>Emu</i> | 10 | 5 | 1.5 |
| SS <i>Oakland</i> | 24 | 12 | 3.6 |
| SS <i>Catterthun</i> | 48 | 24 | 7.3 |
| SS <i>Yongala</i> | 54 | 27 | 8.2 |

Figure 4. Comparison of engine sizes.

A contribution to the management of the buried historical shipwreck heritage: A GIS risk assessment model for the River Richmond mouth, northern New South Wales

W.E. Boyd, S. Pathirana & G. Bell

Centre for Coastal Management, Southern Cross University, LISMORE, NSW 2480

Abstract

The River Richmond mouth at Ballina, northern New South Wales, is typical of many parts of the New South Wales coast, in that it has a rich historical record of shipping and other maritime activities. From a cultural heritage point of view, this rich history is expressed, in part, by a material record of ship wreckage. Whereas many of the vessels wrecked in the vicinity of the river mouth have broken up or been removed, there are some wrecks whose location is known. Furthermore, there is a strong possibility that there are other wrecks in unknown localities, buried within various terrestrial and coastal sediments. This claim is supported by an assessment of both the geomorphological development of the river mouth and the maritime and shipping history during the last 170 years. Cultural heritage managers need to be able to develop appropriate management strategies for the protection and conservation of such material remains, especially in the light of potential changes in land use and the continuing impacts of erosive environmental processes in the coastal zone. This report describes the development of a management support system in the form of a risk assessment GIS model. The risk being evaluated is that of the possible disturbance or exposure of potential buried historical shipwrecks in this coastal area. The model does not attempt to predict the actual location of possible buried shipwreck remains, but focuses on the degree and, to a lesser extent, nature of the risk of disturbance to any buried materials that realistically may be present. At this stage in the development of the model, it appears that the model is moderately robust, although there is scope for some fine tuning. The model appears to be applicable to different situations (e.g. other areas of coastline), and to be used as a model for proposed future changes in, for example, land use zonation.

Introduction

The focus of this paper is two-fold. First, the focus is on the historical shipwreck heritage of the River Richmond mouth at Ballina, northern New South Wales (Fig. 1). The second and more important focus is the process of management decision-making associated with that heritage, especially in relation to assessing the risk of damage to possible buried shipwreck heritage. The area of the River Richmond mouth at Ballina is, in terms of both its shipwreck heritage and the management problems posed

by that heritage, typical of many coastal environments in New South Wales (Dept. Urban Affairs & Planning, 1995). There is, as in many other parts of the coast, a rich record of historical shipwrecks. The history of maritime activity of this particular river mouth stems from Rous' 1828 discovery, though periods of exploration and early settlement during the 1830s and 1840s, the consolidation of European occupation in the catchment of the river, to 1908, when the engineering works—breakwater walls and shore hardening—typical of the present morphology of the river mouth were completed. During this period of close to 100 years, 94 vessels are known to have been wrecked within or close to the river mouth (Boyd *et al.*, 1996a). Despite this rich historical record, it is important to note that very little material or exposed remains of ship wreckage are known, and the exact locations of most of the wreck sites and any possible remains are unknown. Whereas many of the original vessels wrecked in this river mouth were either refloated or were broken up or removed from their original site of wreckage, it is highly probable that historical shipwrecks remain buried within the river mouth and nearby coastal sediments (Boyd *et al.*, 1994). This has important implications in terms of designing strategies for the management of an invisible, and possibly but not necessarily absent, heritage.

A study (Boyd *et al.*, 1996a) of both the geomorphological history of the river mouth and the historical shipping records supports this possibility of a buried shipwreck heritage in this river mouth. Although Boyd *et al.*'s (in press) study of the evolution of the river mouth during the 19th century relied on evidence from relatively few time periods, it clearly illustrated that the geomorphology of the river mouth has changed significantly during the period 1828 to 1908. Indeed this was the major reason for the engineering works which commenced in the 1880s and completed by 1908 to control the geometry of the river mouth. These changes were at times considerable, and are characterised by the opening and closing of channels and river mouths and by the moving of sand bars; one particular river mouth which claimed several ship wrecks, is now infilled with a substantial sand spit upon which dunes of up to 6 m are present. Such major geomorphological changes are illustrated graphically by the documented exposure, in 1933, of a 60 foot (*c.* 20 m) long vessel close to the north breakwater wall in the area of Shaws Bay (Boyd *et al.*, 1996a).

The important historical consequence of a geomorphological record such as this is that the locational focus for wreck sites has shifted in time, and that wreckage from some wreck events may be presently well protected under what is now dry land. Using both the geomorphological model of change and the historical record, Boyd *et al.* (in press) were able to identify those areas in which buried historic shipwrecks may occur. Whereas this model does not purport to predict *actual* location of buried shipwrecks, it does provide realistic geographical limits to the locations of sites of probable burial. Such a predictive approach works well with archaeological and historical site in any context, since there is always an essential association between artifacts and their landscape context which allows the construction of both historical or archaeological analytical models and site preservation predictive models (e.g. Boyd *et al.*, 1996b).

Heritage risk modelling and GIS

This paper extends the geographical heritage modelling described above by examining the potential risk of damage to possible buried shipwrecks in the Richmond River mouth. Based on the locational model described above, and using data representing sources and processes of potential disturbance to buried heritage, a Geographical Information System (GIS) is developed in which layers of data can interact to model the likelihood of disturbance to a particular site. Such a model provides input to heritage management decision making in that it allows some measure of the risk of disturbance to a buried heritage item to be established.

A GIS can be defined in various ways. One useful definition is that a GIS is 'any system or application involving the ability to store spatial data in a series of map layers through the application of some procedure involving one or more of these layers' (Petrie *et al.*, 1995: ii). The application of GIS to archaeology and cultural heritage management is a rapidly growing field (e.g. Lock & Stancic, 1995; see also Petrie *et al.*, 1995, an annotated bibliography containing details of 328 reports and articles, including 51 overview reports). This rapid growth is largely in response to (i) the substantial amounts of data generally generated within in cultural heritage (especially archaeological) research project, and (ii) the need within cultural heritage management to place sites into both their past and modern spatial and temporal contexts. Reviewers of the use of GIS in archaeology and cultural heritage management identify several major categories of applications (e.g. Kvamme & Kohler, 1988; Allen, 1990; Savage, 1990; Weimer & Zoetbrood, 1994). Of particular importance in cultural heritage management are the following categories: (i) the construction of regional or site-focused databases; (ii) predictive modelling of site or landscape relationships as an archaeological analytical method (i.e. for the interpretation of past site distributions

and relationships); and (iii) predictive modelling of site distribution, survival and environmental context within the modern landscape as, variously, management and risk assessment tools. The former two functions tend to dominate the use of GIS in cultural heritage management; around 50% and 30%, for example, of projects representing these functions respectively tend to dominate cultural heritage management GIS projects described by Petrie *et al.* (1995). The few remaining examples represent a diverse set of interests within management-based modelling, ranging from site-specific to regional issues of management, but generally with a regional emphasis on models addressing the impacts upon cultural heritage of current land use practices (e.g. Boismar & Reilly, 1988) or potential future land use (e.g. Richards, 1990; Palumbo, 1993). The general thrust of these approaches is the modelling of cultural heritage data into some spatial form—either two dimensional (i.e. land surface distribution only) or three-dimensional (depth included)—and superimposing details of existing or proposed land use details on this spatial representation of the cultural heritage data. Consideration of the resulting correspondence of data sets provides input to both cultural heritage and land use management.

The use of GIS in this project, while focusing on land use and heritage management, is a special case of the use of GIS in risk modelling. During the last three decades, GIS has evolved through three phases, reflecting the major applications identified above: as an information database, as an analytical tool, and as a decision supporting system (Eastman *et al.*, 1995). In recent years, much attention has been given to developing decision support systems in a range of applications varying from environmental management (Stein *et al.*, 1995) to handling uncertainty (Shi, 1995). In particular, modelling and mapping risk (such as the possible impact of environmental conditions on public safety or the likelihood and impact of environmental change) involves handling uncertainties which refer to a body of usually inexact knowledge. Eastman *et al.* (1993) distinguish two classes of uncertainty: data and rules. Data uncertainty relates to any measurements or observations which are mapped in the GIS, while rule uncertainty relates to the conclusions that can be drawn from these data. In risk modelling, the conclusions which may be drawn from data are inherently uncertain.

In GIS several approaches are available for combining data layers to assist decision making. Generally, criteria are combined using Boolean operators. This involves the logical combination of binary maps. In a binary map only two classes of values are present: class 1 indicates areas that satisfy a condition, and class 0 indicates all remaining areas. The output of a binary operation becomes a new map, with two classes, 1 or 0. The combination of binary maps results from the application of conditional operators: each location is tested to determine whether it belongs to the set of

locations for which the conditional criteria are satisfied. Although this method is commonly applied because of its simplicity, it is often inappropriate for mapping uncertain phenomena such as risk because risk surfaces do not have clearly defined boundaries (i.e. risk is rarely absolutely present or absent, but is present to some degree). When examining the risk factor associated with certain phenomena, it is usually not suitable to give equal importance to each criterion being combined. Evidence, such as soil type, needs to be weighted depending on its relative significance to the risk being assessed. To deal with this alternative approach, Bonham-Carter (1995, p. 285) suggests that the use of what are known as binary evidence maps is more appropriate for applications that involve weighted components in data models. If the evidence to be combined together is binary, each map is multiplied by its weight factor, summed over all the maps being combined, and normalised by the sum of the weights. This allows a number of data sets to be combined according to some algorithm. The result of this approach is to produce a map showing regions that are ranked according to a derived score. Such an approach is applied in the research being described in this report.

The Richmond River shipwreck heritage risk GIS model

The method adopted in the study reported in this paper extends approaches to heritage management GIS usage such as by Boismar & Reilly (1988), Richards (1990) and Palumbo (1993). Rather than modelling just for the cultural heritage data, several other factors which are considered to be of importance in the process of site disturbance, are actively integrated into the modelling. These factors are chosen as environmental and land use characteristics which may expose or disturb buried cultural heritage items. The assumption in developing this type of risk model for buried items is that the major risk to the maintenance of the items' integrity is the removal or movement of the sediment matrix in which the item is currently safely and naturally stored. In this context, two broad sets of information, as follow, are considered important; details of the individual components are discussed fully below.

- (1) Factors determining the presence of buried items. In this paper, these are called 'Absolute factors'. The risk model is, first, based on a best estimate of the probable location of buried shipwreck heritage. These factors—historical distribution, land surface elevation, and geological substrate—each determine the absolute possibility of potential buried shipwrecks.
- (2) Factors contributing to the actual risk of disturbance of the buried items. In this paper, these are called 'Cumulative risk factors'. The risk model is, secondly, based on a series of environmental factors—potential for physical erosion, processes of physical erosion, and land use practices—which individually or in combination enhance the risk for site disturbance.

The basic model is represented by the equation: Risk of disturbance to potential buried shipwrecks = Absolute factors x Cumulative risk factors

Methods

The data required to model this risk are derived from several sources. The historical shipwreck location model is that already published (Boyd *et al.*, in press) which has considered both the physical environment of the river mouth and its evolution during the historical period, and the documented history of local shipping and other maritime activities during this period (*cf.* Lopata *et al.*, 1992). The environmental and land use data are derived from two electronic databases. The first is a Multi-Attribute Database for New South Wales (© Department of Water and Land Conservation, NSW, 1995) which consists of attributes on slope, terrain, existing land use, timber cover, vegetation, land degradation and geology. The second is an environmental GIS database for north-east New South Wales which includes information on land planning zonation, contours and soils. This latter database has been compiled at the Centre for Coastal Management, Southern Cross University, using as sources the 1995 Ballina Shire Council Local Environment Plan (© Ballina Shire Council, 1995) and NSW Land Information Centre standard topographic maps (© Land Information Centre, NSW, various dates).

The study area is defined in terms of the published historical shipwreck distribution model (Boyd *et al.*, 1996a), with a buffer zone surrounding it to allow for any inaccuracies of that model. The details are described below under Absolute Factors: Shipwreck location (Shl). The data in each layer of information is reclassified in terms of their probable contribution to the risk of disturbance to buried shipwrecks. Each element is revalued on a nominal scale of 0 to 1 (see below for details), based on estimates of the type, extent, degree and severity of surface and subsurface disturbance that may be attributable to each element. The original and revalued data was stored and processed in PC Arc/info on an IBM 486DX66, and final map production was undertaken in Arcview 2.0.

Details of model components

Absolute Factors (A)

The absolute factors comprise three factors, any one of which can negate the model. These represent the absolute probability that there is a buried shipwreck at any location, and a zero value for any one of these elements indicates a nil probability for the entire risk assessment, i.e. the complete absence of any possibility of a shipwreck being present. The calculation of a zero value for A therefore negates the model, and thus defines an outer margin to the spatial distribution of potential risk to buried shipwrecks. The three elements are as follows; the values assigned to the internal components within each element are given in Table 1.

(i) Shipwreck location (Shl)

The study area is defined by the estimated distributional location of possible shipwreck as defined by Boyd *et al.* (1996a). This coverage provides a boundary covering the changes in shipping channels and hazards and the river mouth location during the historical period. In addition, a 250 meter wide buffer zone is added to the defined areas to allow for some error in the original model, and to allow some protection for any wreck which may have shifted up-river or out to sea due to sand and water movements. This buffer zone is an estimated width, based on the geography of the river mouth and an assessment of the accuracy of the original historical data and the model derived from them. The exact width of a such a buffer zone could vary according to specific circumstances. The GIS model could use several variants of the shipwreck location element. For the moment, a cumulative location for the period 1828–1908 is used, representing the total area in which any pre-1908 now-buried shipwreck may occur. However, individual time period distributions could be equally used, depending on availability of historical shoreline data.

(ii) Elevation (El)

The elevation model used here is somewhat crude. Nevertheless, this offers a reasonably conservative estimate of those areas which may have served as suitable wreck sites. Given that the wreckages were within or below tidal level, and that some such former areas have been subsequently covered by coastal sediments, notably beach and dune sands and reclaimed land, it is reasonable, if a little conservative, to suggest that any land with a present surface elevation of over 10 m is unlikely to contain buried shipwreck remains. Areas of water surface, that is the ocean and the river surface in this case, do not appear in the elevation model used since that model solely concerns itself with terrestrial surfaces. The surface of water bodies is assigned a negative value.

(iii) Surface geology (Geo)

The surface geology of the study area comprises Quaternary alluvium, Quaternary beach sand and Tertiary basalt. Since any buried shipwrecks can only occur within soft sediments, the type of surficial geology places a real absolute limit on the possibility that a buried shipwreck does exist at any site.

These absolute factors combine geometrically to yield an absolute factor component, A, such that:

$$A = Shl \times El \times Geo$$

Cumulative risk factors

These factors are those contributing factors of risk of exposure or damage to potential buried shipwreck material, and comprise three principle factors as follows (as above, see Table 1 for allotted values).

(i) Erosion Susceptibility (Es)

Susceptibility of soil erosion is related to land surface slope. However, the relation between slope and erosion is influenced by both soil type (i.e. the structural stability of the land surface) and the type of land surface cover (i.e. type and degree of physical binding and protection).

Slope (Sl)

The risk values applied to slope values follow slope classifications in soils mapping and assessment manuals such as McDonald *et al.* (1984).

Soil type (So)

Soils vary in their susceptibility to erosion. In this case, four soil types are present in the study area. Following McGarity's (1956) soil categories map, krasnozem regosol-nomopodzol is identified as a more stable soil than the other three recorded here, and thus is valued as such.

Land cover (Lc)

The land cover coverage used here is limited, grouping current land uses and vegetation categories in 26 groups, of which only four are present in the study area. The values are assigned to reflect the lack of protection against erosion provided by each group.

Since these three factors are interrelated in terms of their capability to influence erosion susceptibility, they are treated geometrically to yield an erosion susceptibility value thus:

$$Es = Sl \times So \times Lu$$

(ii) Erosion processes (Ep)

This component comprises characteristics which are either the consequences or the vectors of physical processes, and thus represent actual physical (i.e. potentially erosive) processes active on the land surface. The factors in this component are follows.

Terrain (Te)

The terrain is categorised as current land form types, each of which has a specific physical process characteristic. These, therefore, are valued in relation to the degree to which these represented processes may induce surface or subsurface disturbance.

Shore proximity (Shp)

The major geomorphic agents in the study area, especially in relation to erosion and surface disturbance, are the ocean and the river. Proximity to these is a major influence on the risk of disturbance, and so this factor is taken to influence the magnitude of potential erosion risk. The influence of these two major geomorphic agents is modelled by assuming a landward buffer zone along the river and ocean edges which is assumed to be in greatest and most immediate risk to exposure to erosive processes.

| Model element | Details | Assigned value |
|---------------------------------|---|----------------|
| | Absolute factors | |
| Shipwreck location (Shl) | Area of possible locations of shipwrecks | 1 |
| | Marginal buffer zone | 0.5 |
| Elevation (El) | Ocean and other water surface, 0 m a.s.l. | -1 |
| | Land surface at ≤ 10 m a.s.l. | 1 |
| | Land surface at > 10 m a.s.l. | 0 |
| Geology (Geo) | A: Alluvium | 1 |
| | A1: Beach sand | 1 |
| | B: Basalt | 0 |
| | Cumulative risk factors | |
| Slope (Sl) | -: 0 | 0 |
| | A: 0 - 2% | 0.25 |
| | B: 2 - 5% | 0.5 |
| | C: 5 - 10% | 0.5 |
| | D: 10 - 20 | 1 |
| | E: 20 - 33% | 1 |
| | F: 33 - 50% | 1 |
| Soil (So) | Li: Krasnozem regosol-nomopodzol | 0.75 |
| | Mn: Meadow gley podzol | 1 |
| | Nm: Yellow pallid amphipodzol | 1 |
| | U: Gley podzol (freely drained) | 1 |
| Land cover (Lc) | g: Native blady grass | 0 |
| | t: Trees | 0.5 |
| | u: Urban | 1 |
| | w: Beach sand or bare ground | 1 |
| Terrain (Te) | 0: Flat | 0.25 |
| | 2: Sideslope | 0.5 |
| | 4: Floodplain | 0 |
| | 7: Sand plain | 0 |
| | 11: Sand dune | 0 |
| | 12: Swales | 0 |
| | 13: Swamps | 0 |
| | 14: Water | 0.5 |
| Shore proximity (Shp) | 0 - 0.25 km from H.W.M. (soft shore) | 1 |
| | 0 - 0.25 km from H.W.M. (hard shore) | 0.75 |
| | > 0.25 km of any shoreline | 0.5 |
| Timber (Ti) | -: No timber cover | 0 |
| | 1Z: No mature trees | 0 |
| | 2C: Rainforest | 1 |
| | 2E: Heath, scrub & bottlebrush | 1 |
| | 2G: Tidal mangroves | 0.5 |
| | 2R: Native scattered trees | 1 |
| Present erosion (Er) | 0 & 11: No appreciable erosion | 0 |
| | 31: Minor wind erosion | 1 |
| Land use (Lu) | Living area | 0.5 |
| | Business | 0.5 |
| | Open space | 0 |
| | Environmental protection wetlands | 0 |
| | Environmental protection water catchment | 0 |
| | Environmental protection coastal | 0 |
| | Environmental protection habitat | 0 |
| | National parks & nature reserves | 0 |

Table 1. Values assigned to the elements within the risk assessment model for the risk of disturbance to potential buried shipwrecks in the River Richmond mouth. These values represent the revaluing of the original multi-attribute data. The elements are presented in this table in the order they appear in the text, and are in some cases codified according to the original database codes; these codes are used in the legends of some of the original data maps (Figure 2). The original data distributions of all elements excepting Shl (published in Boyd *et al.*, 1996a), El and Shp, and the distributions of their assigned values are illustrated in Figure 2.

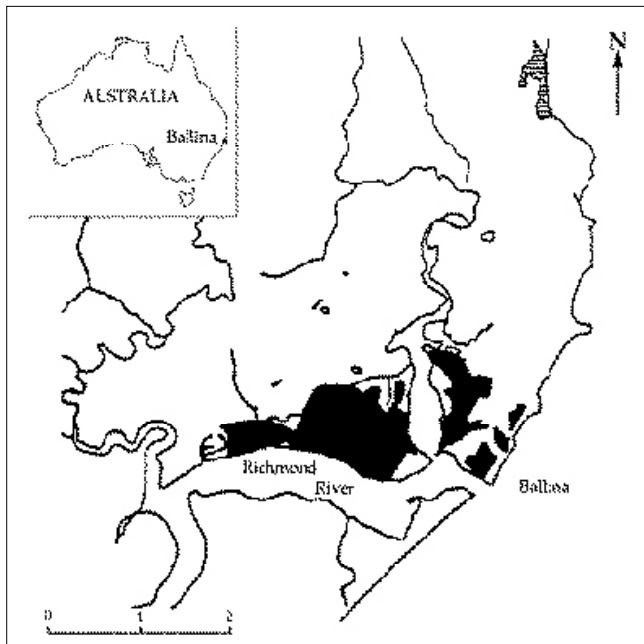


Figure 1. Location map of the study area at the River Richmond mouth, Ballina, northern New South Wales.

Timber cover (Ti)

Whereas timber cover provides some measure of protection against surface erosion, there is a minor potential contribution to the damage of buried items by either root penetration or tree fall. This is, however, considered to be a minor process of disturbance, and thus is subsequently factored down in the modelling computations.

Present superficial erosion (Er)

The present superficial erosion represents contemporary land surface processes and is thus a useful indicator of process. This factor consists of two classification groups within the study area: no appreciable erosion and wind erosion. In assigning values, a 1 value is also assigned to the river surface.

The computation of the erosion process component is complicated by the variable relationships between the indicators of processes. Since the effects of terrain may be enhanced by the proximity of the shoreline, these two are combined geometrically; the remained are independent, and are treated as cumulative effects. Consequently, a value for the erosion process component is calculated thus:

$$E_p = (T_e \times S_{hp}) + (0.1 \times T_i) + E_r$$

(iii) Land Use (Lu)

This is a single value based on the present land use planning zonation. The land use zonation coverage was developed from the 1995 Ballina Local Environmental Plan. The groups of land use in this coverage represent both present actual land use and permitted future land use. It is this factor which may first be altered where predictive modelling or risk consequent upon proposed land use change is required. Placing values on the land use zonation

groups reflects estimates of risk of sub-surface disturbance on the basis of permitted activities and their potential influences regarding impacts, either in terms of depth or extent of disturbance to surface and superficial soil and sediments. There are three main zonation types in the study area. Potential development within environmentally protected areas is limited to protection of area or for the installation of point or linear utilities. These areas, therefore, are of low risk, whereas the business and urban areas are considered to be of medium risk.

The model

The risk of damage or disturbance to potential buried shipwreck (R) is defined, in its simplest way, as follows:

$$R = A \times (E_s + E_p + L_u)$$

There is a possibility that this equation generates negative values. Such values provide potential distinction between computed R values for terrestrial and aquatic environments (i.e. positive values represent risk in terrestrial environments, whereas negative values represent risk in aquatic environments). However, in the modelling presented here, it is considered that the magnitude of risk, rather than its sign, is more relevant, and thus whereas the option for terrestrial/aquatic differentiation is retained in the basic model, for further computation, the absolute value, regardless of sign, is used for the component A . The model thus becomes:

$$R = |A| \times (E_s + E_p + L_u)$$

This model is further moderated by the lack of equivalent data for E_s , E_p and L_u on land and at sea. The data is good for terrestrial environments, but at present is absent for the ocean area. Whereas there are both erosion susceptibility and processes operating in the ocean area, there is at present no way to differentiate areas of different assigned risk value on account of these factors. Furthermore, although there are potential land use impacts in some parts of the ocean floor, especially close to the shore, again these are not documented and land use planning zonation does not account for these. Whereas, therefore, it may be possible to acquire data which will provide values for E_s , E_p and L_u , at this stage in the development of the model, this is not possible. Consequently, the area within the study area which lies seaward of the low-tide mark and the bar of the river mouth is left unmodelled in terms of risk to potential buried shipwreck heritage. Given the importance of off-shore wreckage, this is an area of model development which requires further work.

In the area for which modelling is possible, the extent to which either E_p or L_u influences R will be moderated by E_s . There is, therefore, a need to model some factoring or balancing of values. This is a difficult step, which may in part need to reflect local conditions, as some balance is struck between the relative magnitudes of each factor. In particular, it is noted that the effect of land use on the risk is in part related to E_s , and therefore the land use factor requires to be moderated as $(1 + E_s) \times L_u$. This

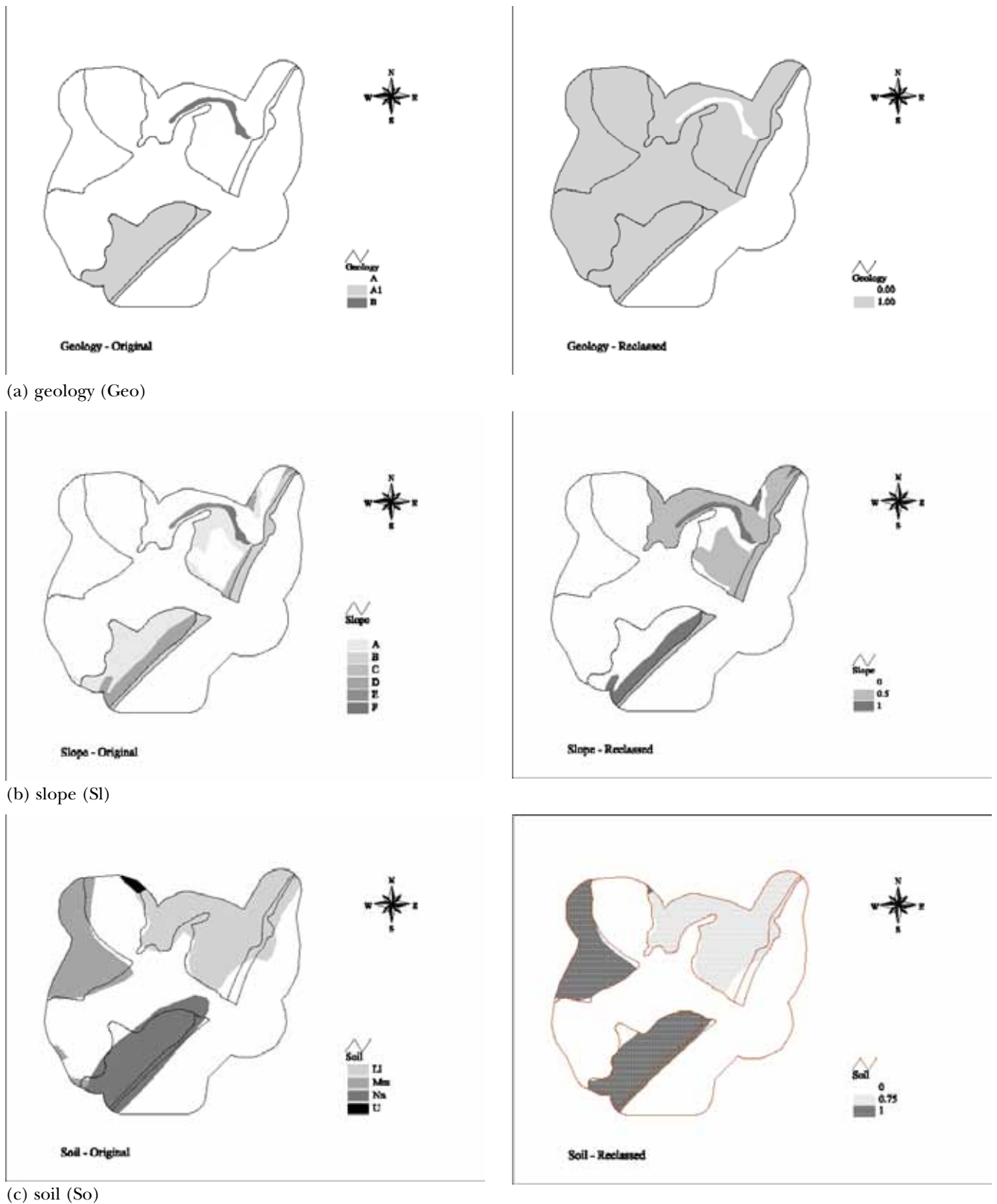
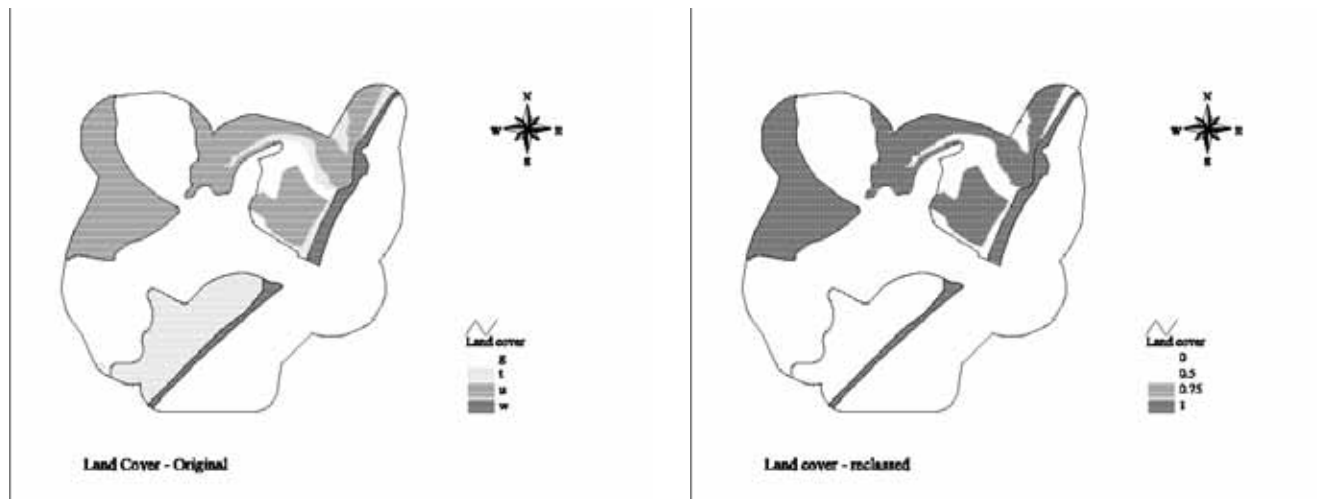
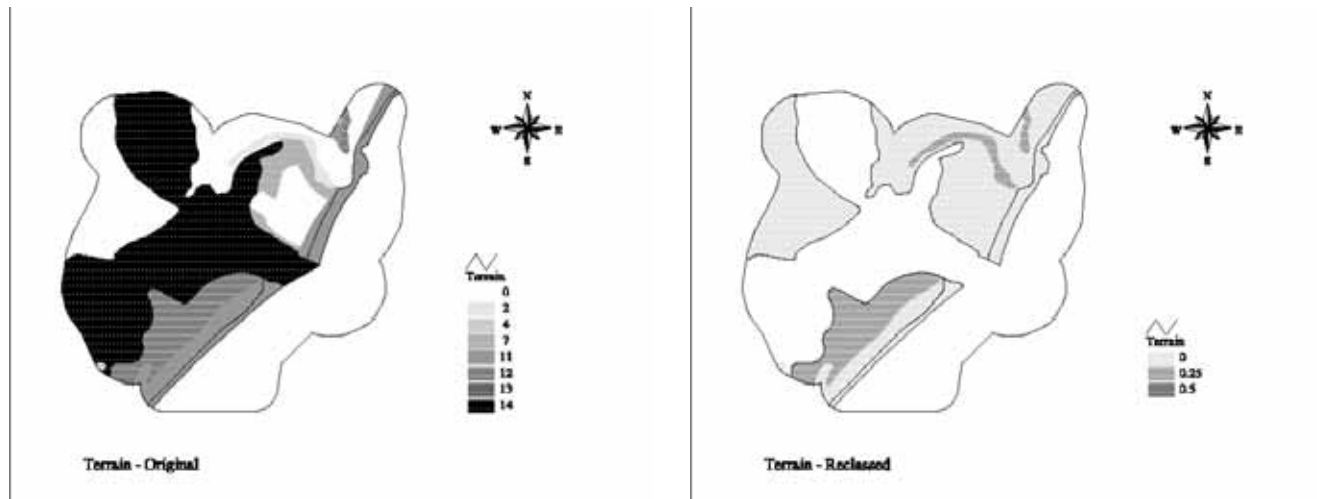


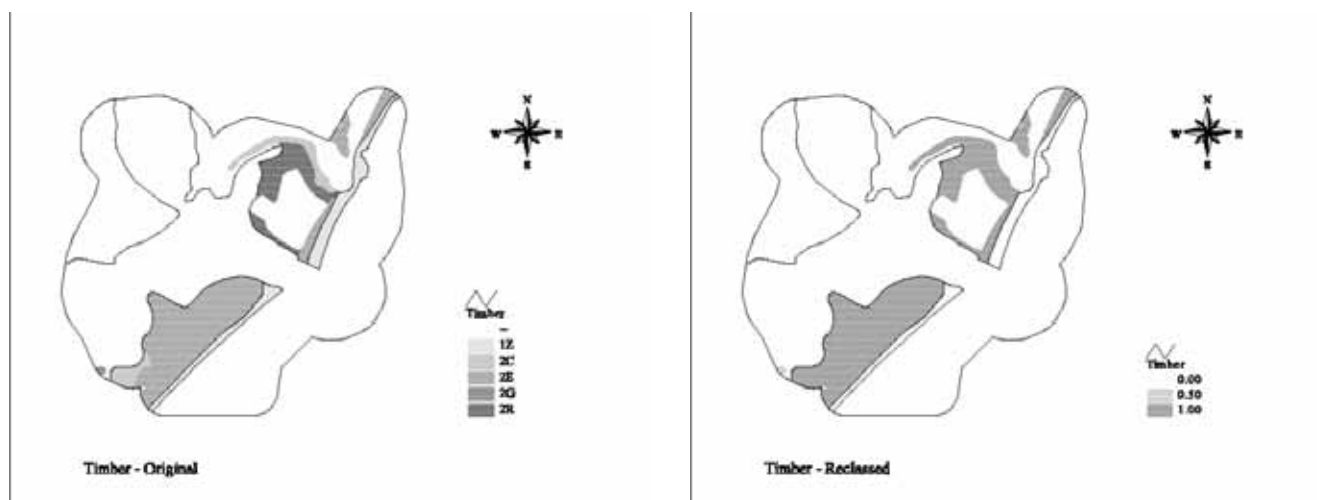
Figure 2. Plots of the original multi-attribute data for the study area (upper map in each case) and of the distributions of assigned values (lower map in each case). The legends in most of these indicate codes used in the original database for the identification of components within each element; names for the codes are given in Table 1, with the exception of the land use zonation classifications, which include several 'envir-protection' components, these being equivalent to the 'environmental protection' components in Table 1. The individual plots are: (a) geology (Geo); (b) slope (SI); (c) soil (So); (c) land cover (Lc); (d) terrain (Te); (e) timber (Ti); (f) present erosion (Er); (g) land use (Lu).



(d) land cover (Lc)

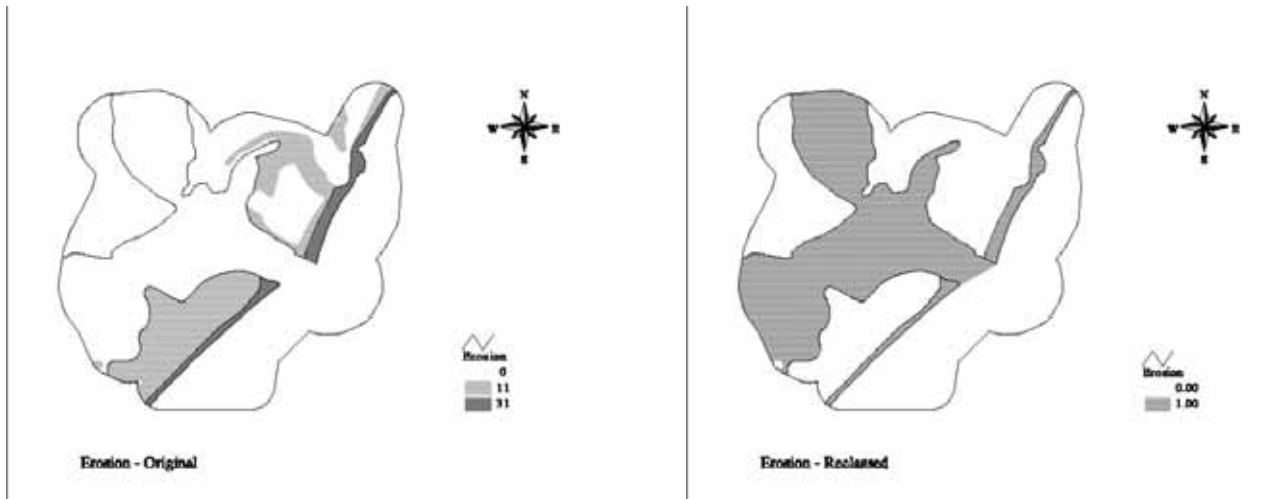


(e) terrain (Te)

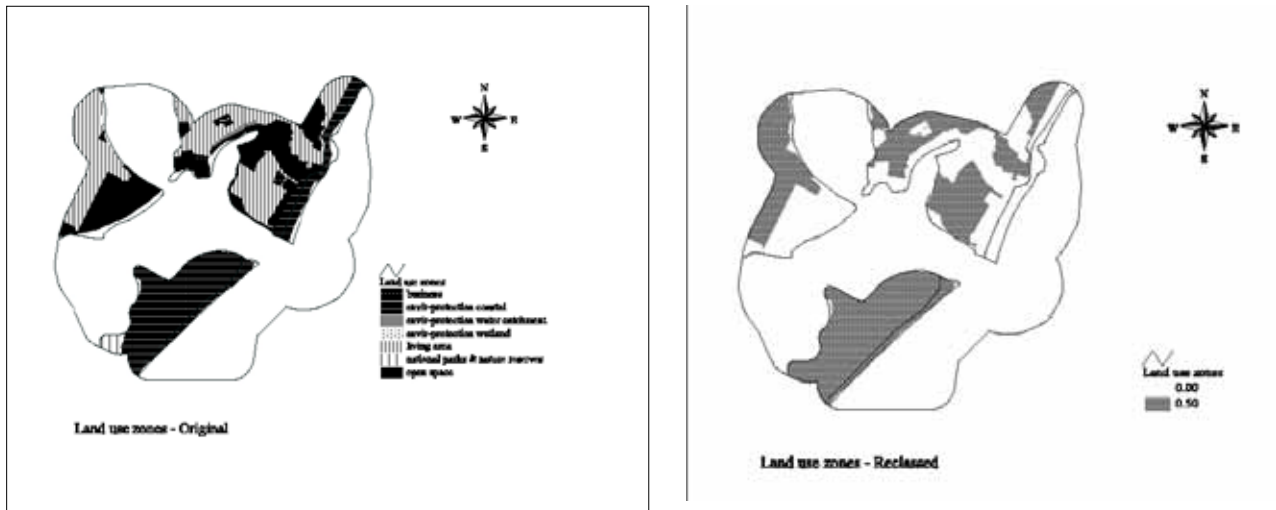


(f) timber (Ti)

Figure 2. Continued



(g) present erosion (Er)



(h) land use (Lu)

Figure 2. Continued.

allows the effect of land use as both a direct disturbance in its own right and an influence on the effect of Es. This modifies the model thus:

$$R = |A| \times [Es + Ep + [(1 + Es) \times Lu]] \quad \text{Model 1}$$

Given this modification to the model, it becomes apparent that the relative contributions of Es, Ep and Lu become unbalanced. If it is assumed, for the moment, that erosional susceptibility, erosional processes and land use contribute equally to the cumulative risk of disturbance to buried shipwreck heritage, there needs to be some factoring of the cumulative components to recognised this. Given that the ranges of values for each of Es, Ep and Lu are controlled by various contributing components within each, there will be an unequal contribution from Es, Ep and Lu. Since $Es = Sl \times So \times Lc$, its minimum possible value is 0.0625 (i.e. $0.25 \times 0.5 \times 0.5$) and its maximum possible value is 1 (i.e. $1 \times 1 \times 1$). Likewise, the minimum and maximum possible values for $Ep = (Te \times Shp) + (0.1 \times Ti) + Er$ are 0.0625 (i.e. $(0.25 \times 0.5) + 0 + 0$) and 1.35 (i.e. $(1 \times 1) + 0.1 + 0.25$) respectively. The Lu component ($= (1 + Es) \times Lu$) has minimum and maximum possible values of 0.2656 (i.e. $(1 + 0.0625) \times 0.25$) and 2 (i.e. $(1 + 1) \times 1$) respectively. On the assumption, therefore, that Es, Ep and Lu each contribute equally, it is necessary to find values for X, Y, & Z as follows:

$$R = |A| \times [(X \times Es) + (Y \times Ep) + (Z \times (1 + Es) \times Lu)]$$

To equalise the maximum values computed above for each of Es, Ep and Lu, rounded values of $X = 2$, $Y = 1.5$ and $Z = 1$ are required. This yields the following version of the model:

$$R = |A| \times (2Es + 1.5Ep + (1 + Es) \times Lu) \quad \text{Model 2}$$

However, it is probable that the assumption of an equal contribution from each cumulative component is incorrect, that is that these three components are of unequal weighting in their contribution to the risk of disturbance to buried shipwreck heritage. Indeed, the relative importance of each may vary from situation to situation. At present, there is little information regarding the relative risk of heritage damage or exposure provided by natural versus human or land use processes. This is a field for further study.

On the assumption that Es, Ep and Lu each have different weightings, Model 2 may be extended by varying the degree to which Es, Ep and Lu contribute to the computation. Assuming that the weightings of Es, Ep and Lu lie between (and this is merely an estimate) 1 and 5 times the values expressed in Model 2, then the model becomes:

$$R = |A| \times [(X \times 2Es) + (Y \times 1.5Ep) + (Z \times (1 + Es) \times Lu)] \quad \text{Model 3}$$

where $1 < X, Y, Z < 5$. This version of the model provides 125 integer options. Given the uncertainties surrounding the relative contributions of natural versus human or land use processes to the risk of disturbance to buried shipwreck heritage, and the fact that there is little information regarding the relative risks of heritage

damage or exposure, the experiment described in this report confines itself to three versions of Model 3 which attempt to represent three major options of the relative balance of natural versus land use input to the model of risk. These three versions are: (i) Model 3i: the influence of erosional processes (Ep) and erosion susceptibility (Es) are downplayed, with values of $X=1$, $Y=2$ and $Z=3$ being used to provide a doubling of importance for land use (Lu); (ii) Model 3ii: erosional processes (Ep) are given prominence over erosional susceptibility and land use (i.e. values of $X=1$, $Y=3$ and $Z=2$ are used); (iii) Model 3iii: erosional processes (Ep) and land use (Lu) are given prominence, being factored as being of twice the importance of erosional susceptibility (Es) (i.e. values of $X=1$, $Y=1.5$ and $Z=2$ are used to achieve this balance). These options yield the following three models:

$$R = |A| \times (2Es + 3Ep + 3(1 + Es) \times Lu) \quad \text{Model 3i}$$

$$R = |A| \times (2Es + 4.5Ep + 2(1 + Es) \times Lu) \quad \text{Model 3ii}$$

$$R = |A| \times (Es + 1.5Ep + 2(1 + Es) \times Lu) \quad \text{Model 3iii}$$

The results

The distributions of buried heritage risk values attributed to the original multi-attribute data (Fig. 2) are given in Figure 3. From these distribution plots, it is clear that the various contributing factors provide different geographical distributions of influence. The absolute factors (Fig. 3a), for example, define a central core area in which risk is greatest, and defined the absolute limits to the area for which further modelling may continue. The distributions of erosion susceptibility (Es), erosional processes (Es) and land use (Lu) (Figs 3b, 3c and 3d) are notably different, thus indicating that there is a degree, at least, of independence between these three contributing factors. Of particular note is the relatively non-coincident distributions of Es and Ep values. Furthermore, the land use component is least discriminating in terms of separation of degree of risk, and clearly is confined to influencing those non-aquatic areas. Figure 4 presents the output from the five versions of the model described above, the two basic versions (Models 1 and 2) and the three versions of the variable balance model (Models 3i, 3ii and 3iii).

Discussion

In terms of the models derived from these values (Fig. 4), it should be noted that the important comparison of values is that of value distributions within each model. Since the relative weightings of the various components vary between models, inter-model comparison of absolute values is inappropriate. However, inter-model comparison of the patterns of distributions is valid. Each of the models, unsurprisingly, provides a different impression of the pattern of risk to buried heritage in the study area. Models 1 and 2, the basic models, provide similar patterns, indicating the basic components that repeat

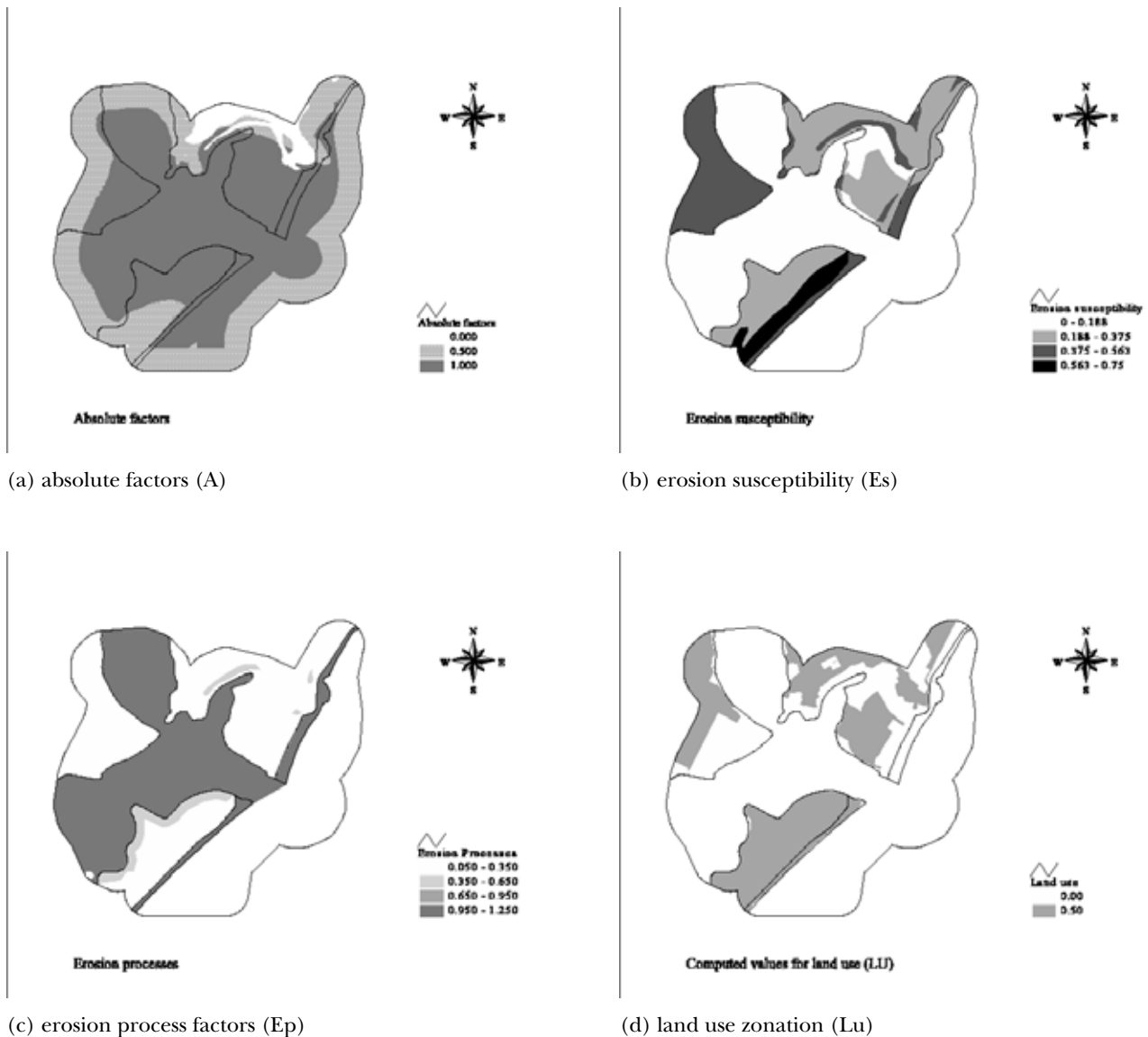


Figure 3. Distributions of values for the major components within the risk model, computed from the revalued original multi-attribute data and used in the development of the heritage risk models: (a) absolute factors (A); (b) erosion susceptibility (Es); (c) erosion processes factors (Ep), and (d) land use zonation (Lu).

themselves throughout the other models. Models 3i, 3ii and 3iii represent the predominance within the model of, respectively, land use, erosion processes and erosion susceptibility, and erosion process and land use. Removing land use as an important contributant (Model 3ii), clearly decreases the differentiation between areas of relative risk, with the exception of identifying those areas in which natural processes are the most probable cause of damage of buried heritage items. On the other hand, where land use is factored in strongly, considerable differentiation of risk level within the landscape is possible. If the purpose of the modelling described here is to contribute to the management assessment of potential impacts of land use and land use change, then Model 3ii is the least relevant.

Finally, it is of interest to note that regardless of the

particular model used, certain broad patterns of risk distribution are always apparent. This suggests that the model is reasonably robust, and that the choice of weighting values (X, Y, Z above) may not be a critical impediment to the successful application of this model. The broad recurring patterns have a further function, by providing input to management decision making. This is done by drawing attention to both specific places at which a high risk may be identified and, perhaps more importantly, identifying the dominant processes which may influence the degree of risk at any place. For example, despite the environmental protection zoning of the coastal dune and beach system (i.e. land use zoning designed to protect the land from the impacts of human use), such areas repeatedly emerge as being of high risk.

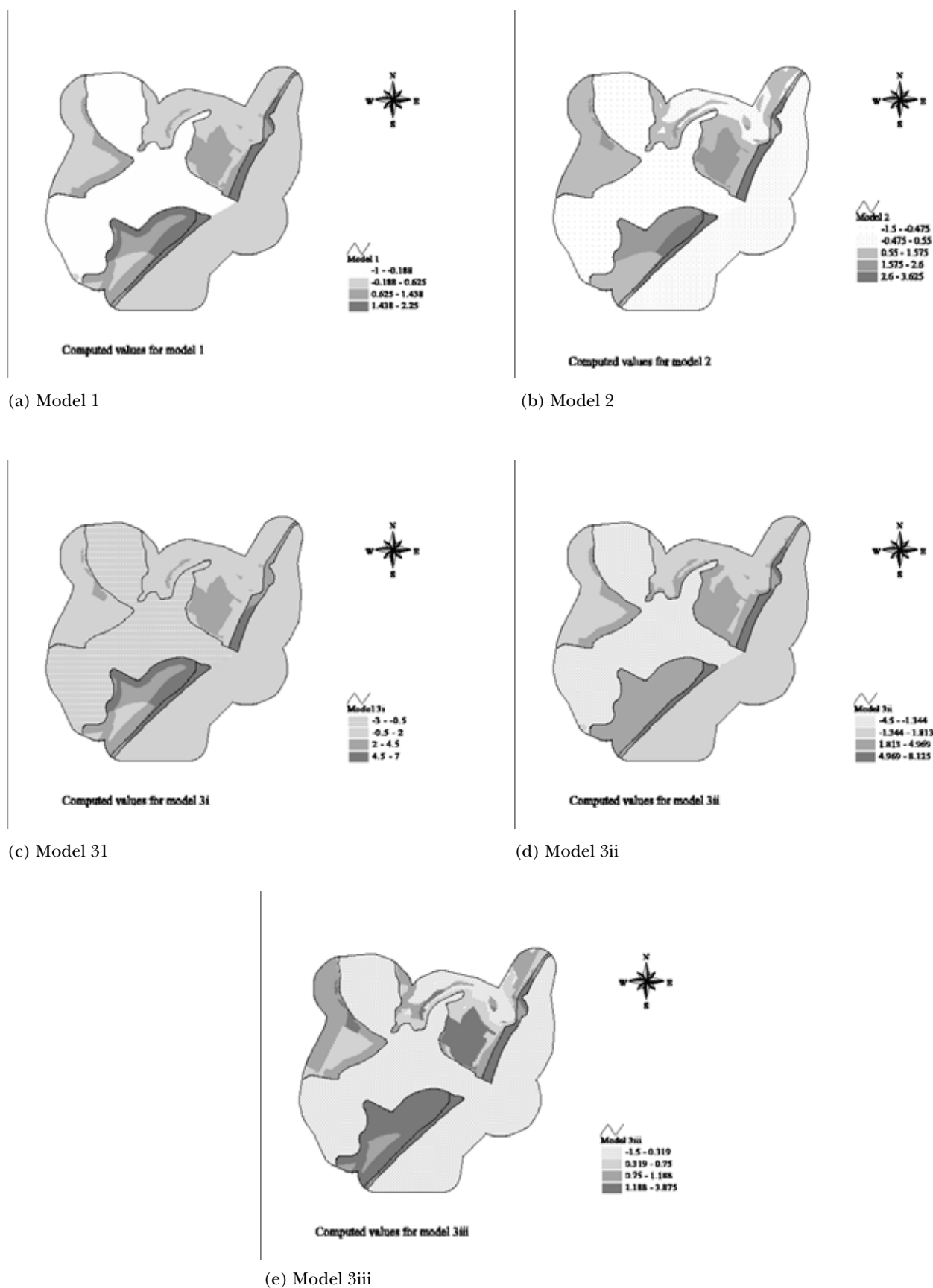


Figure 4. Distribution of computed values for each of models: (a) Model 1, the basic model; (b) Model 2, with equalised input from Es, Ep and Lu; (c) Model 3i, Lu dominant; (d) Model 3ii, Ep and Es dominant; (e) Model 3iii, Ep and Lu dominant.

In these areas, therefore, natural processes are of greatest influence, and thus, from a management point of view, should be of greatest concern. On the other hand, within urban areas, certain places are identified as being of greater or lesser risk. Not all areas being intensely used are at risk, and the diverse pattern of risk is related to both land use and natural processes influencing these areas either individually or in combination. As may be expected, and as indeed is written into the model, there is an interaction between land use practices and the natural erosion processes and susceptibility of a place.

At this stage in the development of the model, it appears that a moderately robust model has been constructed. All components of the model are variable, and may be manipulated, thus making the model applicable to different situations (e.g. other areas of coastline), and to be used to model for proposed future changes in, for example, land use zonation. There are still areas of uncertainty regarding some of the assumptions and inputs to this model, such as the relative influence of various processes on the disturbance to buried items and exact nature of the interrelationships between the processes identified as being important. Despite the possibility that some fine tuning may be necessary, the results of various versions of the model at present lend support to confidence that the model provides a sensible estimation of the distribution of the risk of disturbance or exposure to the buried historic shipwreck heritage of the River Richmond mouth at Ballina.

Conclusions

The River Richmond mouth at Ballina, northern New South Wales, is typical of many parts of the New South Wales coast, in that it has a rich historical record of shipping and other maritime activities. From a cultural heritage point of view, this rich history is expressed, in part, by a material record of ship wreckage. Whereas many of the vessels wrecked in the vicinity of the river mouth have broken up or been removed, there are some wrecks whose location is known. Furthermore, there is a strong possibility that there are other wrecks in unknown localities, buried within various terrestrial and coastal sediments. This claim is supported by an assessment of both the geomorphological development of the river mouth and the maritime and shipping history during the last 170 years. Cultural heritage managers need to be able to develop appropriate management strategies for the protection and conservation of such material remains, especially in the light of potential changes in land use and the continuing impacts of erosive environmental processes in the coastal zone.

This report describes the development of a management support system in the form of a risk assessment GIS model. The risk being evaluated is that of the possible disturbance or exposure of potential buried historical shipwrecks in this coastal area. The model does not attempt to predict the actual location of possible

buried shipwreck remains, but focuses on the degree and, to a lesser extent, nature of the risk of disturbance to any buried materials that realistically may be present.

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