The Duckenfield Expedition
31st March -1st April 2005

The Oceanic Research Foundation Ltd., the NSW Heritage Office and the Australian National Maritime Museum were represented by members and staff during a two-day expedition to the wreck of the ss Duckenfield. Logistical support was provided by Mr Dick Smith in the form of the M/Y Ulysses Blue and crew.

The expedition had two primary objectives.

Firstly, to conduct a re-survey of the ss Duckenfield (Mr David Nutley - NSW Heritage Office; Mr Stirling Smith and Mr Lee Graham -Australian National Maritime Museum). The survey achieved its primary objectives which were to assess the current condition of the site, obtain detailed photographic and video images of the site and to assess the extent and cause of deterioration of the Scotch boiler.

The second objective was to field-test submersible electronic equipment (modulated fluorometers) used in biological research (Dr John Runcie – Oceanic Research Foundation Ltd.). The fluorometers provided credible light and temperature data, and regularly measured photosynthetic activity of selected samples for 12 hours. The test provided useful and revealing data regarding the operation of the device, and specific issues arising from the results are now being addressed in the development of the next generation of modulated fluorometer.

A further objective of the study was to assess the suitability of the Ulysses Blue for proposed future research activities and determine the nature of any constraints that would influence the conduct of these activities. Dr Don Richards and Mr Colin Putt (both Fellows of the Oceanic Research Foundation Ltd.) provided valuable assistance and advice throughout the expedition and gained valuable first-hand experience of the utility of the Ulysses Blue as a research vessel.

Detailed descriptions of both the survey and fluorometer field-testing follow.

On behalf of my fellow expeditioners and myself I would like to extend my warm thanks to Mr Dick Smith for his generous assistance in the form of the M/Y Ulysses Blue and the friendly and professional crew who sailed her.

Dr John W. Runcie
April 2005
Sydney

ss *Duckenfield* 1875-1889
Maritime Archaeological Survey

31 March – 1 April 2005

NSW Heritage Office

Underwater Cultural Heritage Program

PARRAMATTA 2005

David Nutley, NSW Heritage Office

Report Prepared: April 2005.

(Cover Photo: ss *Duckenfield* boiler. D Nutley 2005)

This project was undertaken with support from the Commonwealth Department of Environment and Heritage as a National Historic Shipwrecks Project. The views expressed herein are not necessarily the views of the Commonwealth, and the Commonwealth does not accept responsibility for any information or advice contained herein.

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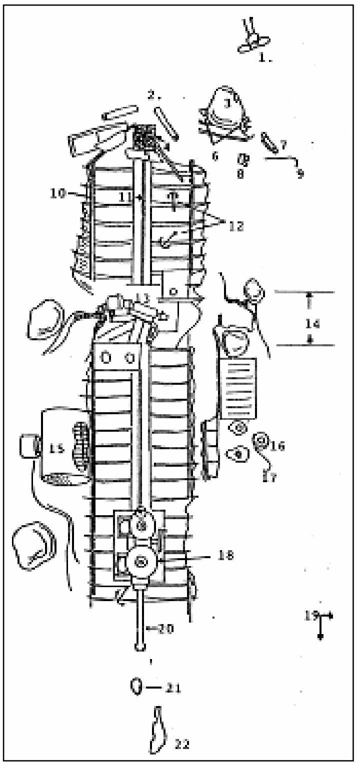
In Brief

The site of the historic shipwreck ss *Duckenfield* was last surveyed by the Heritage Branch of the Department of Planning in 1989, shortly after the discovery of the site was reported by Allan and Neil McLennan. The purpose of that survey was to establish the impact of diver visitation to the site at that time. No further underwater survey has been conducted since 1989. During the intervening 16 years the Heritage Branch, reconfigured as the NSW Heritage Office in 1996, has relied on irregular and informal reports from divers as to the condition of the site. Until 2004, permits were required for entry into a Protected Zone around the site, declared under section 7 of the *Historic Shipwrecks Act 1976.* With the removal of the Protected Zone in late 2004 the Heritage Office has been keen to undertake an updated survey of the site in order to assess any significant changes to the condition of the shipwreck site - using the 1989 survey as the benchmark.



KEY
I. Propeller
2. Hawser pipes
3. Boulder atop forecastle
4. Chain locker
5. Bulkhead 6. Ships' anchors
7. Anchor winch 8. Bitts
9. Davit
10. Bilge keel
11. Keel
12. Kedge anchors from salvage
13. Winch
14. Longitudinal extent of copper ingots across amidships.
I5. Boiler
16. Remains of donkey boiler
17. Davit
18. Surface condensing compound engine
19. Wreckage extends in these directions
20. Drive shaft
21. Single propeller blade
22. Rudder

(Site sketch: Allan and Neil McLennan, 1988)

The informal information the Heritage Office had obtained from recreational divers was that the site was relatively stable overall but that the boiler was showing marked deterioration. This seemed to suggest that the overall diver impact on the wreck site was minimal but raised the question of whether the boiler deterioration was due to a natural progression of corrosion of the iron or whether it was being accelerated by diver activity or anchors from dive boats and fishing boats. These questions required a formal diver based survey.

The *Ulysses Blue* provided a perfect platform for this research work by enabling each of the four person dive team to undertake 2 dives per day - a total of 16 dives within two days. Given the depth of the site (23-24m), and accompanying time limitations on individual dives in accordance with occupational diving operation requirements, the facility provided by *Ulysses Blue* achieved efficiencies that could not have been realised using a purely small boat operation.

The survey achieved its primary objectives which were to assess the current condition of the site, obtain detailed photographic and video images of the site and to assess the extent and cause of deterioration of the Scotch boiler.

The NSW Heritage Office is indebted to:
- Dick Smith for the provision of *Ulysses Blue* and for the opportunity of participating in its first deployment as a research vessel;
- Trevor Clarke and the crew of the *Ulysses Blue* for their great support while onboard the vessel
- Dr John Runcie of the Oceanic Research Foundation (ORF) for the invitation to conduct a joint survey of the *Duckenfield* and for assistance with the photographic recording of the wreck site;
- Stirling Smith and Lee Graham from the Australian National Maritime Museum for Stirling's archaeological expertise, Lee's shipwright expertise and for their joint diving, photographic and video skills;
- ORF members Don Richards and Colin Putt for their support for the project and onboard assistance

Why the survey was conducted

The objectives of the survey were to:

1. assess the condition of the historic shipwreck ss *Duckenfield* in 2005
3. obtain a video record of the site in 2005 that can be included on the NSW Heritage Office's *Maritime Heritage Online* website, http://maritime.heritage.nsw.gov.au.

Survey methods and equipment

The survey used a site drawing prepared by the discoverers of the wreck site, Allan and Neil McLennan, as well as historical accounts and site information developed in the 1989 Department of Planning survey report.

The 2005 survey included:
- a visual assessment of the overall condition of the site
- digital photographic images of key site features
- a video survey of key site features

To ensure the safety of diving personnel, all dives were conducted in accordance with Australian Standards for occupational diving (AS 2299) and training and certification standards for occupational divers (AS 2815) and using DCIEM dive tables. All dives were logged by a qualified Dive Supervisor and were conducted as air dives although one diver (D Nutley) conducted 3 dives on Nitrox. On each day first and second dives for each diver were separated by a minimum of two hours surface interval and there was a surface interval of over 18 hours between the last dive on the first day and the commencement of diving on the second day. Most dives were conducted with one of the two-person dive team tethered to a dive tender in the inflatable - although the tether was dispensed with for some photographic work owing to the effects of the surge.

Due to an ocean swell that commenced at over 2m at on day one and diminished to ~1.5m over the next day and a half, diving operations were conducted from the *Ulysses Blue* Niad inflatable. This was an excellent dive platform and provided flexibility in positioning over the wreck site.

Figure 1: The Niad approaching site buoy - *Ulysses Blue* in background
(S. Smith 2005)

The site was marked with a temporary site buoy which was used as a descent and ascent line. In-keeping with best-practice for anchoring on historic shipwreck sites (to avoid anchor damage to the site), the Niad was anchored upwind/upcurrent from the site and then allowed to hang back close to the site buoy.

Still images were shot using:

a) Australian National Maritime Museum's:
Cannon IXUS 500 digital camera in a WP-DC800 Housing
Mounting a Inon UWL-105 Wide lens
With Inon D-2000 strobe

b) John Runcie (Olympus C4040Z)

Video footage was shot using the Australian National Maritime Museum's:
JVC DVL100 Digital video camera
Mounting a HI Tech wide angle adaptor
In an IKELITE Video housing

A 2m ranging pole was used as a scale in a selection of still images and video clips.

Limitations

Constraints associated with the depth of the site were the major limitation. The maximum duration of a dive was 25 minutes for first dive. Subsequent dives were limited to 15-20 minutes, depending on specific profiles. With a small dive team, this limited the extent of underwater recording that could be conducted and precluded any measured survey due to the time involved in establishing control points.

The weather was clear and fine and the ocean swell, even at its maximum, played no role that limited the conduct of the survey.

On the wreck site there was, at times, a notable surge but this did not significantly hamper photographic work.

Historic context

The 368 ton single screw steamer *Duckenfield* was a classic 60-miler that operated over the 60 miles from Newcastle to Sydney, predominantly carrying coal. In a moderate southerly and poor visibility *Duckenfield* struck Long Reef on Sydney's northern beaches on 24 May 1889. The collier was enroute to Sydney from Newcastle with a cargo of coal, coke and 50 tons of copper ingots. Captain Hunter and a crew of thirteen abandoned ship within 10 minutes but one sailor, James Struthers, drowned.

The remainder were soon picked up by the ss *Hawkesbury* and taken to Sydney. Captain Hunter immediately returned on board the Pilot steamer *Captain Cook* as he perceived that the vessel might drift off the reef. When they arrived there was no sign of the *Duckenfield* which had in indeed drifted free and foundered off Narrabeen.

A week after the event two masts were discovered exposed 8 feet above the water. Rough weather intervened and the masts disappeared for two months. Captain Melvey of the tug steamer *Grand* buoyed a single mast. Salvage specialist Captain John Hall and his divers Briggs and May then began salvage operations. These lasted over a year but were then interrupted and finally' abandoned because of pressure to undertake salvage on more recent casualties - including the *Royal Shepherd* - of which Captain Hunter was again the master!

Subsequently, a team of divers began salvage operations which lasted over a year. The operations were interrupted and finally' abandoned because of pressures to undertake salvage on more recent casualties - including the *Royal Shepherd* of which Captain Hunter was again the master.

The iron hulled *Duckenfield* was built in 1875 for coal merchants J & A Brown and was powered by a 2 cylinder vertical compound engine. The engine remains the dominant feature on the wreck site which has become a popular diving spot.

The ss *Duckenfield* was built specifically for J & A Brown’s Sydney/Newcastle run and was named after the principal Duckenfield mine that was sunk in 1874. The name Duckenfield was brought to the area by coal miner and landowner John Eales of Duckenfield Park (Minmi file.) Duckenfield Park, where the estate house is still standing, was near Morpeth.

.As a regular coaster between Newcastle and Sydney over 13 years of service, the *Duckenfield* played an important role in the development of the town of Minmi 12 miles west of Newcastle. When the *Duckenfield* began service in 1876 the population of Minmi was approximately 600. (Bairstow, 1981) At the height of the Minmi mines operations, 1000 tons of coal were produced daily. J and A Brown owned an area of 6,000 and leased their land to 3,000 residents in the town. There were six hotels, several churches and the shops and factories needed to run the town and mines.

The presence of copper ingots from Wallaroo is a reflection of the development of copper smelting in Australia. Copper ore from South Australia had initially been shipped to Newcastle for smelting. Three years prior to the loss of the *Duckenfield* a smelter became operational at Wallaroo (Lockhardt, J.). Ships of the South Australian Black Diamond line began supplying the smelter works with coal from Newcastle. It appears that they would then return to Newcastle with copper ingots as ballast. The copper ingots on the *Duckenfield* were being transhipped for overseas export.

The fabric content and context of the *Duckenfield* site demonstrate the association of the vessel with the coal and copper industries and key personalities of the time including the ship's owners, coal merchants James and Alexander Brown, and the salvage operator Captain John Hall (Marine Surveyor of the Sydney Marine Underwriters and Salvage Association) and his divers.

The *Duckenfield* was built in May, 1875 by J & W Dudgeon (hull and engines) and was powered by a 2 cylinder vertical compound engine attached to a single four bladed propeller.

Conduct of the survey

The team and equipment were loaded onto *Ulysses Blue* early on the evening of Wednesday 30 March. The survey team and crew were briefed on the objectives of the archaeological survey and as well as the biological research being undertaken by Dr John Runcie.

The site was located and buoyed at Latitude 33^{o} 43'.096 S and 151^{o} 19'.426 E (WGS84).

The diving commenced on Thursday 31st March with National Maritime Museum Maritime Archaeologist, Stirling Smith, conducting a solo, tethered dive to confirm that the site had been correctly located and that the site buoy was in position.

The site buoy being in the right place, Stirling returned to the surface and then a general inspection of the site was undertaken by Dr Runcie and NSW Heritage Office Maritime Archaeologist, David Nutley. Observations were made against the existing site drawing, in particular noting changes to the condition of the boiler. These changes were photographed. Before the 25 minutes of the day had totally expired, a search was made to identify potential control point locations for a proposed measured survey aft of the engine.

On the following dive, National Maritime Museum shipwright and diver, Lee Graham , commenced the development of a photographic record of other key elements of the wreck site.

Two hours after their first dive Dr Runcie and David Nutley, deployed the fluorometer recording instruments and continued the photographic survey of key features of the site. Control points positions were laid out but no positioning measurements could be obtained in the 20 minutes available on this dive. (When the Site Surveyor model for this survey was reassessed that evening it became clear that at least 16 measurements would be required to conduct this survey. Allowing for an average of 2 minutes per measurement there would not be sufficient time in a 25 minute bottom time for a measured survey to be competed and the focus was returned to the primary objective of completing the visual recording of the site.)

The final dive on day one continued the still photography on the site and this was conducted by Stirling Smith and Lee Graham. A bearing of the lie of the wreck site was also obtained and confirmed that its orientation was about 358^0 , or almost directly north south, with the bow to the north.

The photographic survey was completed on Friday 1 April along with and videography of the engine and boiler area by Stirling Smith and Lee Graham. The site was then cleared of all equipment used in the survey work.

Outcomes

The survey achieved a number of important outcomes.

It illustrated that, overall, the site is in a remarkably stable condition with very few changes since the 1989 survey. The engine itself is essentially unchanged. This is a very positive reflection on the treatment of the site by the diving community and the value given by divers to retaining the attraction of the structure as a long term dive attraction.

Figure 2: ss *Duckenfield* - compound engine

(L Graham 2005)

The boiler however had changed quite substantially. Much of its outer plating of had disappeared leaving its original shape defined primarily by the circular flanges that bound the plates together. The effect is to provide a very clear cutaway of the internal structure. The cause of this deterioration is not doubt partly a natural decay of the weaker components of the boiler. The surge felt during the current survey would have helped to contribute to this process. However, there was also evidence of fresh mechanical damage, most likely the result of fouling by anchors. Slabs of corroded layers of iron had been knocked off the surface of the metal and these areas stand out through the bright orange ferrous oxide that accompanies fresh corrosion activity.

Figure 3: ss *Duckenfield* - fresh corrosion on boiler

(D Nutley 2005)

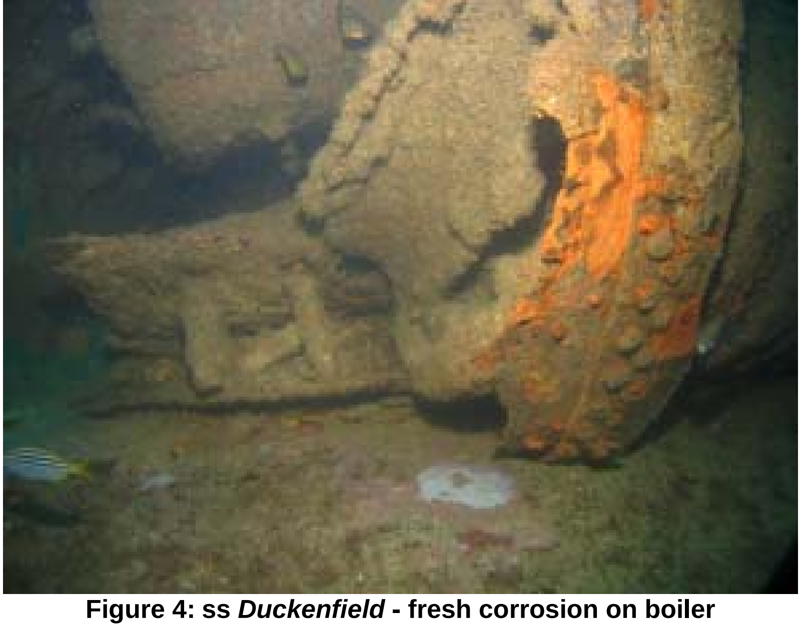


Figure 4: ss *Duckenfield* - fresh corrosion on boiler

(S Smith 2005)

A variety of marine life has colonised the wreck site including algae, small fish and a large cuttlefish that appears to have made the boiler its home base.

Figure 5: Resident cuttlefish at home in the remains of the Scotch boiler
(S Smith 2005)

The 2005 survey established an invaluable visual record of the site through still and video footage. This will be used in printed and electronic articles by the NSW Heritage Office and the Australian National Maritime Museum – including being available on the NSW Heritage Office Maritime Heritage Online web site.

The limitations arising from the depth of the site demonstrated the ongoing need for efficient and cost effective solutions for small area underwater survey. While electronic underwater survey systems are available, these are typically expensive, cumbersome and require a minimum of one or two dives to deploy and to recover. . There is a strong need for an affordable, reliable, easily deployed, electronic underwater surveying device and which does not require multiple control points - a concept suggested by Dr Runcie. Such a device is one that would find strong support in the underwater archaeological community, not only in Australia but internationally. Equally, it would have application not only in other underwater contexts but also on many terrestrial archaeological sites.

The survey plans that could be developed through such a device would form important archival records that would also be invaluable aids for divers and non-divers in understand the nature of these important underwater records of Australia's history.

The 2005 survey also showed that there would be value in increasing the number of divers in the dive team to between 6 and 8 and using Nitrox for all dives. Both these options would add to the quantity of data that could be accumulated in order to develop detailed survey plans.

The small survey of the *Duckenfield* site was invaluable in demonstrating the worth of the facilities onboard *Ulysses Blue* in regard to archaeological investigation of underwater cultural heritage sites - whether for survey, monitoring and other research purposes. It is a wonderful working platform and the association with ORF provides the potential for a dynamic synergy of research purposes. The NSW Heritage Office would be very pleased to explore opportunities for more detailed joint research projects. For the Heritage Office, the central focus of such projects is in providing the community with information about the mysteries of our underwater cultural heritage - and at the same time, ensuring this heritage is a long term asset.

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APPENDIX 1

BACKGROUND NOTES ON *DUCKENFIELD*
PREPARED BY ALAN McLENNAN 1988
The WALLAROO Connection

The *Duckenfield* ingots weigh about 5 kilograms each and are all stamped by hand with the name 'WALLAR00'. Wallaroo was part of the famous South Australian copper fields on the York Peninsular which were discovered in 1859. The fields were so rich that they were credited with saving the colony from bankruptcy. With her sister towns of Kadina and Moonta, the district became known as 'Little Cornwall' as a result of the thousands of Cornish miners who left the poverty of their homeland and brought their expertise in mining to the new colony. Most of the copper went to Britain and it is ironic that the output of these mines, worked by Cornish immigrants, helped force the closure of the many long established copper mines in Cornwall, thus encouraging the emigration of many more Cornishmen.

Wallaroo had a port and a smelter to which the ore would be brought to be processed and shipped overseas. The South Black Diamond line supplied the Wallaroo smelter with coal from Newcastle and the coal ships would apparently take a load of copper on board as ballast for the return trip. The *Duckenfield* copper came via this route and was to be transhipped in Sydney for London.

The mines lasted only until, 1923 but the heritage of the Cornishminers, known as 'Cousin Jacks' lingers on in the names and building styles of 'Little Cornwall,. This is celebrated every other year by the Kernewek Lowender Festival.

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Coal Mining at Minmi

Coal was first discovered in the Sydney basin at Coalcliff by survivors of the *Sydney Cove* wreck in Bass Strait as they fought their up the coast on foot in 1797. It was not until the 1850's however, that mining was undertaken on a large scale around Wollongong to the south and Newcastle to the north. The industry then grew rapidly and soon a fleet of colliers was employed to move the coal and later coke to Sydney. Before direct rail links or good roads these small ships were the only means of transport possible. Most of the ships were owned by the mine owners and often were named after one of the companys' mines, as was the case with the *Duckenfield.*

The Minmi complex of mines, which included the Duckenfield mine, were located 13 miles west of Newcastle. Mines were f[rst begun in the area by Edward Turner of Maitland who hauled coal to Hexham by bullock dray. In 1850 the first coal to be taken by ship from Hexham was loaded on the coaster *Currency Bay*. Coal from the Minmi area was of high quality and known as `cannel' coal because it could be lit with the flame of a candle. In later years Duckenfield coal became well known, for spontaneous combustion on long voyages.
The name "Duckenfield." Became associated with the area when wealthy landholder John Eales of Duckenfield Park (the estate house still stands near Morpeth) opened a pit at Minmi. In 1854 Eales and an A. Christie succeeded in having 'Act of Council', passed to construct a rail line between Minmi and the wharf at Hexham. In 1859 James & Alexander Brown bought out all the

Minmi collieries. The brothers had emigrated from Scotland in 1839 and were to become synonomous with Newcastle Coal Co.. However, in 1864 disastrous floods put the mines out of action for eighteen months. During this time the Browns bought their partners out a handsome profit. The principal Duckenfield mine was sunk in 1874. The main entrance went into the hill on an incline of 1 in 16 for 1 1/4 miles. The area was ideal for mining with the seam following the contour of the gently sloping countryside only a short distance below the surface.

In the week of the Duckenfield's first run to Sydney in 1876, the Duckenfield mine had the following exports:

Sydney 603 tons
Lyttleton 541 tons
Hong Kong 340 tons
Steamer's bunkers 57 tons

At the height of the Minmi mines operation, 1,000 tons of coal were produced a day. Browns owned an area of 6,000 acres and leased their land to the 3,000 souls who lived in the town. The town boasted six hotels, several churches and all the shops and factories needed to run the town and mines. In 1922, despite ah abundance of coal, James and Alexander’s heir John Brown closed the mines after a bitter pay dispute with the miners. Because no one owned land in Minmi and there was no other industry besides the mines, Minmi quickly became a ghost town.

The ss Duckenfield was built to the order of J & A Brown for their Sydney - Newcastle run. The coal she brought south was used for many purposes; to supply the bunkers of steamers in Sydney, to produce coal gas to light the streets and to provide energy for steam engines and heating. She was a typical 'sixty miler, (the distance between Nobby's Head and North Head) of 251 tons net, 368 gross. Her dimensions were 161.2 feet in length, breadth 24 feet , with a draught of 1.2 feet. She had four bulkheads and a raised quarter deck. The decks were sealed by cement. A single fire tube boiler provided steam for the compound engine and single screw. She was built by J & W Dudgeon of London in May, 1875 and was delivered to Newcastle under sail in March 1876. She was then towed to Sydney by the ss Waratah where her propeller was fitted and made her run to Sydney with coal on March 29th, 1876. The ss Duckenfield made about 100 round trips a year until her sinking thirteen years later.

The Duckenfield was well liked by those who knew her, being described as a smart little collier, and a good little ship'. She was certainly the most modern ship in the J & A Brown fleet at the time of her sinking. The other ships the fleet were..

- ps *Bungarre* 85 tons, built in 1861.
- ps *Goolwa* 116 tons, built in 1864.
- ss *Phoebe* 391 tons, built in 1851.

A second ss *Duckenfield* arrived in Sydney in November 1890. She was not a replacement being a much larger vessel with twin engines. She was used on the Newcastle - Melbourne run and had a long life with J & A Brown, not being sold until 1930 to Mollers of Hong Kong. In 1941 she was scuttled in Hong Kong Harbour and later raised by the Japanese only to be sunk the China Sea in 1944.

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SYDNEY MARINE UNDERWRITERS AND SALVAGE ASSOCIATION

The Sydney Underwriter's Association was created by a group of companies in 1876 to represent their interests in maritime matters. Later a salvage section was established in response to the growing list of shipwrecks along the coast which might have been saved if they had urgent assistance.

Captain John Hall was employed as the Associations, Marine Surveyor in 1886. His principal job was to survey ships for seaworthiness and provide reports to the Association. However, it also it fell to him to undertake the majority of the salvage work. He was expected to rush off to ships in distress at a moments notice, besides performing his normal surveying duties, His work was mostly on the river bars of the North Coast where strandings were regular occurrences, however, he also was called as far away as New Caledonia and Gabo Island. Some ships such as the ss Tomki and ss Rosedale were refloated several times on different occasions by Captain Hall. The work was primitive and dangerous with salvage gear often having to be hauled through the bush by bullock teams. Especially on river bars and beaches, working on wrecks such as the ss Tweed at Byron Bay and on the ss Wellington, at the Nambucca bar, Captain Hall was caught by a change in sea conditions and only 'just escaped with his life'.

The Duckenfield salvage was not at first a straight forward affair. A week after the wreck two masts were discovered poking eight feet above the surface 'a little NE of Long Reef'. Rough weather intervened however and the masts disappeared. Both Captain Hall and Diver Briggs claimed later to have dived to over 26 fathoms in search of the wreck! Two months passed with no sign of the wreck until Captain Melvey of the tug steamer Grand discovered a single mast poking just three feet above the surface. At once Hall, and his team began their salvage. On the 21st August the first 117 ingots were recovered. However, work appears to have proceeded in spurts and urgent jobs kept cropping up. Only a week after the second discovery of the wreck, the ss Centennial sank in Taylors Bay, Port Jackson. Efforts involving Briggs and May to raise the vessel lasted for over a year before being abandoned. The copper did come up though. Briggs claims to have dived for a continuous 4 hours and 20 minutes and recovered 10 1/4 tons in one spell. The June 1890 Annual Report of the SMUA states that ‘32 tons of copper ingots had been recovered to date valued at 2000 pounds’. In an interview in 1896 diver May states that they recovered "just under 40 tons" so it is probably safe to assume that between 10 and 18 tons remained.

Captain Hall salvaged over 65 vessels in his 11 years as Marine Surveyor. His career culminated in August 1896 with the successful recovery of gold from the strongroom of the ss *Catterthun* sunk in 30 fathoms at Seal Rocks. Captain Briggs and diver May were greeted as heroes on their return to Sydney. Unfortunately Captain Hall took ill during the salvage and the *Catterthun* was his last job. He took six months leave and returned to his native England. He died in May 1897.

The Association was to continue its salvage work until the salvage section was wound up and its equipment sold off in the early nineteen sixties. The Sydney Marine Underwriters ceased operations in June 1975 when it was amalgamated into the Insurance Council of Australia. A scrap book of their many salvages efforts as well as the company records are now in the Mitchell Library.

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oceanic research foundation ltd.

Measuring *in situ* photosynthetic activity of marine algae.

Background

Understanding the rates and efficiency of photosynthesis is vital to understanding the dynamics of any ecosystem that includes photosynthetic organisms. Photosynthesis converts light energy from the sun to chemical energy; this energy is used to drive plant growth and reproduction. Ultimately, photosynthesis introduces biomass and energy to an ecosystem – without photosynthesis life would be drastically different to what we see today.

While long-term growth measurements are easily carried out by measuring changes in weight, measuring short-term differences in photosynthetic capacity are more difficult, yet provide a vast amount of information describing the capacity of the plant to acclimate to environmental changes. Measuring the efficiency and rates of photosynthesis in the short-term is an important part of modern biological science. Traditionally, the rates of oxygen production or carbon dioxide uptake have been the most commonly used methods for making these measurements.

An additional technique has become widely accessible due to the development of microelectronics. When exposed to sunlight, chlorophyll reemits a small proportion of this received light as red light – this is known as fluorescence. The intensity of the reemitted light is very low and generally only detectable using sensitive electronic equipment. Differences in fluorescence emission before and after a brief (< 1 second) pulse of bright light provides information directly describing the efficiency of photosynthesis. The careful application of this measurement technique under various conditions enables us to measure a vast array of different biological processes that are linked with photosynthesis. This subproject was designed to test a prototype fluorometer at depth and overnight.

The fluorometer.

The fluorometer used in this study is the current version of a series of prototypes being developed by Dr John Runcie and scientists and engineers from the Australian Antarctic Division (Kingston, Tasmania), Lothlorien Electronics Pty Ltd (Ferny Creek, Melbourne). Initial applications of the technology were the deployment of an eight channel fluorometer in East Antarctica; subsequent successful deployments have included use at 200 m depth examining deepwater macroalgal photosynthesis in the eastern Pacific. The tests conducted during this expedition are part of a series of important field tests that will enable the design and construction of a vastly improved suite of fluorometers to be used both in deepwater and the Antarctic later in 2005.

Figure 1. The fluorometer deployed at 24 m on the red alga *Delisea pulchra*. Note deployment is on part of the structure of the Duckenfield. The measuring tube is on the left connected by cable to the logger housing on the right. (Photo: Sterling Smith 2005)

The fluorometer used in this study comprises a cylinder ~120 mm deep by 90 mm diameter, housing the datalogger and battery assembly. This is connected by a cable to an oil-filled clear polycarbonate tube housing the electronic components used in generating and receiving signals that enable measurement of (modulated) chlorophyll fluorescence, temperature and light intensity (irradiance). The oil eliminates the requirement for the measuring tube to have precisely machined waterproof seals, the design has previously resisted seawater ingress to depths of 203 m. The measuring tube is attached to a plastic plate, and samples of macroalgae can be attached to the plate using mesh and elastic material such that the sample is a fixed distance from the measuring tube. Measuring signals are directed through the clear tubing directly to the sample; the sample is positioned about 12 mm from the tube.

Two identical units were programmed to provide a measurement every 10 minutes. Each measurement recorded minimal and maximal fluorescence, temperature and irradiance.

Testing

The two day survey on the Duckenfield provided an ideal opportunity to test the fluorometer overnight, and included midday and midnight when light intensity is at its most extreme. The following design features were examined during the test:

- Modified irradiance measurements: the fluorometer was previously designed to measure irradiance at very low intensities (at depths to 200 m in offshore oceanic waters), so an adjustment was made to the circuit board to avoid signal overload during high light conditions likely to be found at the Duckenfield site.
- Modified saturation pulse and actinic light intensities: similar to the irradiance sensor, these intensities were increased to suit measurements made in a relatively high light environment.
- Duration: the fluorometer is designed to provide data for more than 24 hours.

Results

Effective quantum yield

Estimates of effective quantum yield were low and remained fairly constant at 0.250 until 14:50; after this time values became highly variable with a mean of 0.196. Effective quantum yield values of around 0.3 might be expected after exposure to high noonday irradiances. Maximum irradiances measured in this location were 200 μmol quanta m^{-2} s^{-1}; it is likely this light intensity was sufficient to cause prolonged photoinhibition. However the high variability after 16:50 is less easily explained as due to a biological process and is more likely to due to the instrument. Accuracy of yield measurement during low irradiance conditions and when the battery is partially discharged will be examined. Previous tests suggest low voltage increases variability in yield measurements.

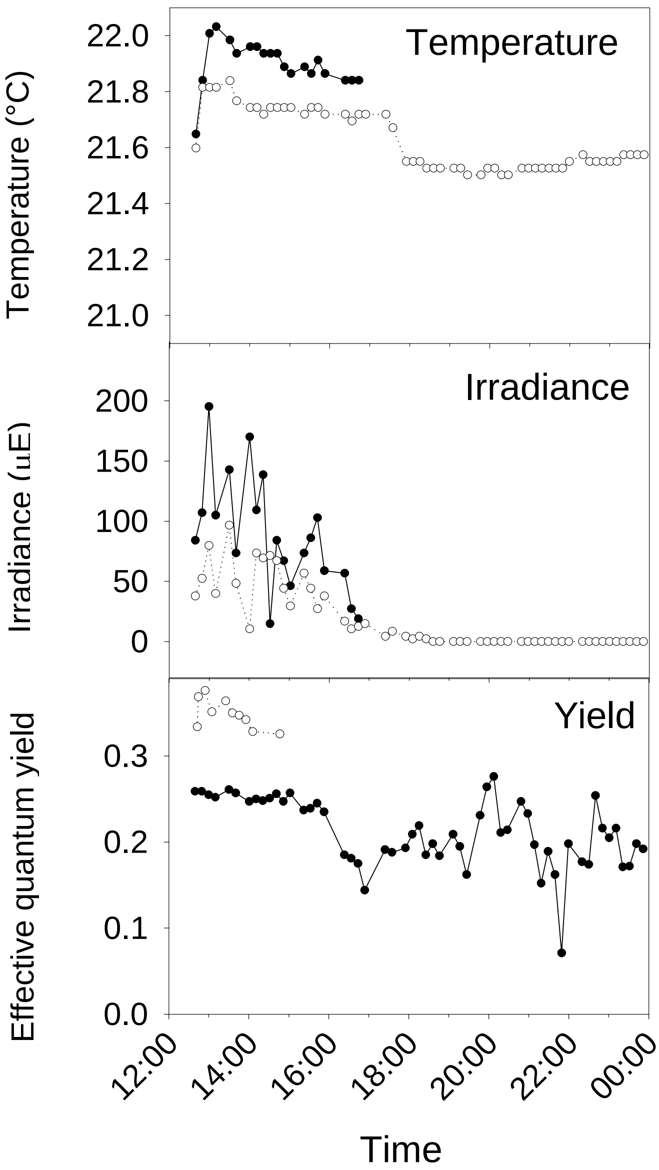

Figure 2. Ambient temperature and irradiance, and effective quantum yield of the red alga *Delisea pulchra* measured close to the Duckenfield in NSW, in 24 m seawater on 31st March 2005. Note the temperature scale represents one degree C.

Irradiance
Light intensity measured at the site was highly variable due to the large macroalga *Ecklonia radiata* periodically covering the instrumentation. High noonday irradiances of ~200 μmol quanta m^{-2} s^{-1} are not unreasonable for depths of 24 m – estimated nonday irradiance above water was 1562 μmol quanta m^{-2} s^{-1}, and the Kd for the water column was 0.115, which is relatively clear for coastal marine waters. The device clearly showed a decline to a steady state at night, however the offset was rather large (~86 units), so there is some work required to determine what is causing this high background signal.

Temperature
The temperature data was very stable, demonstrating a drop of approximately 0.2 C after sunset. Values are consistent with typical inshore water temperatures at this time of year.

Other
Battery charging has presented difficulties: the current system presents both the positive and negative contact terminals used during in-air charging directly to the seawater, and a diode is placed in series to prevent closure of the circuit and discharge when the logger is submersed. Unfortunately the diode apparently prevents the charger from accurately distinguishing a fully charged battery from one that is partially discharged. The partially charged batteries discharged after five and 12 hours, whereas they should last at least 24 hours. Nevertheless, sufficient data was obtained during these intervals. Future experiments must be able to be deployed for at least 24 hours preferably 48, and a new design is currently being implemented since the conclusion of this study.

Summary and conclusion

The fluorometer provided important information that has enabled the identification of potential and real design problems. The high background signal from the light sensor even during night time suggests some form of electrical leak, which will need to be rectified as it may influence other measurements in an unpredictable manner. Battery charging difficulties, and residual current flowing to the large LED even when supposedly switched “off’ will require a significant redesign of the circuitry. High variability of effective quantum yield measurements may be a consequence of low battery voltage. The physical construction of housing, cables and configuration of light sources appears to be optimal.

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