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"... for the encouragement of studies and investigations in Science Art Literature and Philosophy ..."

THE ROYAL SOCIETY OF NEW SOUTH WALES

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Editorial

This issue of the *Journal and Proceedings* comes to you from a new Editor. I am honoured to take on the job of Editor of this venerable journal, but I do so not without a little trepidation given our Society's long history. In my professional life I am an astronomer, but it is by chance that the first three articles in this issue have an astronomical theme, exploring the history of Parramatta Observatory and Governor Brisbane's central role in its establishment, as well as that in the forerunner to our own Society, the Philosophical Society of Australia, in the infant colony of NSW. That he did so to perhaps the neglect of his duties as Governor of the Colony is an interesting story in its own right. These three articles arose from a special Symposium held at National Trust of NSW on Observatory Hill in December 2011 to commemorate Brisbane, organised by the author of the first, Ragbir Bhathal. The other two articles in this issue come from the biological sciences, describing the science emanating from the first decade of the National Marine Research Centre in Coffs Harbour and a study on identification on hatchery produced Murray Cod. Three thesis abstracts also appear.

Penning an Editorial gives one a chance to muse on current issues, and for my first opportunity to do so in the Journal I would like to ponder on what it takes to contribute to the scientific endeavour. In an event close to my own interests as a researcher we celebrate, as I write, 100 years from the event I regard as the first astronomical science to have come out of Antarctica. For, in December 1912 three young explorers, all in their 20's – Francis Bickerton, Leslie Whetter and Alfred Hodgeman – were trudging across the snow in the coastal highlands of Adelie Land in Antarctica. They formed the "Western Sledging Party" of Douglas Mawson's epic Australasian Antarctic Expedition of 1911-14. While the events of Mawson's own tragic sledging expedition form a core story from the "heroic age" of Antarctic exploration, those of the Western Sledging Party show both the serendipity often involved in scientific discovery, as well as the insight to realise that indeed it is a discovery. Our party were three days into a 7-week trip. They had recently abandoned their "air tractor" – there to provide a mechanical means of pulling their heavy load – and were now man-hauling a single sledge across the rough snow surface. There ahead of them they saw a shiny black object, half buried in the ice. About the size of one's hand, they picked it up. That was the serendipity. The insight was that they immediately realised that it must be a meteorite – a messenger from space – for how else could it have got there, all alone in a vast expanse of snow? It must have fallen from the skies! That was the insight, obvious in hindsight, though when survival was a more pressing concern, a remarkable one at the time. The Adelie Land Meteorite, as it came to be known, was the first meteorite to be discovered in Antarctica, and can now be seen on display in the Australian Museum in Sydney. The pressure to publish not being what it is today, it was to be another 11 years before the paper describing this discovery appeared in print. It was also to be another 60 years before the special conditions that transport meteorites across Antarctica to selected sites, and so make it the prime place on our planet for finding them, was to be realised (~30,000, or two-thirds of all known meteorites, have now been found there). The science began, though, with that chance discovery and realisation of December 5, 1912 while on a sledging expedition!

Michael Burton
Hon. Secretary (Editorial)
December 5, 2012

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Symposium – Commemorating Governor Sir Thomas Brisbane, National Trust, Observatory Hill, 1 December 2011

Some scientific aspects of Parramatta Observatory

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Abstract

Governor Sir Thomas Brisbane, the sixth governor of New South Wales built Australia's first private observatory in 1822. He did this to carry out astronomical observations that would not only be of scientific value but also be beneficial to mankind. This paper discusses some scientific aspects of Parramatta Observatory and the problems that the observatory encountered in the observations of the night sky far from the metropolitan centres of astronomical influence in Europe. The paper also proposes that Parramatta Observatory should be placed on the UNESCO/IAU world heritage list of astronomical observatories.

Introduction

Before the 1800s very few observations of the Southern Hemisphere had been carried out by northern hemisphere astronomers and it was considered virgin astronomical territory. The astronomers were busy carrying out positional astronomy and assembling catalogues of stars, double stars, nebulae, clusters and galaxies seen in the night sky in the northern hemisphere. Thus, there was great interest among the astronomers to extend their observations to the rich Southern Hemisphere sky. Brisbane was well aware of the observations that had been carried out of the southern sky by a number of northern hemisphere astronomers. He knew of the Transit of Venus observations, Edmund Halley's 1677 observations at St Helena and Nicolas Louis de Lacaille's observations at the Cape of Good Hope in the 1750s. He was also aware of the fact that the Colonial Office would not provide him with the necessary funds to build another government observatory in Australia since the Cape Observatory had already been designated as a government observatory to study the southern sky. Furthermore, the Cape Observatory had the support of the Board of Longitude and the scientific establishment. The Cape was also of strategic importance to Britain's imperial program and the Observatory was closer to Europe than Australia (Evans 1988). He realised that the only way he was going to observe the southern sky and leave his name for posterity was to establish an observatory with his own funds. He pursued his ambition with vigour.

Well connected

Brisbane was well connected in the social, political and scientific circles in Britain and was already a Fellow of the Royal Society before he came out to Australia. During the occupation of Paris in 1815 he prevented the destruction of the Academie des Sciences. In gratitude he was elected an honorary member of the Academie. Thus, he became well known to the members of France's scientific elite, such as Laplace, Fourier and Bouvard. In fact, Laplace was known in scientific circles both in Britain and Europe for his classic Mecanique Celeste (Celestial Mechanics) which expounded Newton's law of universal gravitation (North 1994). Brisbane had already built an observatory on his estate at Brisbane House in Scotland in 1808 and was well versed in astronomical matters and had kept the time for Britain's armed forces. It was the second permanent observatory in Scotland and it was fitted with the best available instruments made by well known instrument makers, such as Troughton. He had pursued a distinguished military career, having served in Flanders, the West Indies, the Peninsular War and the American War. He rose to the position of Brigadier General and served with the Duke of Wellington in the Napoleonic wars (Saunders 2004). Being a member of the upper social classes in Britain he had access to the powers of influence in government and the scientific establishment.

He had a passion for astronomy and he set about to obtain the governorship of New South Wales because it would provide him with a great opportunity he wrote, "for carrying on extensive Astronomical Observations that are not only highly interesting to science but may be beneficial to mankind" (Brisbane 1815). His higher purpose for doing something that was beneficial for mankind stemmed from his strong sense of Christian duty. He became a one man lobby group with the sole purpose of becoming the governor of New South Wales to build his observatory in Australia. He knew he had the means and the wealth to build a private observatory in Australia. He lobbied his influential contacts for the governorship. In 1815, shortly after the defeat of Napoleon, the victorious Duke of Wellington informed Brisbane that he had recommended him to the Secretary for War and the Colonies, Lord Bathurst, for his appointment as the sixth Governor of New South Wales. However, Lord Bathurst remarked that he "wanted a man to govern, not the heavens, but the Earth" (Bhathal and White 1991). To which Wellington responded by saying that Brisbane had been useful in keeping the time of the Army as well as carrying out his regular military duties punctually.

Imperial science

Brisbane's appointment was strongly supported by Sir Joseph Banks, the influential President of the Royal Society who argued that Brisbane had strong administrative skills and would advance the cause of imperial science in the colonies (Banks 1817). This was sufficient to persuade Lord Bathurst to appointment Brisbane to the Governorship of New South Wales. Banks was a strong supporter of science for utilitarian purposes in Britain's colonies and saw the improvement of British territories as a means for advancing the self-sufficiency of the motherland. Banks was very successful in institutionalising his drive for imperial expansion through the medium of scientific exploration (Gascoigne 1998). Later in 1823, Sir Humphrey Davy, President of the Royal Society echoed the same sentiment when he wrote to Bathurst to say that, "The measure of an Arc in New South Wales would not only be of importance to Astronomy in affording data for determining correctly the figure of the Earth, a matter of great interest to Navigation, but would likewise be useful in laying a foundation for a correct Survey of our Colonies in the great and unexplored Country" (Davy 1823). Brisbane was familiar with the methods of determining the figure of the Earth by making observations of the length of an invariable pendulum and also with the much more accurate method of triangulation (Pannekoek 1961). In fact, he brought with him to Australia Borda's pendulum for determining the figure of the Earth. He was, thus, well placed to carry out Davy's instructions. While Brisbane had sought to establish an observatory for the purposes of pure science, the bureaucrats and colonial administrators saw the observatory as playing a vital role in the economic growth of the country. In later years meridian astronomy and surveying the country became important functions of the colonial observatories in Australia. In a way Brisbane's observatory set the pattern for the colonial observatories which were set up in Australia in the second half of the 19th century. Their programs were planned and dictated by the Astronomer Royal in England. The Astronomer Royal also had a hand in the selection and recommendation of the directors who were to head the colonial observatories.

A private observatory

Brisbane arrived in Sydney in November 1821 to not only govern New South Wales and change the way it was governed but also to build a private observatory. He built the observatory at the back of Government House in Parramatta about 25 kilometres from the centre of Sydney. The wooden building was of simple design and functional. The rather simple architectural style of the observatory building was more in keeping with Jacques Dominique Cassini's views on observatory architecture than Australian colonial views on nineteenth century public architecture. Cassini, the director of Paris Observatory, who came from a long family line of famous scientists, believed an observatory should not be an architectural monument. He wrote, "an observatory could not be a work of architecture because all ornament would be foreign or superfluous to it and should not be allowed unless it would in no way interfere with the use of the building or unless a public monument was intended for which no expense should be spared" (Bhathal 1993). The building was 7.4 metres square and had two domes (3.5 metres in diameter) facing north and south respectively. Figure 1 shows the plan of the building and the location of the instruments. It is based on a drawing by Reverend W. B. Clarke. Figure 2 shows the combined plan of the observatory in 1822 and the completed excavation work which was carried out by Anne Bickford for the Parramatta Park Trust (Parramatta Park Trust 2011). According to Christopher Levins, the director of the Park there are plans to restore the building with appropriate interpretation to show it as a working observatory.

The Transit telescope and the mural circle were located at the south western and north eastern ends of the south room. The mean-time clock was placed just north of the transit instrument while the sidereal clock was placed near the mural circle. Transit observations were made by means of an eye and ear method. This demanded that the observer listened to the clock while he watched a star's image cross the wires in the eyepiece. The observations were recorded in the columns on Brisbane's printed forms for transmission at a later date to the metropolitan centre. The measurements of the right ascensions using the transit instrument and a pendulum clock were made and recorded separately from those of the zenith distance of the stars with the mural circle. The records, according to Dunlop, were to serve not only as "a valuable treasure for the present generation to possess, but an invaluable inheritance for them to transmit to posterity" (Dunlop 1828). The astronomers at Parramatta Observatory served as the collectors of information about the celestial bodies just like the 19th century collectors of specimens in the biological sciences (Moyal 1976).

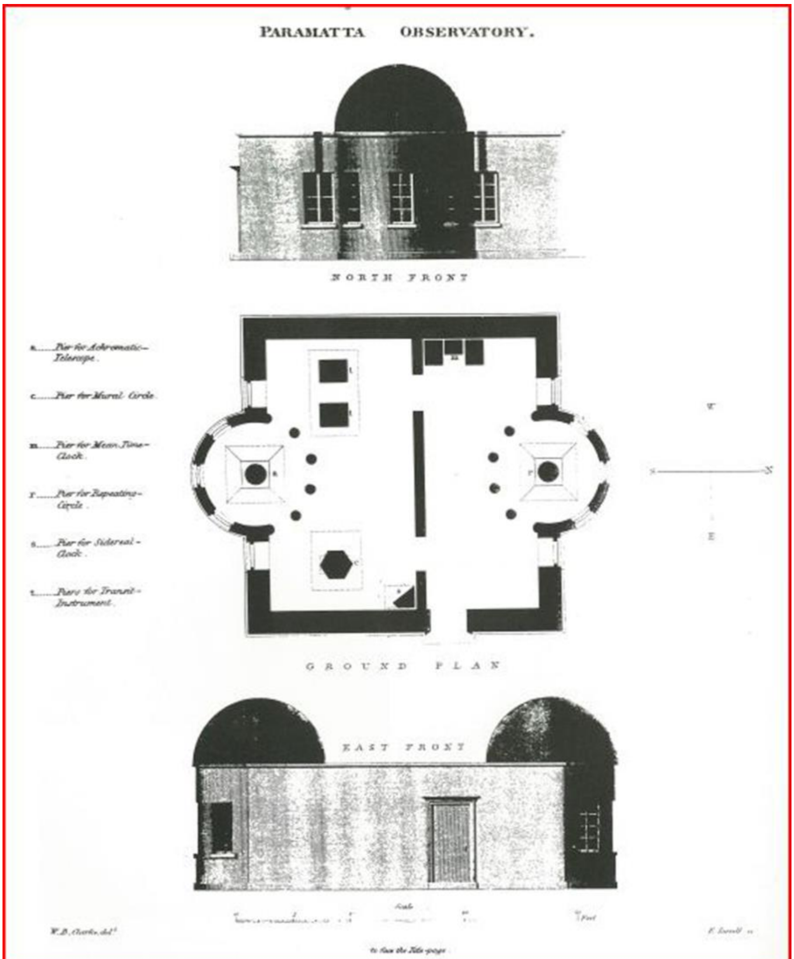

Figure 1. Plan of Parramatta Observatory drawn by Reverend W. B. Clarke. The locations of the Achromatic Telescope (a), Mural Circle (c), Mean-Time Clock (m), Repeating Circle (r), Sidereal Clock (s) and Transit Instrument (t) are shown in the figure.

This exemplified the master servant relationship in the colonial science of the 19th century in the newly emerging colonial territories. The metropolitan centre controlled the type of information that had to be collected, how it was to be collected and how it was to be analysed. The book keeping and accounting had to be done meticulously since the reputation and the status of the observatory depended on it (Schaffer 2010). The colonial observatories had an audience of experts in astronomy in the metropolitan centres of scholarship. They dished out the honours, the accolades and the criticism. They were the judges of excellence.

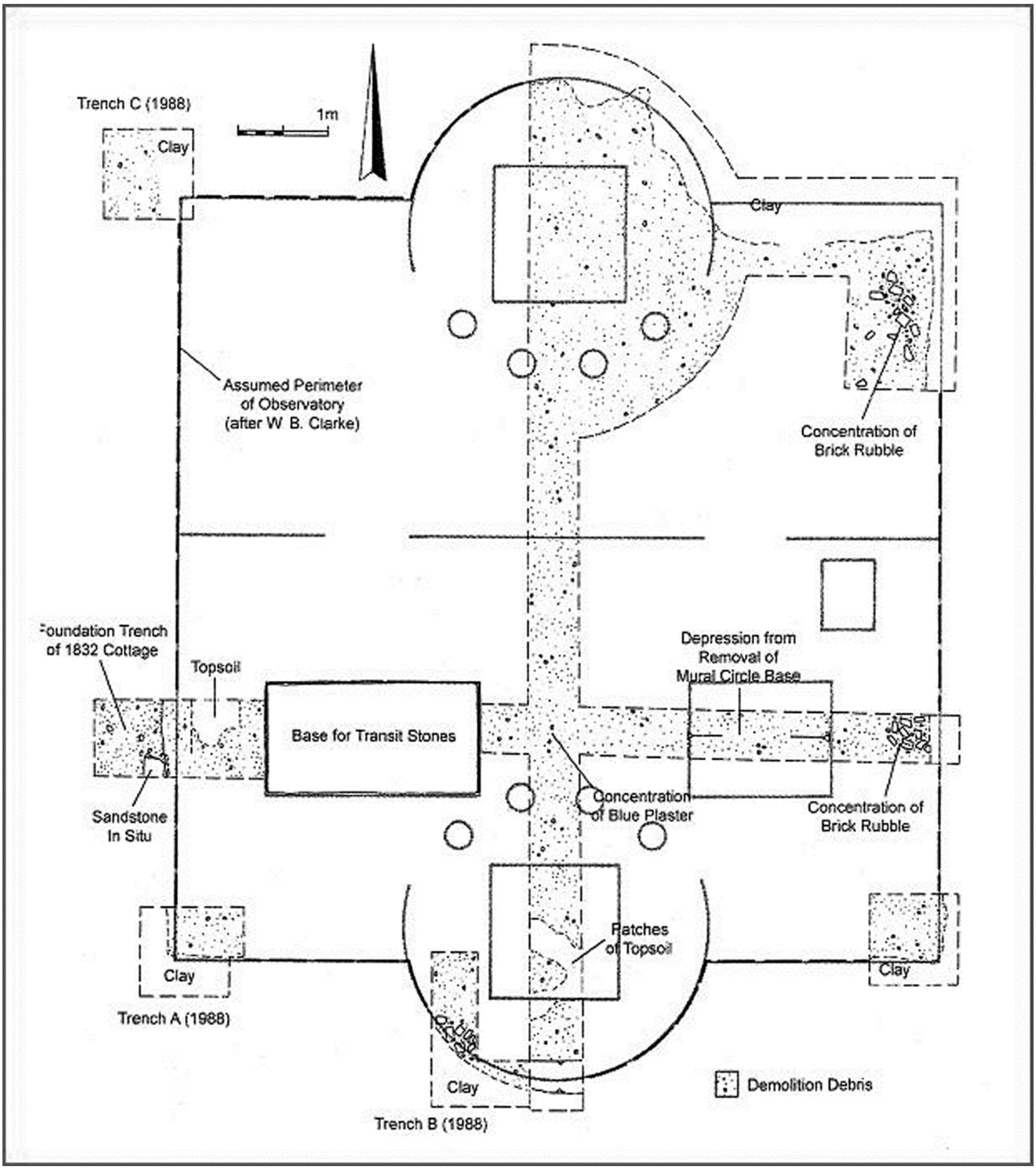

Figure 2. Combined plan of the Observatory in 1822 and the completed excavation work from the Excavation Report prepared by Archaeology and Heritage P/L for the Parramatta Park Trust.

Figure 3. The 5 foot 6 inch Transit Instrument by Troughton was used to determine the position of stars for the Catalogue of 7385 Stars. The stone piers which held this instrument are to be found in Parramatta Park. The instrument is on display at Sydney Observatory.

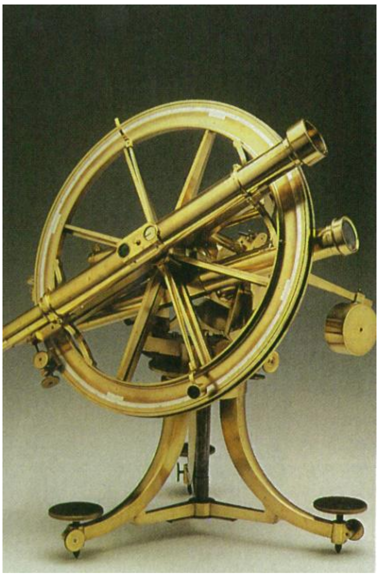

Figure 4. The 16 inch Repeating Circle by Reichenbach was located under the north dome of the Parramatta Observatory. It was used for measuring the angle between the stars for the purpose of determining their positions. This instrument is on display at Sydney Observatory.

Brisbane had not only purchased the instruments at his own expense but had also paid for the services of Charles Rumker, a well known astronomer from Germany and James Dunlop from Scotland who was technically skilled for maintaining the instruments in the observatory. Thus, three men from different levels of 19th century society with its social stratification and norms of behaviour and acknowledgement came together to establish an observatory in Parramatta. While Rumker was the equal of Brisbane in intellectual terms he seems not to have given Brisbane the due respect that he deserved as a member of Britain's ruling classes and the aristocracy. Rumker was not familiar with Britian's class system and the social stratification of British society. Furthermore, Brisbane had not articulated the terms and conditions for the publication of the results of the observations emanating from the Observatory. In fact, he had not come to any agreement with either Rumker or Dunlop regarding the publications from the Observatory. This mix of personalities and the environment they worked in was explosive and eventually led to problems in the proper running of the observatory and the difficult personal relations that developed between them. A further compounding factor was the fact that they were intellectually isolated from the main centres of astronomical endeavour in Britain and Europe.

The instruments included four astronomical clocks, a mural circle, a repeating circle, a transmit instrument, an equatorial telescope, a sextant, Bourdon's pendulum, barometers and thermometers (King, Gordon and Rogers 1847, Russell 1888 and Lomb 2004). The instruments were made by well established instrument makers, such as Troughton, Hardy, Banks and Reichenbach. Brisbane had brought some of these instruments, for example the mural circle from his own observatory in Scotland. The principal instruments were placed on masonry piers in the Observatory (See Figure 1). Illustrations of the Transit Instrument and the Repeating Circle are shown in Figure 3 and Figure 4. By May 1822 the observatory was ready for use. They began systematic observations of the night sky. Since Brisbane was busy with the duties of government, he was unable to devote much time in assisting with the observations. The task fell mainly on Rumker and Dunlop.

Comets and Newton's theory of gravitation

The detection of comet Encke on 2 June 1822 catapulted the Observatory into international fame. The official government observatory at the Cape missed discovering the comet. The comet had been seen previously in November 1818 by Jean Louis Pons of Marseilles and had been named Encke in honour of Johan Franz Encke who had calculated its orbit. According to Agnes Clerke (1893), "Encke at once took the calculations of the elements in hand, and brought out the unexpected result that it revolved round the Sun in a period of three and a quarter years … he fixed May 24, 1822, as its next return to perihelion. Although on that occasion, owing to the position of the earth, invisible in the northern hemisphere, Sir Thomas Brisbane's Observatory at Parramatta was fortunately ready equipped for its capture, which Rumker effected quite close to the spot indicated by Encke's ephemeris". She further noted, "The importance of this event can be better understood when it is remembered that it is the second instance of the recognised return of a comet". The first had been Halley's Comet and it confirmed that comets, like planets, obeyed Newton's laws of gravitation. The discovery provided another confirmation of Newton's theory of gravitation as applied to the motion of comets. Herschel himself as the President of the Royal Astronomical Society, noted that the discovery by Rumker verified the certainty of our theories. Furthermore, Encke's comet introduced the existence of a new class of objects called comets of short period. Although it had been seen in 1786, 1795 and 1806 it had not been recognised as having a periodical appearance (Pannekoek 1961). After its discovery it has been seen at every return. It also had some rather peculiar properties that needed further investigations which taxed the minds of eminent metropolitan astronomers. For example, it was found that the comet lost some of its mass on every return and that it had a variable acceleration which could not be accounted for. These problems were satisfactorily solved in the first half of the twentieth century. One other important result of the discovery was the use of perturbations to find out the mass of Mercury. According to Pannekoek (1961), "To compute the perturbations, there was no way but to follow the comet continuously along its orbit by means of a careful computation of special perturbations. As a reward, this procured an accurate derivation of the mass of Mercury, because in 1835 the comet passed it at close quarters".

The Royal Astronomical Society awarded Rumker a hundred pounds in recognition of his work while Brisbane gave him a grant of one thousand acres of land near Picton, about 100 km from Sydney. He named it Stargard after his birthplace (Bergman 1960). After a dispute with Brisbane in June 1823 he moved to Stargard and returned to the Observatory in May 1926 after Brisbane had departed for Scotland. The inexperienced Dunlop was left to make the observations for the Catalogue. Figure 5 shows the parcel of land that was given to him in Picton. Although it was Dunlop who had spotted the comet at the telescope, the honours went to Rumker who had calculated the position and guided Dunlop in its search. Rumker and Dunlop were to discover other comets. Rumker discovered a comet in 1824 and holds pride of place as being the first discoverer of a comet in the Australian sky. Dunlop went on to discover a comet in 1833. They began a tradition of comet hunters in Australia which culminated in John Tebbutt, Australia's most significant 19th century astronomer, discovering the two great comets of the 19th century, viz: the great comets of 1861 and 1881 comets (Bhathal 1993). The tradition of comet hunting still continues to the present day and is mainly carried out by amateur astronomers.

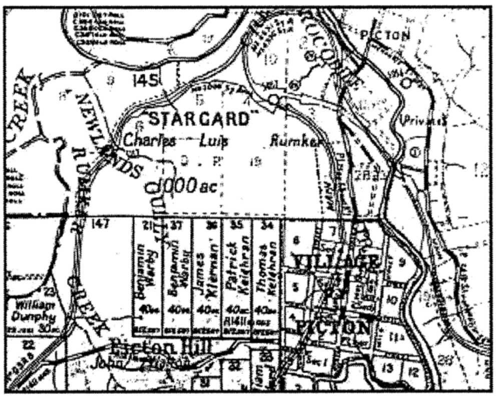

Figure 5. Plan showing the 1000 acres that were given to Rumker by Governor Brisbane. This was a reward for discovering Encke's comet. Picton Historical Society.

1. Catalogues and scientific experiments

The main reason for establishing Parramatta Observatory was to prepare a catalogue of bright stars of the southern sky. Apart from the necessity of obtaining accurate positions for astronomical purposes, there was also the need to obtain these positions for navigational and surveying purposes for Britain's ambitious imperial program of dominating the colonies and using them as producers of wealth for the motherland.

In a short period of time some 40,000 observations of over 7,000 stars were made for presentation in a catalogue. Brisbane used his contacts in the Royal Society and the Royal Astronomical Society to get approval for the publication of the catalogue of stars at government expense. The services of William Richardson, an assistant at Greenwich Observatory, were used to supervise and complete the reduction from the observations collected by the astronomers from Parramatta Observatory. The catalogue was finally published in 1835 as the Catalogue of 7385 Stars Chiefly in the Southern Hemisphere (sometimes referred to as the Brisbane Catalogue or the Parramatta Catalogue). In the preface, Richardson (1835) noted that, "Although the places of the stars in the Catalogue cannot be supposed as correct as those determined in great national observatories, yet it is hoped that it will be of considerable service in astronomy, by exhibiting the positions of upwards of 7,000 stars, properly arranged, being the result of a very extensive survey of the southern portion of the heavens, the greater part of which is invisible in Europe, and has not been so minutely examined since the time of Lacaille, and the Histoire Celeste Francaise of Lalande, works of acknowledged utility".

Brisbane and Dunlop were each awarded the Gold Medal of the Royal Astronomical Society in 1828 without the positions being cross-checked for accuracy by other astronomers. In fact, Richardson's comment that, "the places of the stars in the Catalogue cannot be supposed as correct as those determined in great national observatories" was ignored. Rumker was to receive his medal in 1854. In awarding the medal to Brisbane, the President of the Society, John Herschel (1829) heaped high praise on Brisbane. Later observers found that the Catalogue was spoiled in part due to the fact that the instruments at Parramatta Observatory had been defective. Since he wanted to record as many stars as possible in a short period of time, Dunlop had used the Mural circle for measuring the Right Ascensions of the stars although this instrument was not meant for use for this purpose. This invariably led to errors in the positions of the stars for the Catalogue. Herschel, himself became the harshest critic of the Catalogue. He found that there were wide differences in the positions of the stars in the Catalogue and the observations he made between 1834 and 1838 while he was at the Cape of Good Hope (Evans 1988). He wrote rather scathingly that the Catalogue was only "worthy of the Age of Ulug or Tycho Brahe" (Bhathal and White 1991). This was a period three hundred years earlier when the astronomical instruments to measure the positions of stars were rather crude and left much to be desired in terms of accuracy. The statement by Herschel is in sharp contrast to the lavish praise he had previously bestowed on Brisbane's work. By 1860 the Catalogue had lost much of its value.

Apart from the major work on the Catalogue, Rumker and Dunlop also carried out observations of star clusters and double stars (Dunlop 1829) which are still referred to by their Parramatta numbers. Dunlop (1828) also discovered several nebulae and star clusters and published a catalogue of 621 nebulae and star clusters in the Philosophical Transactions. However, a substantial number of these nebulae could not be found by later day astronomers and it appears

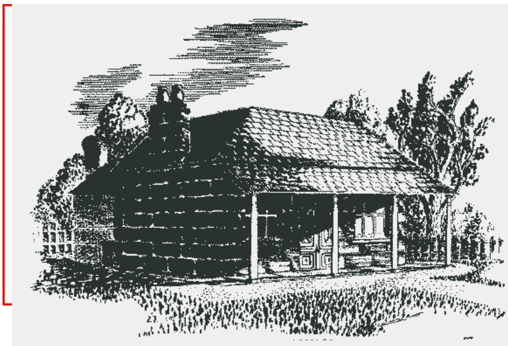

Figure 6. Dunlop's house in Parramatta from which he made his astronomical observations. The house was located between Marsden Street corner and St John's gates on the north side of Hunter Street. Collinridge Rivett (1988). Mitchell Library.

that Dunlop made several errors in his observations. He recorded the positions of the objects with his homemade telescope which had a speculum mirror of 23 cm aperture. Speculum is made of an alloy of copper and tin. It tarnishes quite readily and the reflectivity of the mirror drops. The smallness of his telescope and the tarnishing of the mirror compounded the difficulties he had in making his observations. Furthermore, his keenness in wanting to make as many observations as he could as quickly as possible at the expense of accuracy led to the mistakes in his catalogue. He carried out his observations from his home. A sketch of his home by Collinridge Rivett is shown in Figure 6 (Rivett 1988). Figure 7 shows the discrepancies in the positions of the celestial objects in Dunlop's catalogue.

The analysis is based on the data from a paper by Cozens, Walsh and Orchiston (2010) and information supplied to the author by Tim Parks. Dunlop's positions of the nebulae were heavily criticised by Herschel who had

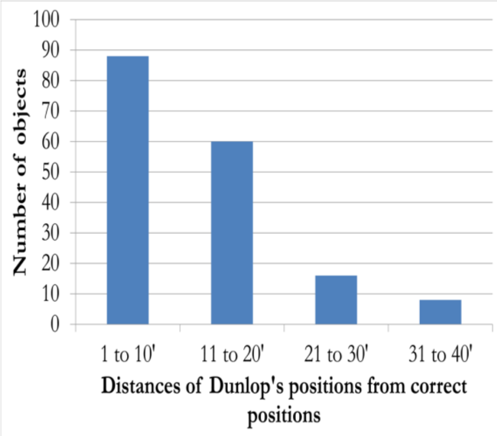

Figure 7. Number of objects versus Dunlop's positions from the correct positions. These observations refer to the objects Dunlop recorded in his catalogue of 621 nebulae and clusters.

gone to the Cape from 1834 to 1838 for making observations of celestial objects. He was only able to find 34% of Dunlop's celestial objects. After Herschel's criticism Dunlop's Catalogue lost much of its credibility. While Dunlop's catalogue may be complete as recently suggested by Cozens, Walsh and Orchiston (2010) it still leaves much to be desired as it contains a large number of objects that he was unable to resolve with the primitive equipment he used. This was not entirely his fault as the technology that was available to him at Parramatta was not the most up-to-date. He had built a home made telescope to make his observations. They suggest that the catalogue will be of use to amateur astronomers. However, it needs to be pointed that with today's computer technology amateur astronomers can access the best and most accurate catalogues online for their needs. In 1838 Herschel returned to England from the Cape with a wealth of data and produced his catalogue of nebulae. According to Clerke (1893), "The resulting great catalogue of 5079 nebulae (including all then known), published in the Philosophical Transactions for 1864, is, and will probably remain, the leading source of information on the subject".

The astronomers at Parramatta Observatory also undertook observations of solstices, moon culminating stars, conjunctions and oppositions of planets and occultations of stars (Brisbane and Rumker 1824, Brisbane 1826). The latitude and longitude of Parramatta was also measured (Brisbane 1823a). Apart from these astronomical measurements, Brisbane also instituted a program of regular meteorological observations, the first to be made systematically in the continent apart from those made by Dawes in the 1870s (Bhathal and White 1991, Brisbane 1824a, Brisbane 1825). He set up a network of meteorological stations which were manned by convicts at Sydney Heads, Newcastle, Bathurst, Port Macquarie, Macquarie Harbour and the Derwent River. This program of meteorological measurements became part of the work load of the colonial observatories in the second half of the 19th century before it became the responsibility of the Commonwealth Government at the turn of the 20th century. The meteorological measurements were important in an agricultural country like Australia. Brisbane was also involved in the first geophysical measurements in Australia and made measurements of the Earth's temperature (Brisbane 1824b). One of Brisbane's other major plans was to determine the figure of the Earth by making measurements with an invariable pendulum. He had brought with him a pendulum which he and Rumker had 'swung' before leaving London. The pendulum was then swung in the new observatory to establish the difference in gravity between Parramatta and London. Brisbane transmitted the results of his experiments to Captain Henry Kater for publication in the Philosophical Transactions of the Royal Society of London (Brisbane 1823b). The results, according to Kater who had compared the measurements conducted in London and Parramatta, were not conclusive. The plan to measure the arc of meridian as requested by Humphry Davy was not accomplished by the Parramatta astronomers.

Royal Society of New South Wales

Brisbane was also active in the promotion of science in the colony. He was elected the first President of the Philosophical Society in Australia which had been formed on 27 June 1821 for the "purpose of collecting information with respect to the natural state, capabilities, productions and resources of Australasia and the adjacent regions and for the purpose of publishing from time to time such information as may be likely to benefit the world at large" (Liversidge 1910). The Society was later reconstituted as the Royal Society of New South Wales. In the 20th century it gave rise to some of the major scientific and engineering societies in Australia.

2. Brisbane recalled

By 1824 Brisbane was having difficulty with the administration of the colony. He had few competent administrators to assist him in the work of the government. His colonial secretary refused to carry out his instructions and supressed letters or answered them without reference to Brisbane. He was unable to resolve the conflicts between the emancipists and the exclusives. Some of them made vicious misrepresentations about his administration to the authorities in London (Liston 2009). There was also criticism in the press regarding Brisbane's astronomical activities and the impact they were having on his carrying out the duties of government. He was accused, among other things, of neglecting his duties as Governor of the colony to make astronomical observations and shoot parrots (Heydon 1966). Despite his attempts to refute these false accusations, Lord Bathurst recalled him to London. The damage had been done. He relinquished the administration of the colony in December 1825 never again to see his Observatory.

The observatory and the equipment were acquired by the government. The Observatory became a government observatory and part of Bank's scheme of imperial science although later events showed that it did not get the same support as the observatory at the Cape which had closer connections with the Admiralty. Furthermore the criticisms of the catalogues it had produced tarnished its image in the metropolitan centres of Europe.

Rumker and Dunlop

Rumker was appointed the first Government Astronomer in 1827 and at the request of the Royal Society he was asked to measure an arc of meridian for New South Wales. In January 1829, Rumker left Sydney for London to purchase new instruments for the Observatory and also to get the Royal Society to publish his Astronomical Observations made at the Observatory at Parramatta in New South Wales. These were published as a supplementary volume to the Philosophical Transactions at government expense. It upset Brisbane because Rumker did not acknowledge Brisbane in the paper despite the fact that Brisbane had paid his salary at the Observatory and taken him to Australia at his own expense. This was not only a grave oversight by Rumker but it was also partly Brisbane's fault for not having worked out an agreement with Dunlop and Rumker as to the terms under which publications were to emanate from his Observatory. For this oversight Rumker was to pay dearly. While in London he became embroiled in a rather unfortunate acrimonious dispute with the powerful and quarrelsome Sir Thomas South, a friend of Brisbane and the President of the Royal Astronomical Society about the price of the instruments he had come to purchase. South was well known in intellectual circles in London for his quarrelsome nature (Hoskin 1989). Furthermore, there was a dispute about the return to Brisbane of the original logs of the observations made at Parramatta Observatory. There seems to have been a misunderstanding between Rumker and Brisbane as to what constituted the original logs and the notebooks that Rumker had used to record his observations. South used his influence to have Rumker dismissed in 1830 from British government service (Bergman 1960). Later, in 1831 Rumker wrote in a pamphlet in which he said, "That no fault was found in me in respect to the discharge of my scientific duties has also been admitted by the Committee and the President of the Royal Society wrote to me: 'I can only therefore lament that any combination of circumstances have deprived Astronomers of your scientific labours in the Southern Hemisphere. And that this combination of circumstances have been explained to me by the Secretary and other members of the Royal Society as consisting in the rows between the Royal and the Royal Astronomical Society (but in reality only between their leading members)' and that I had been sacrificed to oppose the President of the Royal Society, because I had been patronized and supported by him. Is it then not a lamentable confession of the leaders of science in England that for the sake of opposition and party spirit a man must be displaced from a station of infinite importance to Astronomy when his arduous exertions have been acknowledged useful by the scientific world?" (Bergman 1960). Rumker returned to Hamburg, where he became the director of the School of Navigation and later of the Observatory. He led a very productive scientific life and was elected a Fellow of the Royal Society. The 1871 Catalogue of Scientific Papers compiled by the Society, lists 233 papers which he published in various scientific journals. In intellectual terms he had surpassed Brisbane.

Dunlop was appointed the Superintendent of Parramatta Observatory and took over the running of the observatory in 1831. Unfortunately, he did not have the theoretical and intellectual expertise to run the Observatory. He had always been a follower rather than a leader and had prospered under the guidance of Brisbane and Rumker. He did not have the standing of either Brisbane and Rumker in the political or scientific circles in London and Sydney to obtain the resources to run the Observatory effectively. The instruments and the building were allowed to deteriorate. This was compounded by Dunlop's ill health and from about 1837 he found it a chore to look after the Observatory and carry out observations of the night sky. He was seriously ill and could not manage the day to day operations of the Observatory. Because it was situated inland in Parramatta, ships' captains had to make a long and often unwelcome journey to Parramatta Observatory to check their chronometers for the correct time before sailing out of Sydney. In 1841, an event occurred which had dire consequences for the survival of the Observatory. The well known British explorer, Captain James Ross travelled to Parramatta to check the correct time on his chronometer but Dunlop, who was ill and in bed, called on his dog to attend to the English gentleman (Bhathal and White 1991). Ross was extremely offended by this behaviour and complained to the Admiralty about the sad state ofaffairs at the

Observatory. This set in chain a series of events which led the long arm of imperial science to begin a scrutiny of the Observatory's output. Hardly any papers were being published by the Observatory and questions were being asked in London by George Airy, the Astronomer Royal and the Colonial Office which was footing the bill for running the Observatory in the colony of New South Wales

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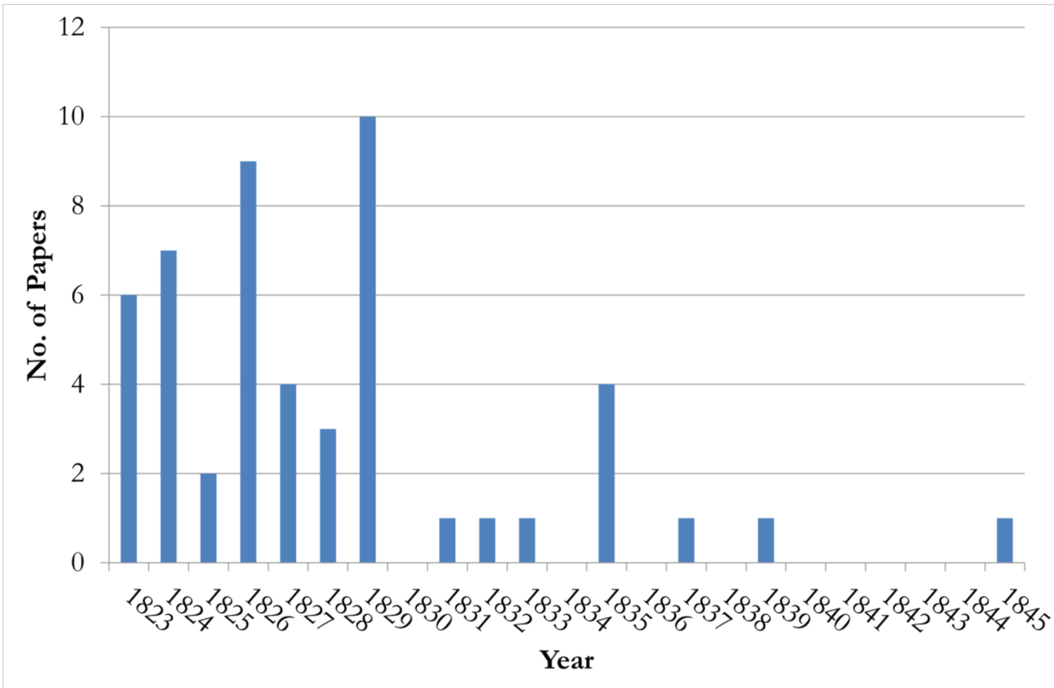

Figure 8. Number of papers published by Parramatta Observatory 1823-1845.

The productive years of the Observatory in terms of publications were from 1823 to 1829. From about 1830 the Observatory began its slow decline. This is illustrated in Figure 8. The data for constructing this graph is taken from the following journals in which the Parramatta astronomers published their observations: British Association Report, Edinburgh Journal of Science, Edinburgh Philosophical Journal, Edinburgh Philosophical Magazine and Journal of Science, Geographical Memoirs on New South Wales, Memoirs of the Astronomical Society of London, Memoirs of the Royal Astronomical Society, Monthly Notices of the Astronomical Society of London, Monthly Notices of the Royal Astronomical Society, Philosophical Transactions of the Royal Society of Edinburgh, Philosophical Transactions of the Royal Society of London and the Transactions of the Royal Society of Edinburgh. The information on the journals was supplied by Tim Parks.

In 1847 a Committee of Enquiry headed by the naval hydrographer, Captain Phillip Parker King was set up to investigate the lack of progress of the Observatory (King, Jordan and Rogers 1847). The report prepared by this Committee led to its eventual closure in 1848. All that remains today are the stone piers of the transit telescope in Parramatta Park. At the insistence of John Tebbutt, an obelisk was erected to mark the remains of Brisbane's observatory. Apart from the astronomical observations, the Parramatta astronomers were also involved in other scientific experiments and measurements.

Back in Scotland, Brisbane went on to build another observatory at Makerstoun. He became the President of the Edinburgh Astronomical Institution and was involved in making the Royal Observatory in Edinburgh more efficient. In 1832, he was elected President of the Royal Society of Edinburgh (Heydon 1966).

Conclusion

Brisbane established Australia's first private observatory which produced Australia's first catalogue of over 7000 stars of the Southern Hemisphere. However, at a later date it was found to be defective and lost much of its credibility. The Observatory was also responsible for discovering Encke's comet. This was an important discovery, because it was only the second time that the predicted return of a comet had been observed but it also threw up problems for further investigations which were resolved in the first half of the twentieth century. The first had been Halley's comet whose appearance had been predicted by Halley based on Newton's theory of gravitation. The observation of Encke's comet made it a permanent member of the solar system and confirmed that comets, like planets obeyed Newton's law of gravitation. This discovery provided another confirmation of Newton's theory of gravitation as applied to comets. It introduced a new class of celestial objects called comets of short period. One other important result of the discovery was the use of perturbations to find the mass of Mercury. Despite the failure of the Observatory to produce an accurate catalogue of southern stars, its fame must rest on the discovery of Encke's comet and for providing another instance for the confirmation of Newton's theory of gravitation based on observations carried out at Parramatta Observatory through scientific instruments. The discoveries of the comets by the Parramatta astronomers were responsible for establishing the tradition of comet hunting in Australia in the second half of the 19th century and beyond.

Although the catalogues of double stars and nebulae had errors in them, they contain objects that are still referred to by the names of the Parramatta astronomers. The scientific programs that were undertaken at Parramatta Observatory laid the foundations for the scientific programs (astronomy, meteorology, geophysics and surveying) that were to be pursued by the colonial observatories which were built in Australia in the second half of the 19th century.

Old Government House and the Domain in Parramatta Park form part of the Australian Convict Sites World Heritage property and are listed on the UNESCO World Heritage List. However, the Observatory which represents Australia's intellectual endeavours and heritage have been completely ignored by Australian heritage authorities and UNESCO. It seems that the convict past is more important than Australia's intellectual history. The Observatory deserves to be placed on the UNESCO/IAU world heritage list of observatories alongside Cape Observatory which was founded at about the same time. Brisbane's achievements can be best summarised in the words of Herschel (1829): "It will be a source of honest pride to him while he lives, to reflect that the first brilliant trait of Australian history marks the era of his government, and that his name will be identified with the future glories of that colony, in ages yet to come as the founder of her science. It is a distinction truly worthy of a British governor".

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The author wishes to thank the Mitchell Library for use of its resources and assistance in carrying out this study. He thanks the Powerhouse Museum for use of its images of the instruments from Parramatta Observatory. He also thanks Tim Parks for supplying information on the papers and the catalogues published by the astronomers at Parramatta Observatory and for his useful comments on the paper. He also thanks the late Peter Tyler and members of the Sutherland Astronomical Society for valuable comments on the paper when he gave a talk on Parramatta Observatory at their monthly meeting. The author also thanks the anonymous referee for valuable comments. Shirley Saunders paper in the Historical Records of Australian Science on the history of Parramatta Observatory gives an interesting insight into the social and political aspects of the observatory. Carol Liston's paper in Clune and Turner's book on the Governors of New South Wales gives a valuable insight into the social and political climate of NSW during Brisbane's time in Sydney. A shorter version of this paper was presented at the Brisbane Commemoration Seminar organised by the Royal Society of New South Wales, the National Trust of Australia (NSW Branch) and Parramatta Park Trust on 1 December 2011 at the National Trust of Australia (NSW Branch) office on Observatory Hill, Sydney.

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Symposium – Commemorating Governor Sir Thomas Brisbane, National Trust, Observatory Hill, 1 December 2011

Sir Thomas Brisbane – Patron of Colonial Science

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Historian, Royal Society of New South Wales

Abstract

British Army office Sir Thomas Makdougall Brisbane was sworn in as Governor of New South Wales on 1 December 1821. His appointment allowed him to pursue his plans for astronomical observations of the southern sky by setting up an observatory near his residence at Government House Parramatta. He also joined the Philosophical Society of Australasia and became Patron of the newly formed Agricultural Society of New South Wales. These societies were the precursors of many important later professional bodies, so that Brisbane's connection with them represents his most important contribution to Australian science.

Introduction

On 1 December 1921 Major-General Sir Thomas Brisbane was sworn in as the sixth Governor of New South Wales.

Lachlan Macquarie was still occupying Government House in Sydney Town, so Brisbane and his entourage settled in what is now known as Old Government House at Parramatta. Governor Brisbane found this location so congenial that his family decided to reside there after Macquarie returned to London early the following year.

Like Macquarie, Thomas Brisbane was a Scot and an army officer, differentiating them from the first four governors who were all officers in the Royal Navy.

How did this come about? Thomas Brisbane came from an ancient landed family in south-west Scotland, at one stage owning 10,000 acres of grazing land. Over succeeding generations with large families to support this inheritance was gradually dissipated, so that the children were expected to be independent – a good marriage for the girls; a career in the army, or sometimes the navy, for boys. Governor Brisbane's father and grandfather (both also named Thomas) were educated and well-read men – products of the eighteenth-century Scottish Enlightenment. Young Thomas was born at Brisbane House in 1773, where he was taught first by a governess then by his father and a local clergyman. At the age of fourteen he was sent to school in London to study the subjects that a young gentleman needed, including mathematics, as well as to soften his Scots brogue.[1]

At sixteen, he commenced his pre-destined military career as an Ensign in the 38th Regiment. He enjoyed the army, and his family purchased promotions for him, while he served on several overseas appointments

[1] The information about Brisbane's early life is largely based on C. Liston, 'Sir Thomas Brisbane', in D. Clune and K. Turner (eds.), The Governors of New South Wales, Federation Press, 2009. See also C. Liston, 'Sir Thomas Brisbane in New South Wales', *Journal of the Royal Australian Historical Society*,.**71**, 2, Oct 1985, pp91-106.

until 1802 when he could not accept a posting to India because of health problems. He was then placed on half-pay while he helped manage his father's estate in Scotland. This gave him the opportunity to develop an interest in astronomy that had arisen from his posting to Jamaica some years earlier when the voyage almost ended in disaster due to poor navigation. While in the West Indies he acquired some instruments and began reading widely about navigation and astronomy. Back home he built an observatory at Brisbane House, which he fitted out with specially designed instruments. This was only the second observatory to be built in Scotland. (Rosen (2003), Morrison-Low(2004). He began an active correspondence with leading astronomers, one of whom was married to a cousin in Edinburgh, and in 1810 he was elected as a member of the Royal Society in London.

Living the lifestyle of a gentleman of leisure, and indulging in a very expensive pastime while on reduced salary from the army strained his resources and he was forced to borrow large sums of money. Relief came when he was recalled to active service as a Brigadier-General in the Peninsula War against Napoleon, where he distinguished himself and was knighted. During the occupation of Paris, Brisbane prevented the destruction of the *Académie des Sciences*, and in gratitude was elected an honorary member of that body. This connection enabled him to broaden his interests through contact with the leading French astronomers, and he remained a dedicated Francophile.

After the war, he returned to his estates, which were now so heavily encumbered that it was necessary to sell half the land. Rescue came when at the age of 46 he married another cousin, Anna Maria, whose father provided a generous financial settlement. In return he formally adopted the cousin's surname, and thereafter became Sir Thomas Makdougall Brisbane. They moved to Ireland where he was appointed to the military staff before being nominated as Governor of New South Wales. Thomas Brisbane had been angling for this position since at least 1815, when he wrote to the Duke of York stating that he wanted to carry out astronomical observations in the colony, in particular to ascertain the shape of the earth. At this time the stars in the southern hemisphere were little-known. He even contemplated chartering a ship privately, and by 1817 he had already purchased astronomical instruments in anticipation. Another attraction of an appointment as Governor was the salary of $2000 per year, but he hastened to assure the colonial authorities that he would not neglect his Vice-regal duties while pursuing his astronomical investigations.

Living at Parramatta had an additional enticement for Brisbane. Government House was situated on a small hill with a clear view in all directions, and without the smoke from fireplaces that polluted the atmosphere in the port of Sydney. It was an ideal location for his planned observatory.

Brisbane's arrival in the Colony was welcomed by the small group of men interested in the natural sciences who earlier in 1821 had formed the Philosophical Society of Australasia, "with a view to inquiring into the various branches of physical science of this vast continent and its adjacent regions; and the mineralogical and geological state of these countries". At this time, the total white population of the Colony was about 31,500 including children. Nearly 14,000 of the population – just under half – were convicts. Of the free settlers and military personnel, 6,300 were adult men.[2] Only a small number of these would have the time, money or inclination to devote to matters of the mind, so the new Society was a select band.

The members were keenly interested in the rocks, plants and animals in their new environment, so met once a week at each others' homes in rotation to discuss their discoveries, and to exchange books from their personal libraries. The Society asserted its exclusive status and serious purpose by penalising members the substantial sum of£10 ($20) if they failed to present a scientific paper on the allotted monthly date, and they were fined five shillings (50 cents) if they arrived more than fifteen minutes late for the weekly meeting. Emphasising their seriousness of purpose, refreshments were limited to a cup of tea and a biscuit. Members also contributed £5 ($10) each towards the cost of establishing a small museum and library at the Colonial Secretary's office, which eventually became the nucleus of the Australian Museum in College Street. So, by joining this group, Governor Brisbane indirectly became the founding patron of the Museum.

The original members of the *Philosophical Society of Australasia*, as they styled themselves rather grandly, are shown in Table 1.

Of these ten, Governor Macquarie had already identified four as troublesome and dissatisfied, together with nine other leading settlers, in his despatches to London dated the day before he left office.[3] Undoubtedly he cautioned his successor to be careful of these men, in particular Judge Field, whose name was vigorously underlined three times by Macquarie. Two other members of the anti-Macquarie faction also had been invitedto join the Society, but declined– Dr Robert Townson, a distinguished scholar who was the only "real" scientist in the colony, but was preoccupied with his pastoral interests, and Rev Samuel Marsden, who was in dispute over other matters with the secretary of the Society, Dr Douglass. Macquarie described Samuel Marsden as "discontented, intriguing and vindictive" and refused to see him except on official occasions.

	Philosophical Society Member	Occupation	Macquarie's Opinion
1	Alexander Berry	Surgeon; landowner	
2	Dr James Bowman	Medical practitioner	"Dissatisfied"
3	Dr Henry Douglass	Medical practitioner	
4	Judge Barron Field	Supreme Court judge	"Dissatisfied"
5	Major Frederick Goulburn	Colonial Secretary	
6	Dr Patrick Hill	Medical practitioner	
7	William Howe	Farmer and magistrate	"Dissatisfied"
8	Captain Francis Irvine	Army officer; farmer	
9	Lieutenant John Oxley	Surveyor, explorer	"Intriguing & discontented"
10	Edward Wollstonecraft	Merchant (brother-in-law of A. Berry)	

Table 1: The original members of the *Philosophical Society of Australasia*

Governor Macquarie had not been invited to join the Society. The Governor's willingness to meet with emancipist former convicts alienated him from the "exclusives". Macquarie was a practical man, a builder and explorer, rather than a thinker and observer like Brisbane. Macquarie was at best a dilettante and not a serious collector (despite the beautiful chests of local curiosities that he took home with him, and which are now treasured artefacts of the Mitchell Library).

In November, soon after Sir Thomas Brisbane arrived in the Colony, the

[2] *Australians. Historical Statistics*, Sydney, 1988, p104.
[3] L. Macquarie, Memorandum, 30 Nov 1821. Mitchell Library, A.772.

Philosophical Society wrote to the Governor-designate:

> *Individuals of this Colony, anxious to obtain information, in the several branches of science and natural history, which this extensive and interesting quarter of the globe offers to industry and research, agreed to meet and form a Society for the attainment of that sole object … I am directed, Sir, to express the anxious wish of this Society, that you would accept the Presidency of their infant body …*[4]

Although he may have felt some reservations based on Macquarie's warning, Brisbane responded from Government House, Parramatta, the following day, 16 November, a fortnight before he was sworn into office:

> *I … beg you will express how highly I appreciate this mark of their [the Society's] consideration, and which I shall accept with much pleasure, although with much deference, arising from the humble opinion I entertain … of my own talents to do justice to such situation …*[5]

Brisbane attended his first meeting at Dr Douglass's home in Parramatta on 2nd January 1822, just over a month after he arrived in the Colony. To balance the numbers in a potentially awkward political situation, he arranged for two of his personal staff to join as well – his wife's personal physician, Donald Macleod (1799?-1851), and his German-educated astronomer, Christian Carl Ludwig Rümker (1788-1862). At this meeting, Barron Field read a paper on the Aborigines of New Holland and Van Diemen's Land. No doubt Brisbane found this an interesting introduction to his new responsibilities. The Society then decided, probably at their President's instigation, that it would send quarterly meteorological tables and astronomical observations to the twenty overseas scientific societies with which it already had established correspondence.

One of the first objectives of the Society had been to place some memorial to James Cook and Joseph Banks near the spot where they first landed in Botany Bay in 1770. They decided this should take the form of a brass plaque attached to the rocks; wording for the inscription caused debate over several months, even as to whether it should be written in Latin or English. At least, now that the Society had a distinguished President, his name could be included as well. He was asked to nominate a date for a little ceremony, and to join the other members for "a little collation on the spot".[6]

Their first attempt to mark the occasion was abandoned, owing to "the perils of the seas", but on Wednesday, 20th March, the President and members of the Society were taken to "the South head of Botany Bay" by the crew of *HMS Dauntless,* when the plaque was "pinned and soldered into a beetling rock, twenty-five feet above the level of the sea," where it remains today, at a place known as Inscription Point at Kurnell[7].

The hydrographer Captain Phillip Parker King (1791-1856) joined the Society later, so that by May 1822 there were fourteen members of the Philosophical Society. King was the only Australian-born member, but as the son of former Governor Philip Gidley King, he could be expected to support Governor Brisbane and the Vice-Regal establishment (although his support evaporated later). The members were all relatively young men, with Thomas Brisbane

[4] Minutes, Philosophical Society of Australasia, 11 Nov 1821. State Records NSW, SZ1007.

[5] Minutes, *op.cit.*, 21 Nov 1821.

[6] Minutes, *op.cit.*, 23 Jan 1822.

[7] *HMS Dauntless* was an armed sloop of 422 tons, under the command of Captain George Gambier, then refreshing in Sydney on the way from Peru to India with specie.

the oldest, aged 48. Because Brisbane's other astronomical assistant, James Dunlop (1793-1848), was an artisan of humble birth and little formal education, he was not invited to join the gentleman members of the Society, and probably would not have been comfortable in their company.

Sir Thomas attended most meetings, and he invited the members to a dinner at Government House on 3 July 1822, to mark the anniversary of the foundation of the Society.[8] Here the guests were able to enjoy a repast prepared by Brisbane's French chef, and listen to a piano recital by their colleague Carl Rümker and Brisbane's sister-in-law Elizabeth. Yet after the meeting six weeks later on 14 August, there are no further entries in the Minute Book; the Society appears to have disbanded, although some writers have suggested that it was still functioning in 1824, but I can find no evidence of this.[9] We know from other accounts that relations between the Governor and Colonial Secretary Goulburn had deteriorated. According to Judge Barron Field in his *Geographical Memoirs on New South Wales* in 1825, the society "soon expired in the baneful atmosphere of distracted politics, which unhappily clouded the short administration of its President" (Field (1825)). Judge Field himself may have been part of the problem, as hinted by the *Sydney Morning Herald* which wrote that "it appears from the available evidence, that the struggle between the Governor and the judiciary caused the early demise of the organisation" (SMH (1921a)).

Or perhaps it was Barron Field's own execrable verse that led to the collapse! He wrote this sonnet after the trip to Kurnell to fix the commemorative plaque:

> Here fix the tablet. This must be the place
> Where our Columbus of the south did land;
> He saw the Indian village on that sand
> And on this rock first met the simple race
> Of Austral Indians; who presum'd to face
> With lance and spear his musket ….[10]

Despite his assurances to the Colonial Office, Brisbane obviously came prepared to devote considerable time to astronomy. He considered Parramatta to be "the Greenwich of the Southern Hemisphere" (Proudfoot (1971)). His instruments were set up at Parramatta almost as soon as he arrived, in order to observe the summer solstice in December (Wood (1951)). Indeed, ninety years ago this month, on 17 December 1921, the *Sydney Morning Herald* announced that members of the Royal Society of New South Wales and the British Astronomical Association gathered at this same site to celebrate "the foundation of accurate astronomy in Australia" a century earlier (SMH (1921b)).

Two months after he arrived in the Colony, *The Australian Magazine* reported in its issue of February 1822 that:

> *His Excellency Sir Thomas Brisbane has prepared a most important and valuable Paper, entitled 'A Particular Table of Equations to Equal Altitudes, for Sydney, New South Wales …' A few copies of this scientific work are now going through the Australian press – 'As it is universally admitted, by all astronomers, that the method of equal*

[8] Minutes, *op.cit.*, 1822.

[9] Professor John Smith, in his Anniversary Address as President of the Royal Society of NSW in 1881, states that there is a reference to the Philosophical Society in the *Australasian Almanac* for 1825, but not afterwards.

[10] B. Field, *Sonnet. On visiting the Spot where Captain Cook and Sir Joseph Banks first landed in Botany-Bay*, published 1825.

> *altitudes combines the greatest simplicity with the utmost accuracy in determining time …*[11]

A rigorous program of celestial observations commenced in April 1822, and the team very quickly made their most notable discovery, the return of Enke's comet, only the second comet to have its return successfully predicted in advance (Pickett & Lomb (2000)). Following a number of other significant observations at Parramatta, Brisbane was awarded the Gold Medal of the Royal Society in London. It is not surprising that the Governor was accused unfairly of spending his nights looking at stars and his days chasing parrots, as he pursued that favourite pastime of the landed gentry – hunting.[12] On the other hand, Brisbane and his family remained aloof from Colonial society, which caused some resentment for precisely the opposite reasons that some members of the "bunyip aristocracy" disliked Macquarie.[13]

The grateful governor granted Rümker 1,000 acres of land at Picton as a reward. Twelve months later he deserted his job at the observatory and moved to his new rural property which he named 'Stargard' after the town in Germany where he was born. Brisbane was furious, and tried to revoke the land grant. Relations between the two men collapsed (Bergman (1960)).

Perhaps the Philosophical Society's aims were too abstract for Sydney in the 1820s. As the *Sydney Monitor* editorialised:

> *Zoology, Mineralogy, and Astronomy, and Botany, and other sciences are all very good things, but … an infant colony cannot afford to become scientific for the benefit of mankind.* (Gasgoine (2002))

Even before the final recorded meeting of the Philosophical Society, eleven of its fourteen members were involved in the formation of the Agricultural Society of New South Wales on 5 July 1822. There had been an earlier attempt to form an agricultural improvement society in 1818, but this failed because Governor Macquarie insisted that emancipists should be accepted as members (SMH (1918)). The new society became a distant forebear of the present Royal Agricultural Society. Somehow overcoming their differences, Judge Barron Field became President, with Governor Sir Thomas Brisbane as Patron, and Colonial Secretary Frederick Goulburn as Vice-Patron. Again it was an exclusive group because of the high subscription fees. It was a quasi-scientific body, albeit with a more explicitly practical rationale than the Philosophical Society. Its prospectus pointed out that "Agriculture and Grazing, in a soil and climate so peculiar as those of New South Wales, present so many features of novelty and difficulty … [that there is a need for] communicating their mutual experience, and benefitting by their reciprocal advice, … [and] for the purpose of effecting … improvements in the breed of animals, and experiments in the growth of produce."[14] It held its first Show – the 'Parramatta Fair' – in October 1824. Despite the early personality clashes, the Agricultural Society survived until 1837, when it collapsed in the economic depression following a run of bad seasons (Stoddart (1986)).

Because of criticisms about Governor Brisbane's administration of the colony, he and Frederick Goulburn were recalled to Britain in 1825. Some of the men whom

[11] *The Australian Magazine,* II, 10, Feb 1822
[12] *Historical Records of Australia*, Series 1, Vol.11, p612.
[13] "Bunyip aristocracy" was the term used by writer and politician Daniel Deniehy to ridicule W.C. Wentworth's proposal for a hereditary peerage to be included in the NSW Constitution.

[14] Agricultural Society of NSW, Anniversary addresses, 1823-1825. Mitchell Library, 630.6/A

Brisbane had nurtured in the fledgling Philosophical Society by then had become his detractors, just as they were for his predecessor, Lachlan Macquarie. Back in Scotland, Brisbane set up his third observatory at his home in Roxburghshire. An appointment to the largely ceremonial position as Colonel of the 34th Regiment provided him with a comfortable income that allowed him to continue his patronage of astronomy. He published the results of his astronomical work in scientific journals and became President of the Royal Society of Edinburgh for 27 years, from 1833 until his death in 1860, aged 87.

After Brisbane was recalled to England, the government acquired his observatory, instruments and library. Carl Rümker then returned to Parramatta in May 1826, and discovered another comet. The next Governor, Lieutenant-General Ralph Darling appointed him to the position of Government Astronomer, the first person to hold this title. Rümker then published the results of his observations since 1822 without acknowledging the role of his former employer, Brisbane. For many years afterwards the two men pursued a vitriolic correspondence over this breach of scientific convention. However, when Rümker went to London in 1829 to purchase new instruments, Sir Thomas Brisbane was able to use his influence to have him dismissed from government service. Rümker returned to his native Hamburg and became director of the observatory there, while continuing to work on his Australian star catalogue. He received many international awards for his achievements, but is little recognised in this country (Bergman (1967)).

Brisbane's Scottish instrument-maker James Dunlop replaced Rümker as superintendent of the Parramatta observatory in 1831. After 1837 his activity declined, possibly because of poor health. Much of his work in this period was never published, and he resigned in 1847, dying the following year (Wood (1967)). Captain Phillip Parker King was another keen astronomer, who had built a private observatory on his property at Dunheved. He went on to become the first Australian-born Admiral in the Royal Navy (ADB (1967)). King was influential in persuading the government to build an observatory in Sydney after the Parramatta observatory fell into disrepair, and he ensured that the instruments from Brisbane's observatory remained in the colony as a nucleus for the new institution.[15]

As we have seen, there were numerous disappointments as well as notable scientific achievements in the four years that Sir Thomas Brisbane spent in New South Wales. The Philosophical Society that he led so briefly is the forerunner of the present Royal Society of New South Wales, formed in 1866, which itself was the progenitor of ANZAAS. It was also the precursor of many other professional bodies, including the Australian Medical Association and the Institution of Engineers Australia. The Agricultural Society that formed under Brisbane's patronage was revived later as the Cumberland Agricultural Society, which eventually became the Royal Agricultural Society, aiming to bring scientific methods to the pastoral industry. The natural history collections of the Colonial Museum that originated under his leadership became the Australian Museum in 1836.

Thomas Brisbane can truly be described as the founding patron of Australian science. He deserves to be remembered on this anniversary.

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[15] Pickett & Lomb, op.cit., p.22.

The Governor Brisbane Symposium

This paper was presented at a symposium commemorating Governor Sir Thomas Brisbane organised by the Royal Society of NSW in conjunction with the National Trust (NSW) and the Parramatta Park Trust. Three lectures were presented at the National Trust headquarters, Observatory Hill on Thursday, 1 December 2011. On Saturday, 3 December, there was an inspection of the archaeological site of Sir Thomas Brisbane's observatory at Parramatta, followed by a tour of Old Government House with particular attention to relics of the Brisbane family.

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Peter Tyler

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Peter Tyler was the Historian of the Royal Society of New South Wales. He died in May 2012 having completed a first draft of this paper. The final paper was prepared with the assistance of A/Professor Carol Liston. Peter was a noted historical researcher, writing books and papers about medical history, building, anti-tuberculosis campaigns, the NSW public service and the state records of NSW.

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Symposium – Commemorating Governor Sir Thomas Brisbane, National Trust, Observatory Hill, 1 December 2011

Sir Thomas Brisbane – a man of scientific method

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Abstract

Sir Thomas Brisbane is a familiar name to those interested in the history of science in Australia. His astronomical observatory at Parramatta, established in 1821, marks the commencement of formal scientific work in the colony of New South Wales. This paper considers Brisbane's scientific achievements within the broader context of his work in Britain as well as Australia and his contributions to the development of professional science.

Introduction

Sir Thomas Brisbane was governor of New South Wales from 1821-1825. In those years he established a private astronomical observatory in the grounds of Government House at Parramatta. His colonial scientific achievements are part of a more extensive scientific career that deserves further consideration. At a time when the name 'scientist' was being invented, Brisbane's career displayed many of the characteristics of a modern scientist – a commitment to scientific investigation through observation, experimentation, publication and leadership including mentoring.

Born into the Scottish landed gentry, the Brisbane family home held an extensive library in English, French and Latin. Like others of their generation, their extended family participated in the intellectual pursuits of the Scottish enlightenment of the late 18th century. Thomas Brisbane (1773-1860) received a good general education at home and in London before taking up his army commission when he was 17. He saw active service in Europe and the West Indies. While on half pay between 1805 and 1811, Brisbane developed his interest in astronomy into a life-time pursuit, both as a personal activity and as a public mentor for its expansion as a science.[16]

Observation

After a near disastrous Atlantic crossing with his regiment in 1795, when his vessel ended up off the coast of Africa instead of the West Indies, Brisbane resolved to learn basic astronomy used to navigate at sea.[17]

Back in Scotland, he was able to refine these skills in Greenock, the nearest town to his home in Ayrshire and Scotland's gateway to

[16] Research for this paper was undertaken in the United Kingdom with the support of the C.H. Currey Fellowship, State Library of NSW.

[17] Much of the detail of this paper is documented in Carol Liston, New South Wales under Sir Thomas Brisbane 1821-1825, PhD, University of Sydney, 1982.

the Atlantic. Schools and private academies taught astronomy and navigation in Scotland in the late 18th and early 19th century. Colin Lamont (1754-1851) was mathematics master at Greenock Grammar School from 1781. Skilled in astronomy and navigation, he had his own observatory at Greenock where he taught mathematics and navigation, as well as a navigation warehouse, selling and repairing navigational equipment (Gavine (1981)). It was natural that Brisbane turned to Lamont to refine his understandings of astronomy.

As heir to the family estate Brisbane had access to credit, which he used to develop his expensive hobby. In 1808 he had constructed in the grounds of Brisbane House a stone observatory, which he equipped with instruments, clocks and books, mostly purchased from leading suppliers in London.

In 1809 when the Glasgow Society for Promoting Astronomical Science was planning an observatory, they visited Colonel Brisbane the younger of Brisbane to see his observatory, and seek his advice. Brisbane assisted them in purchasing second hand instruments and he was invited to lay the foundation stone of their observatory in May 1810.[18] In the same year, Brisbane was elected a member of the Royal Society of London and became a member of the Royal Society of Edinburgh in 1811.

When he returned to active service with the Duke of Wellington in the Peninsula in 1811, Brisbane's precision and time-keeping skills were an asset for the military. Time was the essential component of navigational astronomy. Brisbane observed the time by using a pocket sextant, a chronometer and artificial horizon (MNRSN (1861) p98). Wellington ordered that Brisbane's tables of the sun's altitudes be printed for the use of the army to assist with time-keeping. During the military occupation of France after Napoleon's defeat, Wellington ordered Brisbane to calculate comparative British and French weights to standardise the issue of military rations.

Brisbane was elected a Corresponding Member of the French Academy of Sciences in 1816 in recognition for saving their buildings from a 'rabble of German soldiers' (MNRSN (1861) p99). This honour provided an introduction to eminent French scientists who widened Brisbane's astronomical interests. He remained a lifelong personal friend of Alexis Bouvard (d.1843) whose computational skills led to the determination of the orbits of comets. Bouvard's calculations included the orbit of a comet in 1805 and 1818 that was subsequently called Encke's comet. Brisbane's observatory at Parramatta observed its return in June 1822 and his Makerstoun observatory in Scotland observed its return again in 1829.[19]

With the end of the Napoleonic Wars, Brisbane sought employment that would enable him to continue his astronomical interests. In 1821 he was appointed as the successor of Governor Macquarie in New South Wales. Brisbane immediately planned to establish a private observatory, removing equipment from his Brisbane Observatory, purchasing new equipment and hiring staff to assist him. Charles Rumker, a German navigational teacher previously employed by the Royal Navy, was appointed as a mathematician and calculator as well as

[18] Archives of Mitchells, Johnston & Co, T-MJ 98, Glasgow City Archives.

[19] 1860/214; LBV1 f.341 *JD Forbes Papers*, University of St Andrews; http://www-history.mcs.st-andrews.ac.uk/Biographies/Bouvard.html; Royal Society of Edinburgh (D. Brewster ed) *The Edinburgh Journal of Science*, Vol 1, 1829, p182.

observer and James Dunlop, a Scot who made optical equipment, as technician and an assistant in the observatory.

The British government had decided to establish an official observatory at the Cape of Good Hope in 1820. Brisbane's private venture to another part of the southern hemisphere was seen as an important opportunity to extend knowledge of the southern skies. Longitude was Brisbane's first interest and on the voyage to Australia he observed stars, tested his various clocks and made magnetic observations. Rumker also observed on the voyage, and their unpublished notes were sent to the Royal Astronomical Society in London where they were read but not published.[20]

Brisbane and his assistants started observing as soon as they arrived in late 1821 and the team occupied the new observatory at Parramatta from early 1822. Their main instruments were a transit of five and a half feet by Troughton, a mural circle of two feet by Troughton (brought from the Brisbane observatory) and a 16 inch repeating circle by Reichenbach, Utzschneider and Liebherr (Lomb (2004)).

Dr John Brinkley received regular correspondence from Brisbane, particularly about stars that were visible in both hemispheres. An astronomer and clergyman and the first Astronomer Royal of Ireland, Brinkley's astronomical investigations used Brisbane's Parramatta observations of south polar distances of fixed stars to assist his work on north polar distances.[21] Brisbane arranged for meteorological observations to be kept at various places around New South Wales, as well as at Parramatta. He sent these observations to correspondents throughout Europe. A meteorological table for 12 months from April 1823 to March 1824, sent by Brisbane to Dr Brinkley, was published in the *Dublin Philosophical Journal and Scientific Review* in 1825.[22] Observations were carried out on the length of the pendulum. Published and commented on by Captain Henry Kater, the observations were used to calculate gravity, and subsequently used for standard measurements of the yard.

Brisbane had a wide circle of scientific acquaintances and sent back to these friends and their institutions many specimens of plants, minerals, small animals, reptiles and birds as well as the occasional ethnographic object and Aboriginal skeletal remains. He was awarded an Honorary LL.D in January 1823 from the University of Edinburgh in recognition of his large contributions to the University Museum of Natural History.

Experimentation

An Experimental Governor

Aware that they had appointed a scientist as well as a soldier, Lord Bathurst at the Colonial Office commented that he was pleased to hear of Brisbane's engagement with astronomy and asked for observations that he could pass on to associates.[23]

The Parramatta Observatory by 1823 had conducted observations on Mars, a transit of Mercury, three solstices, two equinoxes, observations on two comets with their orbits after they had been lost sight of in Europe,

[20] Royal Astronomical Society Archives, Parramatta files, various documents.

[21] *Monthly Notices of the Royal Astronomical Society*, vol 1, 1828, p59; John Brinkley in *Complete Dictionary of Scientific Biography*, http://www.encyclopedia.com/doc/1G2-2830900634.html

[22] *Dublin Philosophical Journal and Scientific Review*, vol 1 1825 p150-1.

[23] Bathurst to Murray, 11 November 1822, *Bathurst Papers* British Museum Loan 57/64, p16.

eclipses of the sun, moon and Jupiter's satellites, and identification of stars in Lacaille's catalogue of southern stars made in the Cape of Good Hope in 1750-54.[24]

Friction between Brisbane and Rumker in 1823 led to Rumker leaving the observatory to work at his farm near Picton. Brisbane continued observing after Rumker left, sending his work to the Royal Astronomical Society in London with a request for someone there to complete the mathematical calculations necessary to reduce the observations for publication, as he no longer had Rumker to do this work.[25]

Brisbane's scientific status caused difficulties for the British government in encouraging further scientific inquiry in the colony whilst he was governor. In October 1823 Sir Robert Peel supported the request of the Board of Longitude and Sir Humphrey Davy that the British government encourage Brisbane to measure an arc of the median, having confidence in his scientific team (particularly Rumker) and their instruments.[26] Lord Bathurst agreed to instruct Brisbane to carry out this work, but warned it would need to be carefully worded, because 'the cry attempted to be raised against him in NSW is that he is an astronomer'.[27]

A natural extension of the meteorological observations was to experiment with changing environments for the production of wool. Brisbane proposed that experiments on wool quality be conducted in the Hunter Valley and Tasmania, latitudes equivalent to Spain and Saxony, which were known for their wool in Europe. He continued Caley's experimental garden at Parramatta and was successful with Virginia tobacco and Georgian cotton seed.[28]

Probably his most daring application of scientific method in New South Wales was its application to a social environment – the management of the colony. Brisbane changed many aspects of colonial administration in his first three months in office, having digested the criticisms of Governor Macquarie and the evidence provided to Commissioner Bigge. These changes ranged from convict administration to the distribution of land. Brisbane then observed the impact of these changes but did not tinker with the arrangements he had set in place. He refused to send partial results to the Colonial Office, wanting to wait until the outcomes were clear. It was foolhardy to leave them in the dark about his administration, as it provided the opportunity for his critics to send reports to the British government that had no information to defend Brisbane.[29]

Makerstoun

Recalled from the government of New South Wales at the end of 1825, Brisbane returned to Scotland and established his family at Makerstoun, his wife's family home near Kelso, where he had built his third astronomical observatory by 1828. In 1838 12 chronometers were taken from Greenwich to Brisbane's observatory at Makerstoun to confirm the latitude of both locations.[30]

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24 Brisbane to ? (Cork Institution?)24 February 1823, D207/67/58 Public Record Office of Northern Ireland.

25 Brisbane to F. Bailey RAS, 2 July 1825, *Royal Astronomical Society Archives,* Parramatta files 19.1.

26 Peel to Bathurst, 20 October 1823 *Peel Papers*, British Library MS 40358, f.302 (check HRA).

27 Bathurst to Peel, 21 October 1823, *Peel Papers* British Library MS 40358, f.309.

28 Brisbane to ? (Cork Institution?)24 February 1823, D207/67/58 Public Record Office of Northern Ireland.

29 Brisbane to Craufurd, 1 May 1823, *Brisbane Papers* PRO PMG1/1.

30 Gavine, p162.

Brisbane built a magnetic observatory at Makerstoun near his astronomical observatory and employed a team of scientists throughout the 1840s. Russell was followed by John Brown, a student of Professor James David Forbes, who arranged with the Astronomer Royal George Airy, on Brisbane's behalf, for Brown to spend a few weeks working with James Glaisher at the Greenwich Magnetic Observatory.[31] Brown, Welsh and Hogg worked at Makerstoun until 1849, when they moved to Edinburgh to focus on the calculations of their observations.

Publication

Brisbane was committed to publication and the distribution of the results of his observations and experiments. In many instances, particularly with meteorological observations the results were sent with correspondence to friends and acquaintances throughout Europe and published without commentary apart from the names of the observers– Brisbane, Rumker, Dunlop – and details of the instruments used. In the pre-computer age, the mathematical calculations needed to put the astronomical results in a format useful for comparative analysis meant many years of work, and the expense of publication of lengthy tables. Brisbane frequently contributed toward the cost of publication.

As Brisbane personally funded the work of his observatories, he expected acknowledgement of his investment as well as of his own work within the observatories. In January 1830 Brisbane wrote to the Royal Society in London asking how they had obtained the observations made at his observatory at Parramatta in 1821-23 that were recently published in the Society's *Philosophical Transactions*.[32]

Edward Sabine, Secretary of the Royal Society, explained in February 1830. When Rumker was appointed government astronomer in New South Wales, he was instructed by the Colonial Office to report all his observations to the government and not to publish in learned societies by sending information directly to them. When his reports began to arrive, the British government consulted the council of the Royal Society that recommended, as the government printed the Greenwich observations, it should also print the Parramatta observations. Rumker's reports were printed at the expense of the Colonial Office under Rumker's superintendence. The government then placed all the copies with the Royal Society, which distributed them as an extra part of its *Philosophical Transactions*. The Royal Society did not regard the inclusion of earlier materials observed while Rumker was employed by Brisbane as a problem, as the government observations were a continuation of the same work, so therefore to the public's advantage to know about them.[33]

Brisbane had given his own records of the Parramatta Observatory – the bound books of the transit and mural circle – to the Royal Society in February 1829 and their publication had been recommended to the government. These observations were still being mathematically reduced by William Richardson at Greenwich Observatory and would not be published for at least another year (and indeed were not published until 1835).

[31] LBIII, f.340, 578 JD Forbes Papers, University of St Andrews.

[32] Report on Parramatta observations, *Royal Astronomical Society Archives,* Bailey files MSS 5.24.

[33] Sabine to Brisbane, 6 Feb 1830 *Royal Astronomical Society Archives,* Bailey files MSS 5.26.

The Royal Society had published the work of the employee without acknowledgement of the employer – and in advance of his own work being published. Brisbane's investment in the observatory, the instruments and the salaries of the observers had been completely ignored. The observations from the end of 1821 until June 1823 should have recognised Brisbane. It was only after Brisbane left the colony at the end of 1825, having sold the observatory equipment to the colonial government, which then appointed Rumker as government astronomer, that the government observations could properly be seen as Rumker's work.

Further investigation into the records of the Parramatta Observatory revealed that whilst Brisbane believed he had the official records in his observatory workbooks, Rumker had in fact used loose bits of paper for his observations. Furthermore, when Rumker retired, he took the books to reduce the observations and refused to hand them over to Brisbane when he was leaving the colony. Brisbane was unable to get the books back before he sailed from Australia, but sent his clerk to copy them at Rumker's farm.

Representations from the Royal Society to the Colonial Office in May 1828 led to the Governor of New South Wales directing Rumker to hand over the volumes. As Rumker was going to Britain he was allowed to bring them with him and handed them over in June 1829. However, what he handed over were reams of paper in Rumker's handwriting not the bound books, so Richardson who was charged with reducing Brisbane's observations was concerned that they were not the original observations. Rumker acknowledged that they were only copies, with the originals being given to the Royal Society. He always used loose paper, and only used the books for calculations, and jottings and had torn out pages when he needed to make a better set of records for himself or to use for spare paper![34]

The incident raised important principles at a time when the processes for funding science and the rigour of scientific methods of recording were just emerging. The concern of a committee of the Royal Astronomical Society was that every observatory should keep the original observations. Rumker gave the Colonial Office copies of a second set. Unknown to Brisbane, Rumker had been keeping a second set of records for his own use, more perfect than the observations recorded in the bound volumes that were Brisbane's property and which Brisbane believed contained the true record of the whole of his observatory's work.[35]

Despite the controversy over Rumker's publications, Rumker maintained correspondence with Brisbane, sending him in 1844 his most recent catalogue of fixed stars, which included Brisbane's own observations, and his manual of navigation.[36]

Brisbane's records of the Parramatta Observatory were finally reduced by William Richardson and published as *A Catalogue of 7385 Stars chiefly in the Southern Hemisphere* (the Parramatta catalogue) in 1835. In the mid 1840s Greenwich Observatory returned Richardson's manuscripts for the Brisbane catalogue to Brisbane for deposit at the Royal Astronomical Society when it cleaned out

[34] Rumker's statement on Parramatta observations, *Royal Astronomical Society Archives,* Bailey files MSS 5.7.

[35] Report on Parramatta observations 5 June 1830, *Royal Astronomical Society Archives,* Bailey files MSS 5.5.

[36] 1844/58, JD Forbes Papers, University of St Andrews.

Richardson's office after he was dismissed from the observatory.[37]

After Brisbane's death, Rumker sent his original Parramatta observations to the Royal Astronomical Society, commenting that declining health preventing him from working on them to reduce them. These included original observations for 1822-3; Rumker's copies of observations in these years; Brisbane's own transit observations for 1823-24; Brisbane and Dunlop's original observations for 1824-25; Dunlop's observations for 1824-25 and various observations by Dunlop and Rumker in 1826-27. The full record of the work of Brisbane's Parramatta Observatory was never available in print, nor ever consolidated as manuscript in one place, during the lifetimes of either Brisbane or Rumker.

In 1842 the Royal Society of Edinburgh agreed to publish the magnetic observations from Brisbane's Makerstoun Observatory.[38] The first part of the observations appeared in the *Transactions* in 1845 but further publication was delayed due to the mass of data and complications in reducing it for publication. Adding machines were used but double-checking of calculations made it a massive task.[39] The final publication covered 1,800 pages, being the most north-western observations of their kind in Europe and made entirely at a privately funded observatory. Brisbane was awarded the Keith Medal for this work in 1848, with his astronomer John Allan Brown recognised with the award of a silver Keith Medal.[40] Brown's subsequent publications on magnetic observations established the link between sunspots and magnetic storms (Campbell and Smellie (1983) p42). Further observations from Makerstoun were considered for publication in 1857 and a supplement of observations by Balfour Stewart, director of Kew Observatory, was published in 1861.

Leadership and Mentoring

Learned Societies

The early 19th century saw a profusion of societies to encourage scientific work. Learned societies were about social networks and communication and were initially formed by gentlemen interested in natural science. By the mid 19th century, as technical expertise became more professional with university education, the new scientists took a stronger role.

The Royal Astronomical Society was established in London in 1820 and Brisbane was among its early members, presenting books to it in March 1820 (Dreyer and Turner (1923)). A decade later Brisbane was among those assembled at York in 1831 for the first meeting of the British Association for the Advancement of Science and he attended most of its meetings in the 1830s (Howarth (1931)).

When Brisbane returned from New South Wales, he served as a councillor and vice-president of the Royal Society of Edinburgh and succeeded Sir Walter Scott as President in November 1832. He was proposed by Dr Thomas Charles Hope, professor of medicine and chemistry at the University of Edinburgh (Hope had also nominated him for

[37] In 1845 William Richardson was dismissed from Greenwich observatory when he was charged, though subsequently acquitted, of concealing the birth and death of the baby he had fathered to his daughter. *Proceedings of the Old Bailey*, 11 May 1846 http://www.oldbaileyonline.org.

[38] *Minutes of the Council of the Royal Society of Edinburgh*, 28 April 1842.

[39] *Minutes of the Council of the Royal Society of Edinburgh* 22 November 1848.

[40] *Minutes of the Council of the Royal Society of Edinburgh*, 18 February 1848.

membership in 1811) and seconded by Sir David Brewster, physicist.[41] This was a position traditionally held for life and, despite offering to resign due to declining health in 1851, Brisbane held the presidency until his death in 1860, the last president to do so.

Brisbane was also President of the Edinburgh Astronomical Institution from 1834, when Thomas Henderson became Astronomer Royal for Scotland, until 1846 when it was wound up. Brisbane provided the reflecting circle that Henderson used (Gavine (1981) p153). The Astronomical Institute managed the Royal Observatory on Calton Hill, Edinburgh. In 1846 Brisbane called a meeting to consider whether the observatory should be handed over to the government in exchange for repairs and funding for the position of the Astronomer Royal for Scotland and the Professor of Practical Astronomy at Edinburgh University.[42] Brisbane provided funding for Edinburgh Observatory to purchase a Dent transit clock in 1858, and Lady Brisbane offered it equipment on his death (Gavine (1981) pp178, 180). The catalogue of Brisbane's astronomical instruments that he owned at the time of his death filled six pages, including telescopes, clocks, thermometers, barometers and compasses. His clocks, in particular, were considered very good.[43]

Patronage and developing scientists

Brisbane's support for the career of James Dunlop is a well-known colonial example of his mentoring. Dunlop (born Dalry, Scotland 1793) was a natural, self-taught technician whom Brisbane took to New South Wales as his assistant. He trained Dunlop as an observer and Dunlop later returned to Scotland and worked with Brisbane at Makerstoun for four years. Brisbane proposed James Dunlop as a member of the Royal Society of Edinburgh, describing him as an eminent observer, whose scientific contributions would add to their published transactions. Brisbane noted that it would be difficult for Dunlop to pay membership fees and proposed him for free membership under the rules for deserving parties and this was accepted in 1831.[44] Dunlop returned to the colony in 1831 in charge of the Parramatta Observatory, a position he held until retiring in ill-health in 1847.[45]

Brisbane was a mentor of James David Forbes, a self-taught scientist, who became Professor of Natural Philosophy at the University of Edinburgh in 1833 at the age of 23. Forbes held the position until 1860, the year of Brisbane's death, when he succeeded Sir David Brewster as Principal of St Andrews University. Forbes was General Secretary of the Royal Society of Edinburgh for 20 years (Campbell and Smellie (1983) p45).

Forbes had approached Brisbane in 1830 for advice on purchasing astronomical equipment for the Royal Society of Edinburgh and requested his patronage for membership of the Geographical Society.[46] Brisbane supported the career of Forbes, admiring his 'superior qualifications on all subjects of science and analytical investigation but also many original discoveries, particularly the

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[41] *Minutes of the Council of the Royal Society of Edinburgh*, 26 November 1832.

[42] 1846/29 *JD Forbes Papers*, University of St Andrews.

[43] *Catalogue of the valuable astronomical and philosophical instruments of the late General Sir Thomas Makdougall Brisbane*, *Edinburgh* 1860, Royal Greenwich Observatory, Sussex.

[44] Minutes of the Council of the Royal Society of Edinburgh, 5 December 1831.

[45] H. Wood, James Dunlop (1793-1848) *Australian Dictionary of Biography*.

[46] LB 1 f.354, *JD Forbes Papers*, University of St Andrews.

polarization of heat'.[47] John Herschel supported Forbes at Brisbane's request, commenting that men capable of brilliant original research should be relieved from seeking an income while their brain was active so that they could pursue their researches.[48]

Forbes became a regular house-guest at Makerstoun where he used the observatory for his work. Forbes advised Brisbane on setting up the magnetic observatory at Makerstoun and put him in touch with Professor Humphrey Lloyd, Professor of Natural Philosophy at the University of Dublin who had been responsible for establishing magnetic observatories in Ireland in the 1830s.[49] Forbes was extensively involved in the superintendence of the project.[50] Following Brisbane's death it was Forbes who assisted the family in the sale and distribution of the astronomical equipment, again consulting Lloyd in Dublin about the fate of the magnetic observatory equipment.[51]

Brisbane's observatory at Makerstoun became a training ground for a generation of British astronomers. John Allan Brown was a pupil of Forbes, and Brisbane appointed him as astronomer for his magnetic observatory at Makerstoun. Both Forbes and Brisbane supported Brown's unsuccessful application for the chair of Practical astronomy in Edinburgh in 1844. Brown was subsequently Astronomer to the Travancore Sircar, India and Director of its Observatory from 1852-1865. John Welsh was 18 when he started work at Makerstoun under Brown's leadership from 1843 till 1849, then working for Brisbane in Edinburgh until 1850. Welsh was subsequently appointed Superintendent of the Kew observatory in London from 1852 to 1859.[52]

In conferring the medal of the Royal Astronomical Society on Sir Thomas Brisbane in 1828, it was noted that the first fruits of colonization were in so many lands rape and violence towards its 'unoffending inhabitants' but that in Australia through the work of Brisbane, the first triumph of colonisation was the peaceful one of science and useful knowledge for the future (MNRSN (1828)).

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The National Marine Science Centre, Coffs Harbour: a review of the first ten years of research

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Abstract

The National Marine Science Centre (NMSC) opened in 2002. At that time the establishment of the centre was a joint exercise of two universities – Southern Cross University (SCU) and the University of New England (UNE). By mutual agreement and with a financial payment to UNE, Southern Cross University took over sole operation of the centre in 2010. This review outlines the directions and outcomes of the NMSC over those ten years, in the achievements in research and the communication of that research. Research themes were established and maintained in marine ecology and biodiversity, reproductive ecology and regeneration in marine communities, human impacts and their management, fisheries management, and aquaculture. Later additions included responses of marine organisms to climate change, economics and governance of fisheries, and in an avenue of terrestrial ecology. The research outputs are grouped according to these themes and to the occurrence across the years. Personnel involved and the highlights of some of this research are presented.

Keywords: marine, ecology, invertebrates, corals, fisheries, aquaculture

Introduction

At the start, a prime function of the National Marine Science Centre (NMSC) was to establish undergraduate third year courses in marine science that would be suitable for the students of two universities. Much time and energy were spent on that goal and on the accompanying administrative procedures for both the teaching and the centre itself. Although the original concept of the subject matter for the undergraduate courses remains largely the same, the courses were continually appraised and revised to meet the needs of undergraduate training in marine science. In 2012 the NMSC offers eight third year units for the Southern Cross University (SCU) degree programs; with extra work the units can also be taken at Masters level.

In 2002, research began with inputs from two sources: 1) staff from the universities who were assigned to the centre or who had involvement with the supervision of postgraduate students at the centre and 2) staff from the Conservation Technology Unit of NSW Fisheries (now part of the NSW Department of Primary Industries). The Fisheries Conservation Technology Unit was based at the centre at the very beginning of the centre's operation in an agreement with NSW Fisheries, an arrangement that has continued as a prominent feature of the research activities.

Research themes in marine science were established for implementation at the outset and these included: biology, ecology and biodiversity; reproductive ecology and regeneration in threatened communities; management and human impacts; regional aquaculture and fisheries. The NMSC has been under the stewardship of three Directors over the ten years: Prof. Rod Simpson, Prof. Alistair McIlgorm, and Prof. Les Christidis. Each of these brought their own influence in relation to research themes, funding, and postgraduate training. Other marked influences on these three key components were personnel who had been stationed at the NMSC from its inception: Assoc. Prof. Steve Smith, and from NSW Fisheries: Dr Matt Broadhurst and Dr Paul Butcher. Other personnel have joined the centre since its beginnings, some have come and gone, and some staff gained their postgraduate qualifications while at the centre. Work within the initial themes has continued and been expanded to the present day and some themes have been added.

Research

Following the research activity over the ten years provides an outline of how these research themes developed, how emphases changed, and some significant highlights and features across that research

Table 1 gives the publications in refereed journals from the NMSC, grouped according to research themes. Table 2 lists these same publications in their categories as a numerical time sequence. Areas of particular strengths in research are indicated by the following summaries of refereed journal publications. Work in these areas was also augmented by numerous reports for commissioned research and by conference presentations, the numbers for which are listed in Table 3. To achieve these research outputs, extensive research grants from many funding sources have been obtained.

Marine Biology and Ecology – Invertebrates

Antarctic benthic ecology

One of the earliest topics of research, Antarctic benthic ecology, was brought to the NMSC by personnel transferred there. The work involved the ecology of benthic organisms and assemblages, the effects of human impacts on these organisms and assemblages, and the distribution of coastal species in the southern ocean (Smith 2002; Smith and Simpson 2002; Stark et al 2003, 2004; Lewis et al 2005; Simpson 2007). These research interests continued through to more recent work on trophic structures (Gillies et al 2012a, b).

Biology, patterns and processes, marine parks, tourism and conservation

Processes and patterns in coastal benthic ecology became a feature of the research at the NMSC. The work was often coupled with the measurement, monitoring and management of marine biodiversity. However, to allow this coupling much foundation work is required on basic ecology and patterns within and between benthic communities to provide the baseline studies on which to assess possible effects of different types of human impact on a range of marine biota (Smith and Rule 2002; Smith and Simpson 2002; Edwards and Smith 2005; Rule and Smith 2005, 2007; Hastie and Smith 2006; Smith et al 2008; Harrison and Smith 2012). The documentation of impacts and their effects is used as an essential stepping stone to effective management, and in assisting policy decisions through the provision of sound scientific data. Such work

Theme					
Marine biology and ecology – Invertebrates, seaweed	Corals and associated organisms	Biology, patterns and processes	Marine parks, tourism conservation	Antarctic ecology	Taxonomy, Chemistry
	Scott and Harrison 2005; Dalton and Godwin 2006; Scott and Francisco 2006; Dalton and Smith 2006; Carroll et al 2006; Scott and Harrison 2007a,b, 2008, 2009; Adjeroud et al 2007, 2010; Smith and Hattori 2008; Baird et al 2010; Purcell and Cheng 2010; Dalton et al 2010a,b; Harrison et al 2011; Smith 2011a,b; Dalton and Carroll 2011; Penin et al 2011; Bridge et al 2012; Hill and Scott 2012.	Smith and Rule 2002; Smith 2003, 2005, 2008; Edwards and Smith 2005; Rule and Smith 2005, 2007; Hastie and Smith 2006; Hacking 2007; Jones et al 2007; Townsend et al 2008; Malcolm et al 2010a; Purcell 2010b; Burns and Smith 2011; Harrison and Smith 2012.	Malcolm et al 2007, 2010b,c, 2011a,b, 2012; Smith et al 2008; Malcolm and Smith 2010; Scott et al 2011; Hammerton et al 2012; Smith 2012	Smith 2002; Smith and Simpson 2002; Stark et al 2003; Stark et al 2004; Hughes et al 2005; Lewis et al 2005; Simpson 2007; Gillies et al 2012a,b.	Peart 2006, 2007a,b; Hughes and Lowry 2006; Amaral et al 2008; Yerman and Krapp-Schickel 2008; Yerman 2009; Yerman and Coleman 2009; Liu et al 2012; Peters et al 2012

Table 1: Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

Birds and Mammals	Biology and ecology of seabirds, marine mammals	Terrestrial ecology and evolution			
	Clancy 2005a,b; Oxley and McKay 2005; Totterman and Harrison 2007; Franklin et al 2011	Christidis et al 2010, 2011; Jønsson et al 2010, 2011; Alström et al 2011; Williamson et al 2011; Letnic and Dworjanyn 2011; Driskell et al 2011; McBride et al 2012; Prober et al 2012			
Aquaculture and climate change*	Aquaculture – invertebrates	Aquaculture – fish	Climate change		
* Marine Environment	Liu et al 2004a,b,c, 2006, 2009; Troup et al 2005; Dworjanyn et al 2007; Byrne et al 2008; Dworjanyn and Pirozzi 2008; Mos et al 2011; Scott 2012; Swanson et al 2012	Black and Pankhurst 2009; Guy et al 2009; Rushworth et al 2011	Byrne et al 2009, 2010a,b, 2011; Sheppard et al 2010; McIlgorm et al 2010; Beger et al 2011; Doo et al 2012; Durrant et al 2012; Foo et al 2012; Prober et al 2012		

Table 1 (cont'd…): Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

Fisheries biology and management *refers to "unaccounted" mortality	Reviews and identification of fishing *mortality and reproduction	Modifications of existing gear to mitigate fishing *mortality	Modifications beyond existing gear to mitigate fishing *mortality	Modifications to operational, post-handling practices to mitigate fishing *mortality	Analysis of stocks in fisheries, fisheries organisation and economics
	Kennelly and Broadhurst 2002; Gray et al 2004, 2005b 2006; Broadhurst et al 2005b, 2006a,b, 2007a,b, 2011, 2012a,d,e; Butcher et al 2006, 2008a, 2010a,b, 2011a,b, 2012b; Pinhero et al 2006; Fischer et al 2007; McShane et al 2007; Hazin et al 2008; Hall et al 2009a,b, 2012; Uhlmann et al 2009; Dowling et al 2010; Roach et al 2011; Roberts et al 2011; Zagaglia et al 2011; Leland et al 2012	Broadhurst et al 2002a, 2003, 2004a,b, 2007c, 2012a,b; Macbeth et al 2004, 2005a,b,c; Gray et al 2005a,c; Rotherham et al 2006; Butcher et al 2008b; Graham et al 2009; McGrath et al 2011a,b	Broadhurst et al 2002b, 2004c, 2006c, 2009c, 2010, 2012a,c; Millar et al 2004, 2005; Scandol et al 2006; Macbeth et al 2007; Rotherham et al 2008; Broadhurst and Millar 2009, 2011; Silva et al 2011, 2012a,c	Macbeth et al 2006; Broadhurst et al 2005a, 2007, 2008a,b, 2009a,b, 2012b,c; Broadhurst and Uhlmann 2007; Butcher et al 2007, 2012a; Uhlmann and Broadhurst 2007; McGrath et al 2009; Reynolds et al 2009; Leland et al 2012	McIlgorm and Sykes 2008; Grafton and McIlgorm 2009; Kildow and McIlgorm 2010; Purcell 2010a; Purcell et al 2011; Purcell and Samya 2012

Table 1 (concl.): Research Outputs (refereed – journals, chapters, books) from the SCU National Marine Science Centre.

THEME	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 (AUG)	OVERALL TOTALS
Marine Biology and Ecology – Invertebrates and Vertebrates	3	2	1	9	7	11	7	3	10	11	10	74
Fisheries Biology, Management, Economics	3	1	6	9	9	9	7	11	5	9	12	81
Aquaculture and Climate Change			3	1	1	1	2	4	4	4	5	25
Terrestrial Ecology and Evolution									2	6	2	10
Yearly Totals	6	3	10	19	17	21	16	18	21	30	29	190

Table 2: Numbers of refereed publications (journals, chapters, books) from the NMSC across the years, grouped by broad themes.

	Time Period											
	2002		**2003**		**2004**		**2005**		**2006**		**2007**	
	Rpts	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**
Marine Biology and Ecology - Invertebrates and Vertebrates		4		16	1	7	3	8	4	19	9	10
Fisheries Biology and Management				1	1	4	6	1	3	6	4	3
Aquaculture and Climate Change		1		2		1				1		1
Overall Yearly Totals		**5**		**19**	**2**	**12**	**9**	**9**	**7**	**25**	**13**	**14**

Table 3: Numbers of scientific and technical reports (Rpts) and conference presentations (Cfs) from the NMSC across the years, grouped by broad themes.

	Time Period											
	2008		**2009**		**2010**		**2011**		**2012** (August)		**Overall Totals**	
	Rpts	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**	**Rpts**	**Cfs**
Marine Biology and Ecology - Invertebrates and Vertebrates	3	9	2	1	3		4	2		2	30	78
Fisheries Biology and Management	5	4	2	3		3		2			21	27
Aquaculture and Climate Change	1				1	2	1		5		8	8
Overall Yearly Totals	**9**	**13**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**2**	**59**	**113**

TABLE 3 (cont'd…): Numbers of scientific and technical reports (Rpts) and conference presentations (Cfs) from the NMSC across the years, grouped by broad themes.

was applied to management of the coastal zone in NSW, but the main application has been in conservation planning for marine parks. The research has involved collaboration with external parties, primarily involving Assoc. Prof. Steve Smith. Often, owing to the objectives of the work, team members are from government agencies, from local to federal. The fostering of these collaborations had the additional benefit of ensuring connections to contemporary issues, relevant to concerns across marine parks, tourism, and conservation. Significant works include: (1) marine park management (Smith 2005, 2008; Malcolm et al 2010c; Malcolm et al 2011a,b; Malcolm et al 2012; Malcolm and Smith 2010) and (2) marine debris and conservation (Smith and Hattori 2008; Smith et al 2008; Smith 2008, 2012)

Taxonomy, chemistry

Collaboration with the Crustacean section of the Australian Museum resulted in significant contributions to taxonomy within the amphipod group (Hughes and Lowry 2006; Peart 2006; Peart 2007a, 2007b; Yerman and Krapp-Schickel 2008; Yerman 2009; Yerman and Coleman 2009)

Recently, there has been participation in research in the chemical properties of marine organisms. Liu et al (2012) undertook a comprehensive review of the bioactive compounds in Sargassum seaweed and the implications for Chinese medicine. Peters et al (2012) investigated the properties of bacterial communities on the surface of molluscan egg cases, in relation to their protective value.

Corals and associated organisms

The NMSC is ideally located at a marine transitional zone where warmer waters from the north meet cooler southern waters from the south. The offshore region has many tropical species that reach their southernmost distribution. This transitional feature in the offshore marine environment was one of the main components of the rationale to establish the Solitary Islands Marine Park. It followed that the biology and ecology of corals and associated organisms became another prime feature of the research at the NMSC, with a foundation provided by Prof. Peter Harrison, Dr Anna Scott and Dr Andrew Carroll, encompassing the reproductive and regeneration theme. This has included some highly innovative research on the spawning times, larval development, settlement and metamorphosis of two species of sea anemone that provide essential habitat for anemonefishes (Scott and Harrison 2005; 2007a, b; 2008; 2009). Within that research work a novel biopsy sampling method outlined in Scott and Harrison (2009) provides an opportunity to gain a more thorough understanding of the gametogenic cycles and sexual patterns of host sea anemones throughout their distribution. Work is now being done on developing optimal methods for the culture of host sea anemones in captivity (Scott 2012), and other aspects of the anemone/anemonefish symbiosis are being investigated (Scott et al 2011, Bridge et al 2012, Hill and Scott 2012). Research on the corals of Polynesia has also been undertaken in collaboration with French scientists (Carroll et al 2006; Adjeroud et al 2007, 2010; Penin et al 2011). Investigation into coral reef organisms was also extended to the effects of thermal stress on corals, and to diseases of corals by Dr Steve Dalton. An infectious disease was identified that was temperature dependent and this formed an important component in the assessment of impacts on hard corals in a sub-tropical environment (Dalton and Smith 2006; Dalton et al 2010a,b; Dalton and Carroll 2011). Work has also been undertaken on the management of coral reefs (Purcell and Cheng 2010; Beger et al 2011).

Aquaculture and climate change

Facilities for aquaculture were set up from the start and the initial research was via collaboration between Prof. Simpson and postgraduate students stationed either at NSW Fisheries or at private enterprises. The work covered abalone, oysters, bream, and the freshwater silver perch (Liu et al 2004a,b,c; Liu et al 2006; Liu et al 2009; Troup et al 2005; Black and Pankhurst 2009; Guy et al 2009). Results were also often reported to funding bodies (Table 3). Aquaculture continued on organisms such as sea urchins, fish, aquarium species and seaweed with Dr Symon Dworjanyn, Dr Jeff Guy, Dr Ken Cowden, and Dr Steve Purcell joining the NMSC (Dworjanyn et al 2007; Dworjanyn and Pirozzi 2008; Byrne et al 2008; Mos et al 2011; Rushworth et al 2011; Scott 2012; Swanson et al 2012). Again, much work has also been presented as reports (Table 3).

In 2009 the NMSC aquaculture infrastructure was used in the establishment of an ocean acidification and warming facility. In this facility future ocean conditions can be simulated using flow-through seawater, allowing tests of the physiology and adaptive capacity of marine organisms in response to consequences of predicted climate change. Work from this facility has shown how ocean warming and acidification might interact to impact on the early development and larval phases of sea urchins (Byrne et al 2009; Byrne et al 2010a,b; Sheppard et al 2010; Byrne et al 2011; Doo et al 2012). It appears that very early development of invertebrates may be more affected by warming; at later calcified larval stages warming may mitigate the negative effects of acidification until a thermal threshold is reached after which there are additive negative effects of both these stressors. In recent work it has been shown that some sea urchin larvae exhibit genetic variation to both warming and acidification (Foo et al 2012). The facilities for aquaculture and climate change work have been further upgraded in 2011-2012, ready for increased targeted research in this area, particularly on adaptations shown by sea urchins and on species interactions.

Birds and mammals

Seabirds and marine mammals

Work on seabirds and mammals came about from postgraduate students either assigned to the centre or supervised by staff or associated personnel (Clancy 2005a, b; Oxley and McKay 2005; Totterman and Harrison 2007; Franklin et al 2011). Although such research is distant from the core themes of the centre, this illustrates another facet in the centre's operations; in that it provides associated personnel and excellent facilities for projects that may be one-off or directed towards regional topics.

Terrestrial ecology and evolution

When Prof. Les Christidis joined the centre, he established a research program in the terrestrial sphere as applied to birds, focussing on a newly emerging area of conservation biogeography. The research emphasizes the importance of conserving the ecological and evolutionary processes that will generate future diversity; a research topic that extends the greater concentration of conservation work on extant biodiversity (Christidis et al 2010; Jønsson et al 2010, 2011; Alstrom et al 2011; Christidis et al 2011; Driskell et al 2011; Williamson et al 2011; McBride et al 2012; Prober et al 2012).

Fisheries Biology and Management

NSW Department of Primary Industries

The Fisheries Technology Conservation Unit of the DPI has been the mainstay of the fisheries biology and management research at the NMSC. Personnel stationed at the NMSC include Dr Matt Broadhurst (head of the unit), Dr Paul Butcher, and Dr Karina Hall, and they also collaborate with other national and international researchers in this field. The research of the unit is focussed on fishing mortality for both commercial and recreational fisheries, particularly for New South Wales, and is applied to fish and prawns. The work is centred on unaccounted mortality, that is, the mortality from fishing apart from what is reported as landed catch. There are a number of possible causes for unaccounted mortality and the research of the unit at the NMSC involves four stages in an investigation of the principal causes. Some key papers across those stages are cited here and a full list is given in Table 1. These stages are: (1) reviews and identification of the potential for problematic unaccounted fishing mortality (Kennelly and Broadhurst 2002; Gray et al 2004; Broadhurst et al 2005, 2006a, 2007b, 2012a; Butcher et al 2006, Butcher et al 2008a, Hall et al 2009b, 2012; Butcher et al 2010b, Butcher et al 2011b) (2) modifications of existing gear to mitigate fishing unaccounted mortality (Broadhurst et al 2002a, 2003, 2004b, 2007c; Macbeth et al 2005a,c; Rotherham et al 2006; McGrath et al 2011b; Butcher et al 2012) (3) modifications beyond existing gear to mitigate fishing unaccounted mortality (Broadhurst et al 2002b, 2004c, 2005, 2010, 2012c; Millar et al 2004; Broadhurst and Millar 2011; Rotherham et al 2008; Silva et al 2011) and (4) modifications to operational and post-handling practices to mitigate fishing unaccounted mortality (Macbeth et al 2006; Broadhurst et al 2007a, 2008b, 2009a; Butcher et al 2007, 2012a; McGrath et al 2009; Leland et al 2012). These four stages represent a well-developed application of fisheries science to address a sequence of what is known, how can existing methods be improved, what new methods might be suitable, and how to improve actual practices. The findings not only appear in the scientific literature (Table 1) but are also applied to newsletters, handbooks, and reports for the use by the fishing industries and these are enumerated in Table 3.

Other fisheries work

Research on sea-cucumber fisheries was introduced to the NMSC by Dr Steve Purcell. Although, much of the work applied to the Pacific region, analysis has also been applied to the sea-cucumber fisheries globally (Purcell et al 2011). The first comprehensive book on managing sea-cucumber fisheries was produced for the UN's Food and Agricultural Organisation (Purcell 2010).

During his term as Director, Prof. Alistair McIlgorm brought a new field of research expertise to the NMSC – economics and governance in the fishing industry (Grafton and McIlgorm 2009; McIlgorm and Sykes 2009; Kildow and McIlgorm 2010; McIlgorm et al 2010). The work gained international recognition on the importance of measuring the marine economy (Kildow and McIlgorm 2010) and on the challenges from governance and climate change in fisheries management (McIlgorm et al 2010). The research also produced many reports on the economics behind the control of marine resources and the care of the marine environment for government institutions and the Asia-Pacific region.

Postgraduate projects

Training the researchers of the future through postgraduate programs has been a prominent feature of the activities at the NMSC since its inception. Table 4 lists the completed research degrees (MSc (10) and PhD (21)) across the years and according to the research themes at the NMSC. Also, there have been 25 honours students, each with an investigative project, over that time. The apparent anomaly in the high number of completed PhDs in the 2005-2007 time slot can be explained by the high number of honours and postgraduate students brought to, and attracted to, the centre by Prof. Rod Simpson and Assoc. Prof. Steve Smith in the first years.

Research outside of the scientific literature and engagement with professional bodies

Personnel at the NMSC have been actively engaged in conducting research for a number of organisations, primarily for governmental bodies. Over all, the topics fall within the same areas of expertise as illustrated by the publications in the scientific literature. There are numerous reports from such work and the numbers are shown in Table 3, grouped according to the research themes. Many of these reports are extensive with peer review scrutiny. Also in Table 3, the numbers of conference presentations are similarly grouped in the research themes. Among the conference presentations there have been five keynote addresses. As to be expected, the numbers of conference presentations in any

Theme	Time Period								Overall Totals	
	2002-2004		2005-2007		2008-2010		2011-			
	MSc	PhD	MSc	PhD	MSc	PhD	MSc	PhD	MSc	PhD
Marine Biology and Ecology - Invertebrates and Vertebrates	1	2	1	8		3		2	2	15
Fisheries Biology and Management	1		1	2	2	1	2	1	6	4
Aquaculture	1		1	1		1			2	2
Overall Totals for Time Periods	**3**	**2**	**3**	**11**	**2**	**5**	**2**	**3**	**10**	**21**

Table 4: Completed Research Postgraduate Awards with supervision at NMSC.

year tend to be related to the occurrence of conferences dealing with the research themes.

Research personnel of the NMSC have been active in many professional societies and advisory committees over the ten years. This involvement has ranged across all the research themes and has included participation in environmental management groups that were formed to address specific concerns. Some notable examples of the latter are: Assoc. Prof. Steve Smith (advisory groups for estuarine and nearshore ecological health); Dr Anna Scott (organisational roles for the Coral Reef Society); Prof. Alistair McIlgorm, Dr Steve Purcell (working groups for the Asia Pacific region).

Communication of research findings to the general community

There has been wide-ranging communication of research work at the NMSC to the general community, via public talks at the centre, local and national media interviews, presentations to a wide selection of clubs and societies, and newspaper and magazine articles. In particular, researchers in the Conservation Technology Unit working on recreational fisheries make regular contributions to a number of fishing magazines, alerting the fishing world to relevant findings.

The aquarium at the NMSC had modest beginnings with two central tanks for viewing by the public. From 2006, the aquarium facilities have been greatly expanded to allow an entrance fee display for the public. It also provides an educational role by displaying research projects and findings as well as information and films about the marine environment and its resources. For schools, there are educational activities for class participation.

Summary

The NMSC has had a very successful first ten years. Although its physical establishment was made possible by way of a grant from the federal government, the operation and the concomitant financial support of the centre were the responsibilities of two universities at the outset and, later, solely that of SCU. The progress of activities at the NMSC in the early years always had difficulties through the differing agendas of two universities. After UNE retreated to its inland rural base, the NMSC has received increased support for the facilities and staffing via the more marine orientated SCU which now had a better focus with definite ownership.

The outputs and involvement in research have been very impressive for such a small number of research staff located at the NMSC, which was four at the beginning, increased to twelve by 2009 and stands at seventeen (including four adjunct appointments) in 2012.

With the opening of new facilities in 2012, the NMSC is poised for increases in personnel and for further advances in productivity in the established research themes across regional, national and international spheres.

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The influence of saline concentration on the success of Calcein marking techniques for hatchery-produced Murray cod (*Maccullochella peelii*)

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Abstract

Chemical marking is a useful technique to determine natal origin of fish and is increasingly used to determine the success of fish stocking programs. This study sought to optimise an osmotic-induction batch marking technique, using the calcium-binding chemical, Calcein, to enable future identification of hatchery-marked Murray cod (*Maccullochella peelii*). It was hypothesised that higher saline concentrations would create a more reliable bone mark but it was unknown whether saline exposure would influence fish survival. A laboratory trial was undertaken to determine the optimum saline concentration required to maximise survival of Murray cod and marking of bony body parts. Fish were exposed to a no salt control, a no Calcein control or one of three different saline concentration treatments then housed in either 60 L aquarium tanks or hatchery ponds and monitored for 43 days post marking. There was no significant difference in mortality rates among the three treatments under controlled aquarium conditions or among marked fish released into hatchery ponds. Whilst saline concentration did not influence fish survival, marking using concentrations less than seawater produced a detectable mark and reduced stress on Murray cod fingerlings. Mark intensity, however, was greater when fish were exposed to higher saline concentrations.

Introduction

Fish stocking is used globally as the most common management tool to increase recreational fisheries following decline or overharvest (Cowx, 1994; Halverson, 2008). Restocking activities aim to either create new recreational opportunities or improve existing fisheries but few studies are undertaken pre or post-stocking to determine overall effectiveness (Verspoor and De Garcia Leániz, 1997; Pearsons and Hopley, 1999). Discrimination between hatchery-reared and wild fish would substantially assist assessment of stocking success (Crook et al., 2012) but validated techniques are largely unavailable for many recreational species (Crook et al., 2007). Techniques relying on chemical marking agents, such as calcein (2,4-bis-[N,N'–

di(carbomethyl)- aminomethyl]fluorescein) and oxytetracycline, that mark otoliths and other calcified tissues have been developed (Crook et al., 2012) and are routinely used as a means of monitoring fish stocking programs (Johnson, 2005). There is concern about the retention rates of calcein in different species (Crook et al., 2012). There is a subsequent need to verify appropriate marking techniques for each new species that is considered.

Murray cod (*Maccullochella peelii*) is an iconic species within the Murray-Darling River system (Australia) that has experienced substantial declines in recent times (Allen *et al.*, 2009). Historical populations supported a large-scale commercial fishery but declining catches led to an eventual fishery closure (Rowland, 2005). Efforts to recover the species focus largely on restrictive harvest controls for recreational fishers (Allen *et al.*, 2009) or restocking activities (Rowland, 1988). Over nine million Murray cod fingerlings have been stocked into the Murray-Darling Basin since commercial-scale hatchery production of Murray cod commenced (Rourke et al., 2011). There has been no structured effort to quantify stocking program success and no suitable technique developed to distinguish wild and stocked fish. The lack of an effective marking technique is presently limiting efforts to determine stocking success throughout the natural range of this species.

Several techniques to discriminate hatchery and wild fish exist but the most successful, and widely accepted, is chemical marking (Coghlan *et al.*, 2007; Hill and Quesada, 2010). The main benefits of chemical marking are a reduced requirement to handle and transport fish and that many fish can be marked over a very short time period (Nielsen, 1992). Most chemical marking techniques focus on staining the otolith and therefore require fish to be sacrificed in order to determine natal origin (Crook et al., 2007). Non-lethal identification techniques are therefore preferred, and in recent years osmotic induction has been widely used to apply a reliable long-term mark (Smith et al., 2010).

Osmotic induction requires fish to be immersed in a hyperosmotic solution to effectively 'dehydrate' cells (Smith et al., 2010). Fish are then placed within a chemical marking bath, usually containing Calcein, and all bony structures within the fish retain a permanent chemical signature (Guy *et al.*, 1996; Mohler, 2003). Calcein binds with alkaline earth metals and causes calcified parts of organisms (e.g., otoliths, fin spines and scales) to fluoresce when examined under an ultraviolet light source (Wilson et al., 1987). Subsequent capture and identification of live Calcein marked individuals has determined excellent retention rates for salmonid species up to twelve months (Frenkel *et al.*, 2002; Mohler, 2003; Negus and Tureson, 2004; Crook *et al.*, 2007). Similarly, external marks have been demonstrated in live percichthyids for up to 100 days (Crook et al., 2009), and salmonids for up to 19 months (Game and Wildlife Trust, Unpublished Data).

Immersion into a saline bath for extended periods could have substantial physiological impacts on fish and exert stress which could influence post-marking survival and it is generally accepted that many freshwater taxa have critical levels of salinity tolerances (Hart et al., 1991). Saline impacts are classified as either lethal, where fish may die following contact, or sub-lethal, where fish exhibit adverse physiological responses but eventually recover (Chessman and Williams, 1974; Kefford *et al.*, 2004). Sub-lethal effects are relevant to batch marking studies. Fish may exhibit stress during the marking process and make an apparent recovery but could have sustained physiological damage during saline immersion. Murray cod exposed to sub-optimal water quality are known to exhibit epithelial cell degeneration and mucous membrane sloughing (Schultz et al., 2011). Recovery from these conditions can be slow. If exposure to a saline bath elicits a similar physiological response, it may influence post marking survival and exclude chemical marking as a useful technique for this species.

This study sought to identify impacts of saline exposure to osmotically-induce Calcein marks in Murray cod fingerlings. It was expected that higher concentrations of salinity could influence fish welfare through increased osmotic stress which may influence post-release survival. Fish were marked using a range of salinity concentrations to facilitate osmotic induction of Calcein. Post release survival of fingerlings was monitored for up to 57 days under pond and aquarium conditions. Physiological responses were also monitored through regular random sampling to determine potential immune system repression resulting from saline bath exposure. The overall aim of this project was to identify an optimal saline concentration that could maximise success of Calcein batch marking programs, as indicated by mark intensity and survival rates for Murray cod fingerlings.

Methods

Study location

The study was carried out at the Narrandera Fisheries Centre (NFC) which is located four kilometres south east of Narrandera, New South Wales in south-eastern Australia. Juvenile Murray cod were sourced from a commercial hatchery (Uarah Fisheries) and were transferred to the experimental facility and allowed to acclimate for five days prior to commencement of experimental procedures.

Laboratory trials

Fish were Calcein marked using an osmotic induction method modified from Crook *et al*, 2009. Fish were first placed in a saline treatment bath for at least three minutes, then briefly rinsed in freshwater before being transferred to a 0.5 % Calcein solution for a further three minutes (Figure 1). Saline baths for an experimental control (Group A – 0 % salt) and three different treatment regimes (Group B – 1 % salt; Group C – 3 % salt and Group D – 5 % salt) were prepared by dissolving coarse natural salt (Lake Charm Salt Co.) into 10 L of hatchery water. Group C sought to replicate a salinity close to that of seawater (Doroudi *et al.*, 2006) whilst Group D represented higher salinity than seawater (1.5 times) which was consistent with salinity levels commonly used to osmotically induce chemical marks in other species (Mohler, 2003; Crook *et al.*, 2007; Smith *et al.*, 2010). A 0.5 % Calcein solution was prepared by adding 50 g of Calcein powder (Sigma Aldrich) to 10 L of hatchery water. Previous work on another percichthyid species, Golden perch (*Macquaria ambigua*) determined that altering Calcein concentration had no effect on mark intensity (Crook et al., 2009). On this basis it was subsequently decided to maintain a consistent Calcein concentration (0.5 %) for each experimental treatment.

Fish were immersed into control and treatment saline baths for a total of three minutes prior to Calcein marking for all except treatment group B. These fish were held in the 1 % salt solution for one hour (60 min) prior to marking. This treatment was included to replicate standard hatchery preventative practice to reduce the likelihood of fungal or bacterial infection with Murray cod fingerlings. If standard preventative practice saline concentrations elicited a strong mark on Murray cod fingerlings, then batch marking could be simplified and incorporated into normal hatchery practices without requiring additional handling.

A total of 1,120 Murray cod were marked in four treatment groups of 280 fish (3 months old, average weight 1.35 ± 0.2 g. Following marking, fish were transferred to a large freshwater tank (2000 L) to rinse excess Calcein, and to recover for two hours post-marking (Figure 1). Following recovery, fish from each treatment were divided into 28 sub-groups of 10 fish. Each sub-group was placed in one of 28 glass aquaria (60 L) which had been partitioned into four separate, equally sized zones using 3 mm black polyethylene mesh (Figure 1). Aquariums were individually numbered and each zone randomly designated as A, B, C or D according to experimental treatment. A standard sized house brick with 14 holes was placed into each zone to provide habitat for the fish. Two additional aquaria were stocked with 10 Murray cod fingerings that were not exposed to either saline conditions or immersed into Calcein. These fish were untreated controls and used to compare against Group A for any potential effect from Calcein immersion.

Aquaria were maintained in a temperature controlled room (22.8 ^{o}C) with fish fed Skrettings Gemma Diamond 1.5 mm dry diet (57 % protein, 15 % oil) three times per week. Fish were inspected daily with any dead fish removed, recorded and stored in 10 % buffered formalin. Each tank was cleaned and had a 25 % water exchange once a week during the trials. After approximately 11 days in the tanks an outbreak of white spot disease (caused by the ectoparasite *Ichthyopthirius multifilus*) was observed. To control this disease aquarium water was maintained at 0.5 % salt solution for the remainder of the experiment.

Uncontrolled pond trials

Assessment of fish survival under controlled laboratory conditions may not be directly applicable to standard stocking operations. It was determined that wild-released fish would be subjected to water quality changes which may be influenced by the marking technique. To replicate a more-natural release scenario, hatchery fry ponds were used to house a further 600 Murray cod (3 months old, average weight 1.40 ± 0.2 g) which were Calcein marked according to methods described for Treatment C (3 % saline solution and three minute immersion).

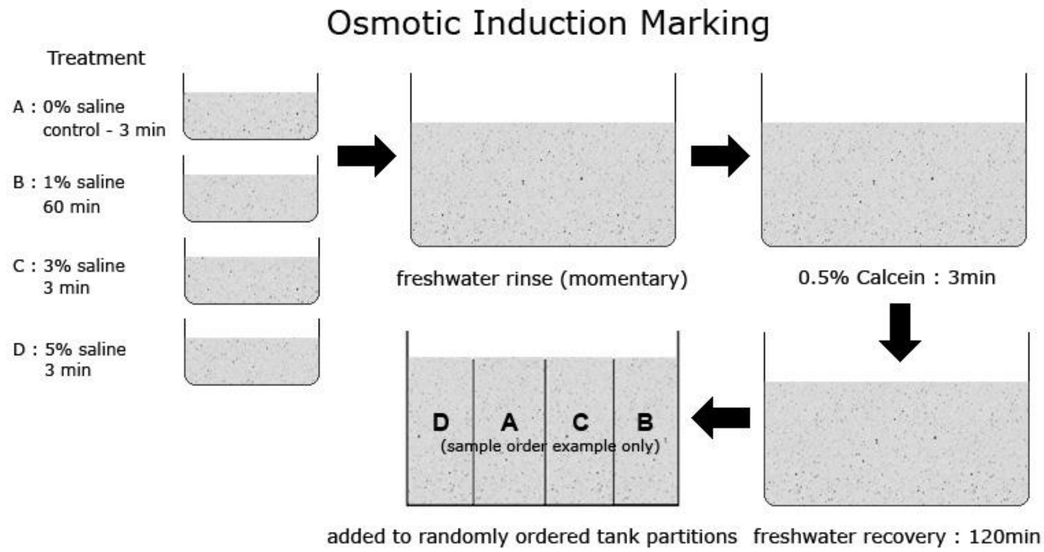

Figure 1: Schematic representation of the experimental approach. Fish from each replicate were allocated to a salinity concentration treatment, momentarily rinsed in freshwater, and then placed into a Calcein bath.

A further 600 Murray cod were exposed to conditions consistent with Treatment C but not exposed to Calcein. This sought to control for any potential effects arising from Calcein immersion. Insufficient fish were available to replicate all four experimental groups and treatment group C was selected after a preliminary analysis of aquaria data. Fish were counted into groups of 30 marked and 30 unmarked fish and then placed into one of twenty cages (0.91 m x 0.91 m x 0.71 m) situated in two fry rearing ponds. Each cage received approximately 10 g of blood worm (distributing organisation Aqua-One) every second day to supplement any natural food that may have entered the cages from the pond.

After 57 days fish were removed from the cages, anaesthetised with Benzocaine (100 gL^{-1}; Pharmaq Ltd), and examined under UV light to determine mark retention. The number of marked and unmarked fish returned from each cage was recorded.

Mark detection strength

Rather than just report whether marking was achieved or not, we used mark intensity as a surrogate for longevity of the mark following Negus and Tureson (2004) who found marks of greater intensity persisted longer in Chinook salmon. Intensity was quantified using a battery-operated general purpose modulated probe fluorometer (GFP meter; Opti-Sciences Inc., Hudson, New Hampshire). After calibration using standard compounds with known ppm fluorescein, the meter reports fluorescence intensity in 'tics' in the range from zero to 1,800 (maximum detectable limit). Any values exceeding the maximum detectable limit returned as a system overload, at which point the maximum value of 1,800 was assigned for statistical analyses.

Mark intensity was assessed following the completion of controlled aquaria trials. Five fish were removed from each control and treatment group. One intensity reading (ppb fluorescein) was taken from the inner operculum, anal spine and jaw of each fish and recorded for later analysis.

Data analysis

All data analyses were performed using the SAS software package and statistical tests were considered significant at $P < 0.05$.

Laboratory trials

A generalised linear model using a probit link function for a binomial distribution was used to compare fish survival between the four different laboratory salinity treatments (A, B, C, D). The proportion of survivors in each treatment at the conclusion of the laboratory trials (after 43 days) was compared among treatments after the effect of tanks was partitioned. Wald confidence intervals were calculated for these four adjusted survival rates.

Pond trials

A generalised linear model using a probit link function for a binomial distribution was fitted to assess the survival rate of Calcein marked individuals with non-marked fish in hatchery ponds (after 57 days). In this analysis, the proportion of marked and unmarked fish were compared after the partitioning out the effects of each pond and the cages which were treated as randomised blocks nested within the ponds.

Mark detection strength

A mixed linear model was used to compare the fluorescence tics returned from different body parts in the different treatments 43 days post-tagging. Treatment (A, B, C or D) were treated as fixed effects and fish were considered experimental subjects. Fluorometer readings from each body part (inner operculum, anal spine and jaw) were treated as repeated measures taken from each fish. The fluorescence measurements were log (base10) transformed and the assumptions of normality and homoscedastic variances confirmed by inspection of the residuals. Significant effects were followed up by comparing the least squares means in each treatment group against the control (Group A) for each body part using Dunnett's adjustment for multiple comparisons to maintain the family-wise error rate at 0.05.

Results

Immediate response

Fish exposed to low salinity concentrations (Control group A or Treatment group B and C) exhibited few signs of distress, maintained equilibria and demonstrated excellent flight response during saline bath exposure. Fish exposed to relatively high saline concentrations (Treatment group D) exhibited signs of distress, including increased opercular beat rate and some degree of equilibrium loss during saline immersion. Fish visibly recovered within one hour of immersion and no fish died during the marking process or in the immediate post-marking period during transportation to ponds or aquaria.

Laboratory trials

There was a significant tank effect in the experiment ($\chi^2 = 120.1$, df = 18, $p < 0.0001$) After removing the tank effect, the average survival rate varied between 72 % (Control group A), 66 % (Treatment group B), 58 % (Treatment group C), and 74 % (Treatment group D), however survival rates were not significantly different between the four treatments ($\chi^2 = 1.24$, df = 3, $p = 0.75$) (Table 1).

Treatment	Lower 95% CL	Average survival rate	Upper 95% CL
A (0% control)	0.49	0.72	0.95
B (1% saline)	0.45	0.66	0.88
C (3% saline)	0.37	0.58	0.79
D (5% saline)	0.52	0.74	0.96

Table 1. Average survival rate (and 95% confidence limits) of Murray cod fingerlings exposed to four treatment groups A (0% saline control), B (1% saline solution for 60 minutes), C (3% saline solution for 3 minutes) and D (5% saline solution for 3 minutes).

A white spot outbreak was detected in several aquaria after 11 days. Fish from all treatments were infected, including the Calcein-immersion controls (n = 3 fish). Five aquaria were removed from the experiments because of increased mortality rates from white spot. The experimental groups experienced similar mortality over the seven day period whilst the infestation was contained (Group A, n = 13 from 9 tanks; Treatment B, n = 19 from 11 tanks; Treatment C, n = 24 from 12 tanks; Treatment D, n = 17 from 11 tanks).

Uncontrolled pond trials

There was no significant difference in the survival rate between the two ponds ($\chi^2 = 0.05$, df = 1, p = 0.50) or between fish that were Calcein marked or not ($\chi^2 = 1.63$, df = 1, p = 0.20). After removing the pond effect, 92.3 % of Calcein marked fingerlings survived compared to 90.2 % of unmarked fingerlings.

Mark detection strength

Strong mark detections were recorded from all three body parts (Figure 2). There was a significant difference in the mean tics returned from each experimental group which was dependent on which body part was being measured ($F = 13.7$, df = 6, 24, $p < 0.001$). Follow up comparisons indicated that experimental groups A and B did not differ but both had significantly lower tics than treatments C and D from jaw and anal spine readings (Figure 3). Measurements taken from the inner operculum did not differ among any of the saline treatment groups.

Discussion

Changing salinity concentration had little impact on Murray cod fingerling mortality. No significant differences were observed under pond or controlled aquarium conditions during the post-marking observation period suggesting that salinity concentration had no effect on survival of Murray cod fingerlings. A major expectation from fisheries managers is that chemical marking could become a reliable tool to determine stocking success (Mohler, 1997). Further research is therefore required to ensure that chemical marking does not influence long-term survival, and that the chemical mark is reliable and detectable over longer timescales.

Most mortality observed in the post-marking period was attributed to a white-spot outbreak. A prophylactic salt treatment was subsequently applied and infected fish recovered rapidly so the trial continued. It was originally hypothesised that a potential effect of saline immersion could be epithelial cell destruction or mucous membrane degradation which may influence immune system efficiency. There are four pieces of evidence which suggest the experimental trials did not contribute to the disease outbreak.

Firstly, the disease outbreak infected saline immersion controls and treatment groups which suggest that infection was not correlated with exposure to a saline bath.

EXPERIMENTAL GROUP	ANAL SPINE	JAW	INNER OPERCULUM
A (0% saline control)			
B (1% saline)			
C (3% saline)			
D (5% saline)			

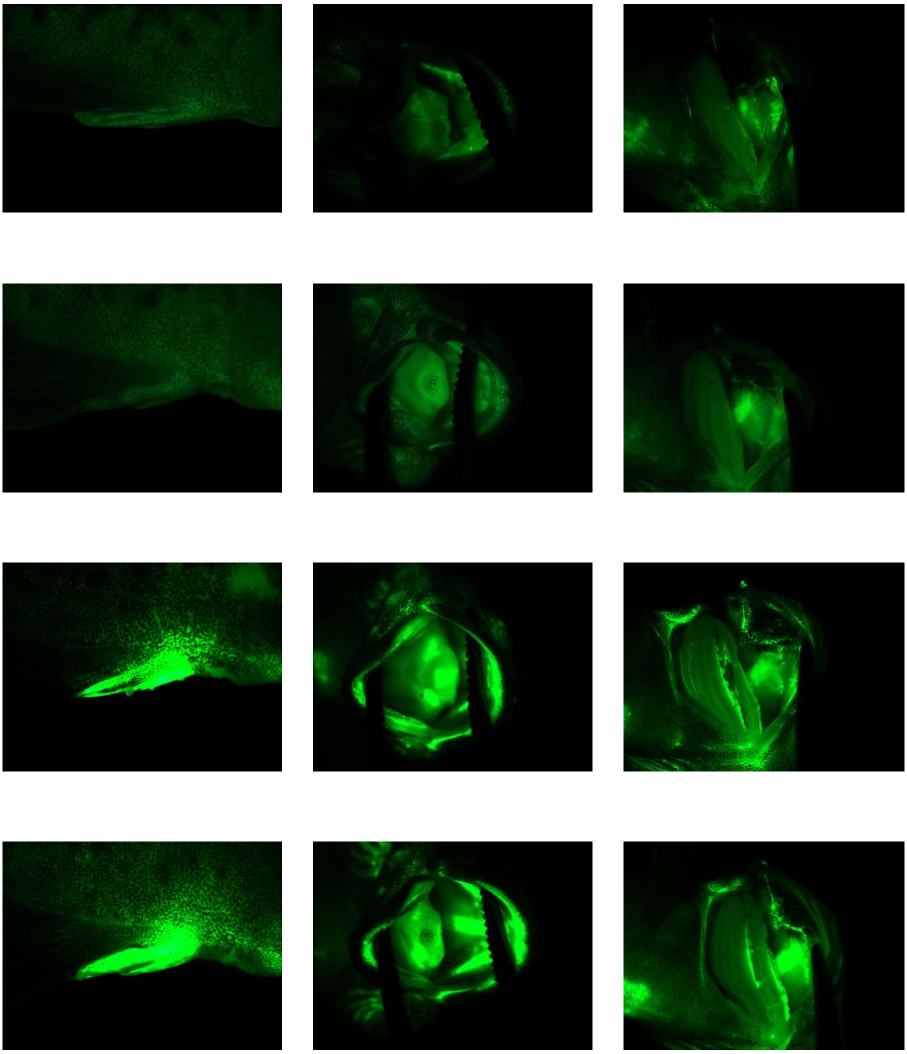

Figure 2. Stereo microscope images of Calcein-marked Murray cod. Images show the interaction between experimental group (and hence salinity concentration) and the strength of fluorescence from various body parts of juvenile Murray cod. (Images converted to greyscale and examined with a Leica M165FC with GFP3 UV filter).

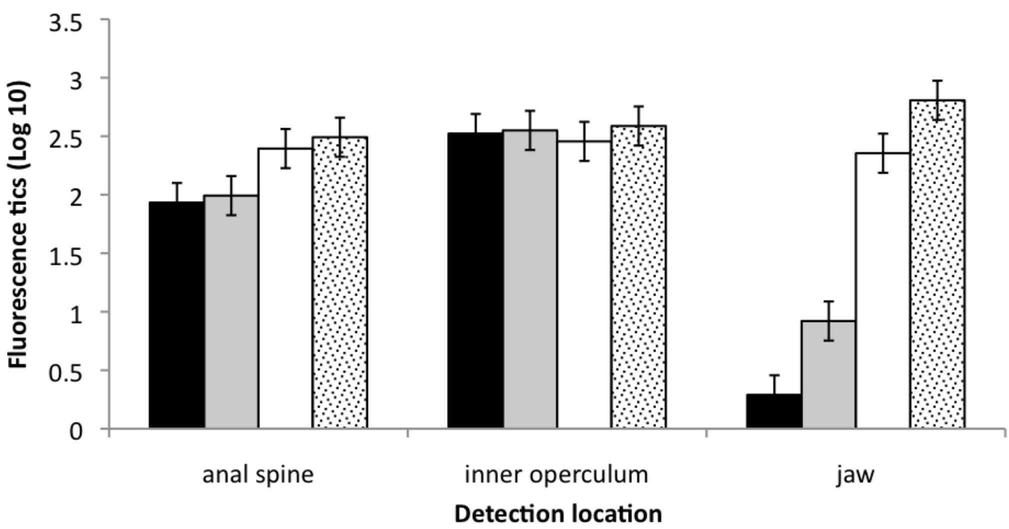

Figure 3. Comparison of fluorometer readings returned from different body parts of fish from each experimental group. Mean fluorescence tics were log (base 10) transformed for subsequent analysis. Treatment groups are defined as A (0% saline control - black), B (1% saline solution for 60 minutes - grey), C (3% saline solution for 3 minutes - white) and D (5% saline solution for 3 minutes - mottled).

Secondly, fish within the Calcein controls also succumbed to the disease suggesting that immersion in the marking chemical was also unlikely to have facilitated the outbreak. Third, low mortality was recorded from both marked and unmarked fish from the hatchery pond trials where fish were not held under controlled conditions. Finally, juvenile Murray cod are aggressive, territorial and are known to be susceptible to white spot disease if stressed when held under relatively high densities (Rowland and Ingram, 1991). The observed levels of mortality likely resulted from these behavioural responses rather than experimental effects. This justified the application of a prophylactic treatment to continue the experiment.

Australian biota are known to possess some tolerance to hypersaline conditions but most lethal effects are not observed until concentrations are many times that of sea water (Hart *et al.*, 1991; Doroudi *et al.*, 2006). For example, the LD50 of Murray cod in saline water is shown to be 15,700mg/L. (James et al 2003). Juvenile Murray cod exposed to saline levels equal to or lower than sea water were relatively unaffected by the saline immersion technique. Treatment groups exposed to salinity levels greater than seawater experienced substantial stress responses during saline immersion. These observations suggest juvenile Murray cod have an inherent intolerance to highly saline conditions. The implications of this are important for osmotic induction techniques. Firstly, this means that saline bath concentration needs to be carefully prepared and that salinity levels should be assessed prior to immersion. This would prevent the possibility of accidental mortality if techniques are not precisely followed.

Secondly, our study did not examine the influence of saline immersion longer than three minutes. Precision in immersion timing could be critical to ensuring the welfare and long-term survival of batch marked fish. To minimise stress, saline concentrations lower than sea water should be considered for future osmotic induction work on juvenile Murray cod. Maintaining accurate saline concentrations and immersion times are likely to be critical to ensure successful marking of juvenile Murray cod with minimal stress.

Mark intensity varied from different body parts suggesting that calcified structures absorbed different levels of fluorescein. The anal spine and jaw consistently reported lower intensity under reduced osmotic pressure during the marking process. Increased mark intensity from higher saline concentrations are observed in salmonid marking programs (Negus and Tureson, 2004). Some chemical marking techniques are known to induce autofluorescence which can increase the probability of false positives (Crook et al., 2009). Chemical marks are also more readily incorporated into structures containing large amounts of calcium carbonate (Lochet et al., 2011). The operculum is the largest single bony structure within teleost fish and could therefore be expected to absorb high amounts of Calcein during the marking process. Increased intensity under fluorescence could be expected from such regions, irrespective of saline concentration, if localised Calcein uptake was high. Lower readings from both the jaw and anal spine justify the use of osmotic induction to maximise uptake (See Figure 2).

The main objective of chemical marking programs is to provide a non-lethal mechanism to identify natal origin which persists indefinitely. Ongoing fish growth results in deposition of additional layers on calcified structures and deposition of opaque tissue suggests that external detectability of Calcein fluorescence may decrease with age (Crook *et al.*, 2009; Lochet *et al.*, 2011). Calcein was detected from all bony structures post marking but long-term non-lethal detection using external analysis methodologies requires further investigation.

It is possible to induce a Calcein mark into fish without osmotic induction (Smith *et al.*, 2010). Indeed our study validated this because all marked fish, including no salt controls, returned a positive reading in the short assessment period. There is, however, much evidence to suggest that mark intensity degrades in response to prolonged exposure to ultra-violet light (Honeyfield *et al.*, 2008; Smith *et al.*, 2010) and becomes less detectable as fish grow (Game and Wildlife Trust, Unpublished Data). Fish stocked into rivers and impoundments, where prolonged ultraviolet exposure could be expected, may therefore have a limited time period where Calcein marks can be reliably detected using non-lethal techniques. Using osmotic induction to increase the uptake of Calcein seeks to prolong the external detection of Calcein marks over the long-term. Internal structures, like otoliths or vertebrae, should retain a permanent mark and Calcein fluorescence should be detectable via examination of thin sections well beyond the external detection period (Crook et al., 2009). External detection should therefore be considered in conjunction with other detection techniques when planning stocking success studies relying on chemical marking (Frenkel *et al.*, 2002; Crook *et al.*, 2012).

Improved intensity can also be achieved by increasing Calcein concentration in some species (Mohler, 1997; Smith *et al.*, 2010) but was not considered practical for Murray cod juveniles. Compared to other commercially-available marking chemicals, Calcein is substantially more expensive and has limited potential for re-use on multiple batches of fish (Crook *et al.*, 2007). High levels of Calcein are also known to be toxic under some circumstances (Bumguardner and King, 1996) or result in no discernable intensity increase in others (Crook *et al.*, 2009). This variability in response to altered concentration suggested that increasing uptake of Calcein by manipulating osmotic pressure could reduce potential toxic effects whilst also minimising cost. These are both important considerations if chemical marking is to be applied on a large spatial scale by commercial operators.

Conclusion

Murray cod fingerlings were successfully marked using Calcein under a range of saline bath concentrations. Potential welfare issues under higher salinity suggest that moderate to low saline concentrations should be considered when facilitating osmotic induction. Under these conditions fish exhibited low mortality and relatively high mark retention rates. Further research into the length of time Calcein marks are externally detectable would be useful when considering non-lethal methods of hatchery fish discrimination. Further research is also required to ensure that chemical marking does not influence long-term survival. Over the long term, combining non-lethal external techniques with lethal validation using thin sectioning of saggital otoliths would provide a useful mechanism to report on success of Murray cod stocking programs.

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Proceedings of the Royal Society of New South Wales

The 2012 programme of events – Sydney

The usual venue for Society meetings is the Union University and Schools Club, 25 Bent Street, Sydney.

Friday 24 February 2012 at 7.00 pm
Annual Dinner and Awards

The Chief Scientist and Engineer of NSW, Professor Mary O'Kane presented a number of the Society's awards and gave the Occasional Address.

Wednesday, 7 March 2012 at 6.00 pm
***The Four Societies Lecture*.**

Counting atoms for a living – tales of Accelerator Mass Spectrometry.
Dr Andrew Smith, Senior Principal Research Scientist , ANSTO.

Held in conjunction with the Australian Nuclear Association, the Nuclear Panel of Engineers Australia and the Australian Institute of Energy.

Wednesday, 4 April 2012 at 5.30 pm
145th Annual General Meeting

Dr Donald Hector was elected President of the Society.

The Royal Society Forum 2012 at 6.30 pm

The media and scientific research: impact and influence
Mark Scott AO, Managing Director of the ABC and Professor Jill Trewhella FRSN, Deputy Vice-Chancellor (Research) at Sydney University, discussed the influence of the media on research.
Moderated by the ABC's Robyn Williams AM.

The Forum was held at the Powerhouse Museum, Ultimo and was broadcast on *Big Ideas* on the ABC's Radio National.

Wednesday, 6 June 2012 at 6.00 pm
1200th Ordinary General Meeting

Transit of Venus 2012 – what we and others saw
Dr Andrew Jacob

Held at Sydney Observatory, Observatory Hill

Wednesday, 4 July 2012 at 6.00 pm
1201st Ordinary General Meeting

Autoimmune diseases: obesity, nutrition, exercise and eating disorders
Professor Ian Caterson AM

Thursday, 19 July 2012 at 2.00 pm
The Dirac Lecture

The accelerating universe
Professor Brian Schmidt FRSN, 2011 Nobel Laureate for Physics

Presented at University of New South Wales in conjunction with the University of New South Wales and the Australian Institute of Physics.

Wednesday, 1 August 2012 at 6.00 pm
1202nd Ordinary General Meeting

Photonic circuits for the new information age: faster, smaller, smarter and greener
Professor Benjamin Eggleton

Wednesday, 5 September 2012 at 6.00 pm
1203rd Ordinary General Meeting

Climate change, regional drought and forest mortality: are we seeing a new global phenomenon?
Speaker: Professor Derek Eamus

Wednesday, 3 October 2012 at 6.00 pm
1204th Ordinary General Meeting

Outsmarting superbugs
Speaker: Professor Liz Harry

Wednesday, 7 November 2012 at 6.00 pm
1205th Ordinary General Meeting

The unexpected nuclear renaissance: nuclear techniques benefiting mankind
Speaker: Dr Adi Patterson

Monday, 19 November 2012 at 6.00 pm
The Liversidge Lecture in Chemistry

Low carbon technologies: from brown coal and biomass to solar hydrogen
Professor Thomas Maschmeyer

Held at the University of Sydney.

Tuesday, 20 November 2012
The Jak Kelly Award

Student presentations followed by a lecture by Dr Stephen Bosi. Held at the University of Sydney in conjunction with the Australian Institute of Physics.

Wednesday, 5 December 2012
1205th Ordinary General Meeting

Presentation by the Jak Kelly award recipient, followed by the Christmas party

Held at St Paul's College, University of Sydney,

The 2012 programme of events – Southern Highlands

The usual venue for Southern Highlands branch meetings is the Performing Arts Centre, Chevalier College, Bowral.

Thursday, 19 April 2012

Advanced radiation oncology modalities for cancer
Dr Anatoly Rosenfeld

Thursday, 17 May 2012

Coal seam gas (CSG): what does science tell us about the impact?
Dr Bryce Kelly

Thursday, 21 June 2012

Serial sexual homicide stalking, psychopathy and sexual deviance
Dr Stephen Allnutt

Thursday, 19 July 2012

The accelerating universe
Professor Brian Schmidt FRSN, 2011 Nobel Laureate for Physics

Thursday, 16 August 2012

Understanding the extent and impact of rubbish in marine ecosystem
Dr Chris Wilcox

Thursday, 27 September 2012

The Wonderful World of Hydrogels
Dr Marc in het Panhuis

Saturday, 20 October 2012

Where Art and Science Meet
Dr Thomas H. Rich, Professor Patricia Vickers-Rich, Peter Trusler

Thursday, 15 November 2012

Australian Energy at the Cross Roads
Dr John Wright

The Dirac Lecture

Thursday, 19 July 2012

The accelerating universe

Professor Brian Schmidt FRS FRSN, Nobel Laureate for Physics, 2011

Professor Brian Schmidt FRS FRSN delivering the 2012 Dirac Lecture.

In conjunction with the University of New South Wales and with the Australian Institute of Physics, at the Society proudly presented the 2012 Dirac Lecture on Thursday, 19 July 2012. This year's lecture was delivered by Professor Brian Schmidt, 2011 Nobel Laureate for Physics.

Professor Schmidt took us on a fascinating journey of astronomy and cosmology, describing the work that he and his colleagues have done over the last two decades and where it fits in our understanding of the nature of the universe.

To establish a reference framework, we were taken on a quick tour of the universe using the speed of light as a ruler (the Moon is less than two light seconds from us. The Sun is 8 light minutes away. The nearest star, Alpha Centauri, 4.3 is light years away. We are 30,000 light years from the centre of our galaxy, the Milky Way. The nearest galaxy, Andromeda, is 2 million light years from us. The cosmic ray background establishes that the age of the universe is about 13.7 billion years, with the Hubble telescope being able to detect objects 12 billion light years away).

Although astronomy is one of the oldest sciences, modern cosmology had its beginnings in the 19th and 20th centuries when techniques such as spectral analysis began to be applied to light from the skies. Of particular importance was the phenomenon known as Doppler effect – objects that are moving towards us have their light shifted towards the blue end of the spectrum, while objects moving away have their light shifted to towards red. By analysing the spectra of galaxies, in 1916, Vesto Slipher found that all galaxies he observed were shifted towards red and therefore were moving away from us. The conclusion from this was that the universe is expanding.

Einstein's special theory of relativity published in 1907 proposed that acceleration due to gravity and acceleration due to motion are equivalent. This led to his general theory of relativity and the notion that space is curved. The solution to Einstein's equations are dynamic, implying that the universe should be in motion. To avoid the conclusion that the universe was expanding, Einstein introduced a "fudge factor" called the cosmological constant (Einstein later referred to this as his greatest blunder!).

One conclusion from the concept of an expanding universe is that at one point must have been a big bang. Observations suggest that the age of the universe could be as young as 9 billion years if its expansion was slowing due to gravity but this is contrary to observations that the oldest stars appear to be at least 12 billion years old.

Not only was Brian Schmidt interested in solving this problem and determining the age of the universe but he wanted to understand what its eventual fate might be. In the 1990s, by observing faintness/brightness plotted against high/low red shift it had been found that supernovae appeared to have very constant brightness and therefore could be used as a standard "candle". (It was later found that this was not quite so but further work to better understand Type 1A supernovae allowed for corrections that gave a very good correlation.)

Improved digital detection technology and data processing capability in the 1990s set the stage for major advances in astronomy. Many more supernovae could be observed and this gave the team led by Brian (whose area of specialisation was data processing) to study many high-resolution images and by tracking these images and filtering out background noise, to find supernovae candidates for much more detailed analysis. Brian's team found that distant supernovae were outside the range expected for a universe whose expansion was slowing. Detailed analysis of their data suggested that the expansion of the universe was in fact accelerating. This was contrary to the mainstream view of physicists at the time and, indeed was contrary to the findings of another team using a different approach to analysing the data. Professor Schmidt's team published their work and in 2011 were awarded the Nobel Prize.

The notion of a universe whose expansion is accelerating poses some interesting questions for cosmologists, not the least of which is what could be pushing it apart? Einstein's theory allows for the concept of "dark energy". The data from analysis of Type 1A supernovae can be explained if the forces are assumed to be about 30% "pull" from gravity and about 70% "push" from dark energy. For the universe to be flat (and an analysis of the background radiation of the universe shows that indeed it is flat, that is, the universe is not closed and it is not open), 27% of the universe would need to be matter and 73% would need to be dark energy. But the problem is that this is much more matter than appears to exist. The solution to this currently most favoured by cosmologists is the comcept of "dark matter" – matter that we cannot see. And it is not a small ammount – less than 5% of all matter is thought to be observable.

Professor Schmidt concluded his lecture with some long-range forecasts for the future of the universe. In some places, gravity will win and matter will merge; in others, space will accelerate faster and light from those areas will never reach us. There could even be a "big rip". In this scenario, a few million years before the end, gravity would be too weak to hold the Milky Way and other galaxies together. Our solar system would become gravitationally unbound, the stars and planets would be torn apart and at the very end, individual atoms would be ripped apart.

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Thesis abstract

Diet, Nutrition and Haematology of Dasyurid Marsupials

Hayley Stannard

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Western Sydney, Richmond, Australia

Stannard's PhD thesis examined diet, nutrition and haematology of six dasyurid species, which are a family of insectivorous and/or carnivorous Australian marsupials. Diet and nutrition were studied to obtain information on diet choice by translocated animals and food digestibility in captive animals. Haematology was studied in captivity as it is associated with clinical health and influenced by nutrition. The broad aim of the study was to aid current wildlife management practices and future conservation efforts (such as reintroduction and translocation programs) for these six species and other marsupial species in Australia.

Examination of the diet of a population of translocated red-tailed phascogales (Phascogale calura) at Alice Springs Desert Park confirmed that they are primarily insectivorous. They are also opportunistic predators within the park, consuming birds, small mammals, and on occasion reptiles and plant material.
Study of nutrition in red-tailed phascogales and kultarrs showed apparent digestibility values were above 81% for dry matter, energy, protein and lipids on a number of captive fed diets. Maintenance energy requirements were determined for the red-tailed phascogale (954 kJ kg0.75 d-1), kultarr (Antechinomys laniger) (695 kJ kg0.75 d-1), stripe-faced dunnart (Sminthopsis macroura) (359 kJ kg -0.75 d-1) and fat-tailed dunnart (Sminthopsis crassicaudata) (542 kJ kg -0.75 d-1). The morphology of the gastrointestinal tract of both dunnart species and the kultarr were simple and consisted of a unilocular stomach and relatively uniform intestine. Digestibility studies in a larger dasyurid species, the eastern quoll, showed they had high apparent digestibility values for dry matter, gross energy, protein and lipids (>84%). There was a significant difference in apparent digestibility of dry matter, gross energy and protein between the two diets provided, kangaroo mince and chicken necks.

Analysis of blood parameters in the eastern (Dasyurus viverrinus) and spotted-tailed quoll (Dasyurus maculatus) provided new data for blood chemistry and differential white cell values. Seasonal differences were determined for total bilirubin, glucose, creatinine and sodium levels. Eastern quolls one year of age and under had significantly higher alkaline phosphatase values than older animals.

The results from this thesis have implications for captive management and future conservation efforts for Dasyurids. The study has shown the diet choice of translocated phascogales in a new environment, which has contributed to improving translocation techniques used for this species. Nutritional experiments suggest that no single diet, if fed alone is appropriate for feeding captive dasyurids; and live insect diets provide behavioural enrichment, and enhance mental and physical stimulation. The ability of captive animals to catch live food also increases the likelihood of their survival post-release, if they are subject to translocation in the future. Energy requirements differ between species and do not necessarily relate to body mass but likely relate to physiological adaptations and species ecology. The blood levels determined in this study can be used to assess clinical health of quolls and assist with captive management and future reintroduction programs. The data gained in this study has been incorporated into the daily management/husbandry practices for these species.

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Thesis abstract

Behavioural and Trophic Ecology of Reef Sharks at Ningaloo Reef, Western Australia

Conrad Speed

Abstract of a thesis for a Doctorate of Philosophy submitted to Charles Darwin University, Darwin, Australia

The focus of my project was to quantify the long-term movements, environmental associations, and trophic role of reef sharks at Ningaloo Reef, and relate findings to management. I reviewed 50 years of research on coastal shark movement and behaviour. A number of common horizontal and vertical patterns exist, and I relate these to habitat specificity, site fidelity, habitat partitioning and management (Speed et al. 2010).

I monitored long-term (> 2 yrs) behaviour of four species of reef sharks (*Carcharhinus melanopterus, Carcharhinus amblyrhynchos, Triaenodon obesus and Negaprion acutidens*) at Ningaloo Reef using a combination of visual censuses, acoustic monitoring, and stable isotope techniques. All species showed site fidelity to inshore areas, one of which was an aggregation site (Skeleton Bay). Temporal and spatial overlap within Skeleton Bay was high for all species (Speed et al. 2011).

Examination of environmental influences showed that sharks were more affected by water temperature than other variables, such as tide height and moon phase. Furthermore, adult female *C. melanopterus* maintained average body temperature above average water temperature, which provides evidence for behavioural thermoregulation (Speed et al. 2012b).

I assessed the trophic ecology of reef sharks using a combination of stable isotope analysis and acoustic monitoring. Trophic level estimates were comparable to previous estimates based on traditional dietary studies, and high δ13C in muscle tissue suggests a dependency on coastal food webs. There was support for an increase of δ15N with body size, which suggests that larger animals feed higher in the food-web (Speed et al. 2012a).

Movement patterns around a sanctuary zone (Mangrove Bay) indicate that individuals were detected < 40 % of monitoring time. Adults had larger home ranges than juveniles, and activity hot spots for adults were outside of the sanctuary zone. Some adults made long-distance movements (> 10 km); the longest being > 260 km (round trip). Management of reef sharks at Ningaloo should incorporate the use of MPA zoning with other measures such as migration corridors, as well as size and bag limits.

Future research should adopt an interdisciplinary approach of biotelemetry and molecular techniques. This would provide further detail on dispersal and interconnectivity of populations at Ningaloo Reef and increase the resolution of habitat use and behaviour of these elusive predators.

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Thesis abstract

Water Vapour Radiometers for the Australia Telescope Compact Array

Balthasar Tobias Indermuehle

Abstract of a thesis for a Doctorate of Philosophy submitted to UNSW, Sydney, Australia

In the millimetre wavelength regime of the electromagnetic spectrum used in radio astronomy, poorly mixed pockets of precipitable water vapour cause a change in the refractive index of the atmosphere, thereby inducing an excess path that the signal must travel through. This results in a phase delay for antennae receiving an astronomical signal. In an interferometer such as the Australia Telescope Compact Array (ATCA), variations in phase delay between the antennae thus lead to degradation in the image quality obtainable due to signal decorrelation. This phase fluctuation induced noise increases both with frequency and baseline length. It therefore also puts upper limits on the usable length of baselines without experiencing significant decorrelation, thus limiting the spatial resolution of the interferometer.

We have developed Water Vapour Radiometers (WVRs) for the ATCA that are capable of determining excess path fluctuations by virtue of measuring small temperature fluctuations in the atmosphere using the 22.2 GHz water vapour line for each of the six antennae. By measuring the line of sight variations of the water vapour, the induced path excess and thus the phase delay can be estimated and corrections can then be applied during data reduction. This reduces decorrelation of the source signal. I demonstrate how this recovers the telescope's efficiency and image quality as well as how this improves the telescope's ability to use longer baselines at higher frequencies, thereby resulting in higher spatial resolution.

The design process of the WVRs is discussed, including a review of three other WVR systems for comparison with our system design. A detailed site characterisation is provided with emphasis on millimetre observing conditions and it is determined to what extent WVRs can improve telescope data. A thorough examination of the frequency space used for the WVRs follows in order to avoid and detect radio frequency interference of both terrestrial and orbital origin. A detailed description of the WVR hardware design is given and concludes with a detailed account of the atmospheric modelling and water vapour retrieval mechanisms I have developed. The thesis concludes with a list of future opportunities and developments to improve the existing WVR system.

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The Clarke Medal 2012

The Clarke Medal was established to acknowledge the contribution by the Rev William Branwhite Clarke MA FRS FGS, Vice-President of the Royal Society of New South Wales from 1866 to 1878. The Medal is awarded annually for distinguished work in a natural science done in Australia and its Territories, being awarded by rotation in the fields of geology, botany and zoology.

This year's award is in the field of Zoology in all its aspects and is awarded to **Dr Marilyn Renfree AO FAA**, a Laureate Professor at the University of Melbourne.

Professor Renfree graduated from the Australian National University and subsequently studied under a Fulbright Scholarship at University of Tennessee and Ford Foundation Fellowship at the University of Edinburgh. In 1991, she was appointed the Ian Potter Professor of Zoology at the University of Melbourne. Her research focuses on the control of reproduction and development in mammals, particularly marsupials and monotremes. She has received large research grants from the National Health and Medical Research Council and the Australian Research Council.

Professor Renfree is a fellow of the Australian Academy of Science and has received numerous awards including the Academy's Gottschalk Medal and the Gold Conservation Medal of the Zoological Society of San Diego. She is a most worthy recipient of the Clarke Medal.

The Medal will be presented at the Annual Dinner of the Royal Society of NSW to be held in April 2013.

The Edgeworth David Medal 2012

The Edgeworth David Medal, established in memory of Professor Sir Tannatt William Edgeworth David FRS, a past President of the Society, is awarded for distinguished contributions by a young scientist.

This year's award is awarded to **Dr Joanne Whittaker**, a postdoctoral fellow at the School of Geosciences at the University of Sydney.

Dr Whittaker's area of interest is investigating Indian Ocean plate reconstructions and continental breakup as part of the "Gondwanaland extension, breakup and continental margin evolution", a research project funded by Statoil Hydro. Her particular area of interest is in plate tectonics, geophysics and geology, investigating the formation and evolution of continental margins and the oceanic crust. Her PhD, from the University of Sydney, was on tectonic consequences of mid-ocean ridge formation, evolution and subduction.

Dr Whittaker has an enviable peer-reviewed publication record and has been invited to present at a number of Australian and international conferences. She won the Australian Institute of Policy and Science NSW Tall Poppy award in 2010. She is a worthy recipient of the Edgeworth David Medal for young researchers.

The Medal will be presented at the Annual Dinner of the Royal Society of NSW to be held in April 2013.

Royal Society of NSW Medal 2012

The Society's Medal was the first initiative of the Society to recognise its members' contributions, deriving in concept from the Society's Money Prize of 1882. It was awarded for published papers from 1884 to 1896, was then discontinued, and revived in 1943 as an award for a member of the Society who had made meritorious contributions to the advancement of science, including administration and organisation of scientific endeavour and for services to the Society.

The Royal Society of NSW Medal for 2012 has been awarded to **Mr John Hardie MRSN** for his contribution to the Society for over thirty years, six of which were as its President.

John Hardie is a geologist who has spent most of his career in education. He joined the Royal Society of NSW in 1972 and is one of its longest serving Council members. He was Secretary of the Society in 1992 and served as President in 1994 and from 2007 to 2012. He has worked tirelessly to promote the interests of the Society both within NSW and more widely. John has also been active in the establishment of the Royal Societies of Australia, an Australia-wide body established to represent jointly the six Australian Royal Societies.

The Medal will be presented at the Annual Dinner of the Royal Society of NSW to be held in April 2013.

Royal Society of NSW Scholarships 2012

The Royal Society of NSW Scholarships are funded by the Society to recognise outstanding achievements by early-career individuals working in a science-related field. Three Scholarshipas have been awarded in 2012.

Ms Jendi Kepple

Ms Kepple is enrolled in a PhD program at the University of New South Wales, working on the research topic "Robust Design of Imperfection Sensitive Composite Launcher Structures/ Stiffened Composite Panels" ,with Professor Gangadhara Prusty. Her research is contributing to the program for the DESICOS Project "New Robust Design Guidelines for Imperfection Sensitive Composite Launcher Structures". This is a European Union 7th Framework Program project led by Professor Dr. Richard Degenhardt of the University of Applied Sciences Gottingen in Stade. Ms Kepple has been invited by Prof Degenhardt to spend 6 months at the DLR laboratories in Germany to conduct testing on buckling of imperfection sensitive cylinders. The award will contribute to funding her visit to Germany. Ms Kepple graduated in 2012 from the Uiversity of NSW with a Bachelor of Engineering majoring in Aerospace Engineering. She was awarded First Class Honours.

Ms Anwen Krause-Heuer

Ms Krause-Heuer is in the third year of a part-time PhD at the University of Western Sydney, under the supervision of Professor Janice Aldrich-Wright. Her studies have been based in the field of medicinal inorganic chemistry, particularly the development of new cancer drugs based on cis-platin. A new class of platinum complexes has previously been developed which are believed to enact their cytotoxic activity by insertion of a planar aromatic region between the base pairs of DNA, causing unwinding and lengthening of the strand, thereby preventing replication. While the potency of these compounds is well known, their biochemical and biophysical properties are not well understood. Studies in this area have formed the basis of the research conducted during Ms Krause-Heuer's PhD studies. Ms Krause-Heuer is a graduate of UWS, being awarded a BSc Advanced science degree with 1st class honours and the University Medal in 2006. She works at ANSTO in material science.

Ms Helen Margherita Smith

Ms Smith's PhD at the University of Sydney is entitled "Replacing Natives with Exotics: Wildlife Responses to Black Rat Invasion in the Sydney Harbour National Park" and is under the supervision of Associate Professor Peter Banks. After her honours, Ms Smith has had two years professional experience dealing with invasive plants and working with rats as an intern with the Australian Wildlife Conservancy. The PhD project is closely tied to a Sydney-based conservation program that has reintroduced the native bush rat (*Rattus fuscipes*) back into the SHNP, having not been seen there for more than 100 years. The purpose of the reintroduction of the native bush rat is to block the invasion of alien black rats, an outcome which is predicted by invasion biology and competition theory. The project offers a unique opportunity to compare both native and invasive rodent for their impacts on local wildlife.

The winners have been invited to make a presentation on their work at the first Society's first 2013 meeting to be held in Sydney on Wednesday, 6 February.

Archibald Liversidge:
Imperial Science under the Southern Cross

Roy MacLeod
Royal Society of New South Wales, in association with Sydney University Press
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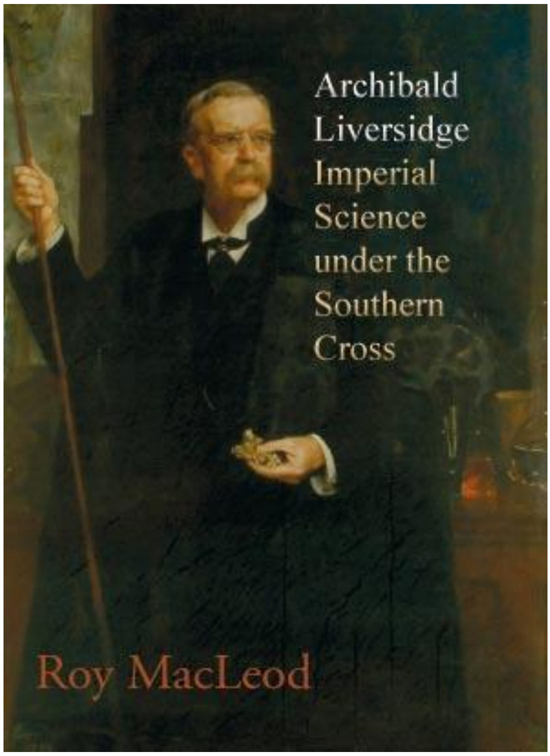

When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology And Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.

In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the *Australasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.

To order your copy, please complete the form Liversidge Book Order Form available at: http://royalsoc.org.au/books and return it together with your payment to:

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