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## Editorial: A new era in vaccinology?

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2020 — a year like few others in the *Journal's* 154-year history. One noteworthy event has been the development of several vaccines effective against COVID-19 in an impossibly short time — twelve months after the virus was first isolated.

What are the scientific highlights of the year? These focus on the pandemic. The development of novel messenger ribonucleic acid (mRNA) vaccines, in which the shape of the virus is the focus for vaccine elements that stimulate the body's immune system to attack the virus is a revolution and welcome in terms of the speed of development.<sup>1</sup> The extremely low temperatures now necessary to transport the first two mRNA vaccines will, no doubt, be moderated with future research. And it is likely that we will need future vaccines to combat future viral epidemics and pandemics, as our numbers on Earth continue to grow and opportunities for zoonotic viruses to spread from their host animals to human beings also grow, as we spread into new ecosystems. I believe it is a mistake to think of the pandemic as a once-in-a-hundred-years event, just because the last serious pandemic was a century ago. We have been lucky with the various flu

epidemics and other contagions that have occurred recently.<sup>2</sup>

The revolutionary mRNA vaccines developed in breathtaking time for inoculating against COVID-19, despite the lack of previous vaccines against other respiratory diseases, such as the common cold, got me thinking. The vaccines prime the immune system to recognise the alien virus and attack it. Recently, new treatments against various cancers have enlisted the immune system to attack cancer cells and tumours, increasingly successfully. My question: could we use mRNA vaccines in the fight against cancer? (Pardi et al. 2018) Let's hope so.<sup>3</sup>

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2 Indeed, Edward Holmes FRSN, one of the first scientists, with his Chinese colleagues, to map the genotype of SARS-CoV-2, the COVID-19 coronavirus, and publish the structure on January 11, 2020, on the open access Virology website, within a week of its identification, makes the same warning. I have asked Professor Holmes to write a memoir note, when he has time, of the discovery a year ago. See Wu et al. (2020) and Zhang and Holmes (2020). I look forward to publishing it. (I have also invited John O'Sullivan, head of the CSIRO astrophysics team that invented WiFi in 1996, to write a piece on the discovery of that ubiquitous technology, which I will also publish, if he writes it.)

3 Z. R. C. Marks, Ph.D., M.B.B.S. tells me that, despite a large field of research looking at mRNA targeting of cancer directly, fine-tuning the immune response is tricky, whereas specific, targeted approaches seem to hold the most promise, such as CAR-T cells: host immune cells engineered to fight specific tumour cells. BioNTech, joint developer with Pfizer of the first vaccine, is exploring the use of mRNA in treatments for malignant melanoma and prostate, head-and-neck and breast cancers.

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1 *The Economist* reckons that these vaccines “may turn out to be the technology-in-use with the greatest economic impact over a single year ever seen.”

The bushfires of last summer, a phenomenon described as the onset of the “pyrocene” by Stephen Pyne in the June issue, have resulted in a wider awakening of the progress of global warming, and the need for a federal energy policy worthy of the name. There is now widespread agreement in Australia that ageing coal-fired electricity generators will be phased out, but the issue of how to transition to renewable energy is not resolved, while reducing greenhouse-gas emissions. This issue of the *Journal* introduces a new section, *Counterpoint*, in which conflicting views are presented: Alan Finkel, the then Chief Scientist, has the view that gas turbine plants should ease the transition to renewables;<sup>4</sup> this is supported (by himself, Richard Bolt of Swinburne UT, and Peter Rez of Arizona State), while the opposite side is taken (by 25 scientists, including three FRSNs, by a past Chief Scientist, Penny Sackett, and by Andrew Blackers of ANU). Read their contributions and decide.

In the year of the COVID-19 plague, other advances fade into the background, but this issue contains some interesting papers, as well as 19 abstracts of recent doctoral theses in N.S.W. and the A.C.T. In a submitted paper, Forbes et al. report on research into differences between recreational fishing in manmade reservoirs and riverine fisheries. In a requested contribution, marking the success of the new Hunter Valley Branch, Kenneth Dutton FRSN describes the Skotowe manuscript, compiled by an early commandant of the Newcastle penal settlement, whose father had mentored the young James

Cook in Yorkshire. The MS describes the local fauna and flora, with illustrations.<sup>5</sup> A second commissioned paper, by Steven Patterson, outlines the fascinating history of the development through the centuries of blue pigments. It turns out that chemists can still not design or even predict the colour of a new compound (that is, colour is an emergent property), and blue pigments have been rare in the wild.<sup>6</sup> We publish an obituary of Richard Stanton DistFRSN (1926–2020).

As with past issues, I thank Jason Antony — editor of the Society’s *Bulletin* — for his efforts in polishing the appearance of the *Journal*. I also thank Dr Mike Richards and Don Hector FRSN for their assistance with this editorial.

A note: in 1968, the Society published a volume celebrating the centenary of the Royal Charter in 1867: *A Century of Scientific Progress: The centenary volume of the Royal Society of New South Wales — a history of several aspects of Australian scientific development, with particular reference to New South Wales* (Sydney, Royal Society of NSW, 1968). This is now available on-line at the *Journal* archive.

The 2020 Archibald Ollé Prize for the best paper in the *Journal* was awarded to the late Ann Moyal FRSN (1926–2019), for her paper, “P. A. M. Dirac and the maverick mathematician” (Moyal 2017), reporting war-time correspondence between

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4 The International Energy Agency states: “solar PV is consistently cheaper than new coal- or gas-fired power plants in most countries, and solar projects now offer some of the lowest-cost electricity ever seen” (IEA 2020).

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5 I thank Jessica Milner Davis FRSN for assisting in the birth of this paper.

6 I thank Pamela Griffith FRSN for assisting in the birth of this paper. Wendy Sharpe FRSN tells me she uses “Ultramarine Blue, Cobalt Blue and sometimes Prussian and Cerulean Blue.” Ben Quilty FRSN tells me that his favourite blue is Ultramarine Blue; he adds that “the base colour for the entire Australian continent is Flinders Violet (not blue).”

Paul Dirac (1902–1984), doyen of British physicists, and the young mathematician, José Enrique Moyal (1910–1998), who disagreed about a statistical basis for quantum mechanics, then a revolutionary theory. Moyal, later a professor at Macquarie University, was the author’s husband, and has since been vindicated, I believe. This is the first award made since 1997.

Balmain, 23 December 2020.

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# Implementation of a harvest slot for Murray cod: Initial impacts on the recreational harvest in a manmade reservoir and comparison to riverine fisheries

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## Abstract

Freshwater reservoirs support valuable commercial and recreational fisheries resources worldwide. Recreational fisheries in reservoirs are commonly managed using length-based harvest regulations, although empirical data is required to ensure these regulations are fit-for-purpose and that any changes do not result in negative population responses. Following a change from a 600 mm minimum legal length to a 550–750 mm harvest slot (HS) limit for both reservoir and river based recreational fisheries for Murray cod, *Maccullochella peelii*, we used a stratified random sampling design to assess the summer recreational fishery in Lake Mulwala, an important reservoir fishery. Specifically, we assessed the immediate effects of the HS on angler effort, catch and harvest in this fishery. Standardised parameters based on data from existing angler surveys were also used to investigate variability among fisheries for Murray cod. We found that (1) in Lake Mulwala, more than 50% of Murray cod harvested after the introduction of the HS were between 550 and 600 mm; (2) boat-based anglers almost exclusively targeted Murray cod and harvested more and larger fish than shore-based anglers; (3) the Murray cod population was severely truncated with high mandatory discard rates (93.7% for boat fisheries and 99.8% for shore fisheries) of fish below the lower HS limit; (4) standardised parameters varied among waterbodies, and comparatively higher effort, discard and harvest densities were observed in the reservoir fishery. The reliance on newly harvestable Murray cod in Lake Mulwala highlights the need for early and ongoing monitoring of regulatory changes across riverine and reservoir environments, encompassing both social and biological aspects of the fishery.

## Introduction

The impoundment of rivers and the formation of reservoirs provide a range of unique opportunities for fisheries, leisure activities, aquaculture and irrigation for agriculture (Mosisch and Arthington 1998; Renwick 2001; Hutt et al. 2013). Reservoir

based commercial and recreational fisheries are highly valuable both socially and economically in many of regions worldwide (De Silva and Sirisena 1989; Ambak and Jalal 2006; Loomis and Ng 2012). The success of reservoir fisheries is often related to higher growth rates in these artificial habitats than

in natural rivers and streams (Wilde and Sawynock 2005; Forbes et al. 2015a). Reservoir fisheries can also alleviate pressure on wild riverine stocks and provide a reliable resource for anglers. However, many reservoirs are constructed for reasons other than recreational fishing and leisure activities, thus creating a conflict between users and stakeholders (Mosisch and Arthington 1998). The quality of reservoir fisheries are often influenced by these conflicting uses and the use of reservoir waters for their intended purposes, such as drinking water or irrigation, which may conflict with fisheries management goals.

A key regulatory tool available for managers of reservoir fisheries are length-based harvest regulations, which are widely used in recreational and commercial fisheries management (Gwinn et al. 2015). Harvest slot (HS; harvest of intermediate sized fish) regulations are considered especially effective at achieving fishery objectives when the harvest numbers and numbers of trophy fish captured are more important to anglers than total yield or harvest of trophy fish (Gwinn et al. 2015). However, changes to harvest restrictions, such as a transition from a minimum legal length (MLL) to a HS, can influence the structure of a fish population in ways that may not be favourable to all angling groups (Allen et al. 2013; Gwinn et al. 2015). Furthermore, a change in legal length may affect the distribution of effort, such that anglers move to or from a particular fishery depending on the perception of angling success (Boxrucker 2002). As a result, sound scientific monitoring is required throughout all stages of regulatory change (Cooke et al. 2015; Arlinghaus et al. 2016). This monitoring requires understanding of initial changes in angler effort and

harvest, and how these aspects develop or adapt over time and the subsequent impact on the fishery (Allen and Pine 2000; Stone and Lott 2002).

In Australia's Murray-Darling Basin, Murray cod, *Maccullochella peelii*, is a major recreational target species (Brown 2010; Hunt et al. 2010; Forbes et al. 2015c) because of its large size and edibility (Rowland 2005). Murray cod populations have exhibited a historic decline partly caused by recreational and commercial exploitation, as well as catchment development and river regulation (Rowland 1989; Reid et al. 1997). Despite the previous decline, recovery at the state jurisdictional level is apparent (Rowland 2013; West et al. 2016), and NSW and Victoria agencies continue to support increased opportunities to participate in recreational fishing for this species. Artificial reservoirs are particularly important in the recovery of Murray cod fisheries. In Australia, more than 84 million native and introduced fish were stocked between 2009 and 2015 for recreational benefit, thus resulting in several put-and-take fisheries that are beneficial to the economy in many regional areas (Hunt and Jones 2018). This effort has included removal of state-wide seasonal spawning closures in selected reservoirs (e.g., Copeton Dam, Blowering Dam and Lake Eildon) where Murray cod populations rely on stocking with little or no natural recruitment (Forbes et al. 2015b).

A length-based harvest restriction for Murray cod was re-established in 1992 with a MLL of 500 mm in New South Wales (NSW), Australian Capital Territory (ACT) and Victoria across all river and reservoir environments (Lintermans 2004; Koehn and Todd 2012). This restriction was followed by the additional regulation of allowing harvest



of one fish over 750 mm in Victoria and 1000 mm in NSW (Lintermans 2004; Koehn and Todd 2012). The MLL was then changed from 500 to 600 mm in 2010 in NSW. In Queensland, a 600 mm MLL and 1100 mm maximum size limit currently exist, and South Australia has a limited catch-and-release season for Murray cod with no harvest permitted. The states of NSW, ACT and Victoria introduced a 550–750 mm HS in 2014. The change was enacted to provide spawning opportunity before harvest eligibility for smaller fish; to protect larger, more fecund fish; and to decrease truncation in length around the minimum length limit (Nicol et al. 2004; Koehn and Todd 2012; Gwinn et al. 2015).

Information collected from fishery dependent surveys, such as effort, discard and harvest, are commonly used to inform aspects of fishing quality and the relative success of management strategies such as length-based harvest regulations imposed on recreational fisheries (Kozfkay and Dillon 2010; Hunt et al. 2011). Combining these basic fishery metrics with the behavioral dynamics of anglers (e.g., species targeted fishing, preferences for harvest or catch-and-release, and fishing gear used) increases the understanding of factors that drive variability and change within recreational fisheries, thus potentially leading to improved management (Johnston et al. 2012; Arlinghaus et al. 2013). In this regard, it is important to compare effort, harvest, discard and targeting preference/proportion of harvest from each species across different waterbody types to determine variability in the fishery over larger geographical areas. However, creel surveys are seldom conducted for Australian freshwater recreational fisheries, thus hindering examination

of change before and after HS introduction. Nevertheless, collection of baseline fishery data at the onset of regulatory change are valuable and contribute to quantifying long-term effects (Cooke et al. 2015).

In this regard, the objectives of this study were to (1) quantify the levels of daytime shore-based and boat-based fishing effort, harvest and discard, targeting practices, fishing methods and reasons for releasing/discarding fish in Lake Mulwala after the introduction of the HS; (2) evaluate the HS effectiveness to sustain recreational harvest in Lake Mulwala, given the biology of Murray cod and the management of the reservoir; and (3) examine aspects of the recreational fisheries (catch, effort and harvest practices) in Lake Mulwala, Murrumbidgee River and Murray River using standardised parameters to evaluate variability among these fisheries. This study will also provide harvest and catch rate information on which future comparisons can be made.

## Methods

### *Study site*

Lake Mulwala (36°00'22"S; 146°00'11"E) is an impoundment on the Murray River in south-eastern Australia, which was formed in 1939 by the construction of Yarrawonga Weir. Lake Mulwala covers an area of 3,561 ha, and has a capacity of 118,000 ML (Murray-Darling Basin Commission 2004). Habitat within the lake includes large amounts of dead standing and fallen hardwood trees, extensive beds of *Egeria densa*, macrophytes and remnant (inundated) river channels (Koehn 2009), as well as wetlands around the lake margins (Howitt et al. 2004). The lake forms part of the state border between NSW and Victoria, and it is used to store and re-



supply water for irrigation (Howitt et al. 2004). The lake has become an important recreational area supporting waterskiing, swimming, boating and recreational fishing (Howitt et al. 2004). The management of the lake for irrigation purposes and the lowering of water levels has raised community concerns about its impact on amenities and recreational uses (Howitt et al. 2004).

Lake Mulwala is one of Australia's premier recreational fisheries for Murray cod, hosting regular fishing tournaments that attract thousands of anglers (Kearney and Kildea 2001; Howitt et al. 2004; Koehn and Clunie 2010; Hall et al. 2012). The Murray cod population in the lake showed evidence of decline under a minimum legal size of 500 mm (Howitt et al. 2004). The impoundment is thought to be an important nursery ground for cod populations in surrounding rivers (Howitt et al. 2004).

#### *Survey design and sampling protocols*

To quantify fishery metrics for Murray cod within Lake Mulwala, we used a stratified random sampling design with day (calendar date) as the primary sampling unit (PSU) for all strata. Each survey day covered the period from sunrise to sunset. Night fishing (sunset to sunrise) was not included in the sampling design. The temporal survey frame was the three month summer season; 1 December 2014 to 28 February 2015. The season was stratified into two periods: (1) the month of December, during which the Murray cod fishery opens after a three month fishing closure (termed summer-early period); and (2) a two month period (January and February; termed summer-late period) to accommodate the expected high fishing effort and catch resulting from the reopening of the Murray cod fishery in December and subse-

quent school holidays. Thus, our survey covered the most intensively fished part of the year. Day-type stratification (weekend and weekday strata) within each survey period was also used. Public holidays were included as part of the weekend day stratum. Thus, the base-level strata were day-type (week-day, weekend), within period (summer-early, summer-late) and within season (summer). Four weekdays and four weekend days were sampled in summer-early, and three weekdays and three weekend days were sampled in summer-late. Sampling days were randomly selected within each survey period.

Progressive counts from a boat were used to quantify the shore- and boat-based fishing effort originating from all public and private access points within the fishery. Progressive count start locations and travel direction through the fishery were randomly selected (Hoenig et al. 1993). A pilot study was used to determine the time required to travel through the fishery, and 3 hours was allocated to complete a progressive effort count. Each survey day was divided into four non-overlapping intervals, and a progressive count was randomly allocated without replacement (within each base-level stratum) to one of the four intervals. We specifically excluded traveling boats and anglers moving along the shore from effort counts when their destination or their immediate intent to engage in any recreational fishing activity could not be determined.

A roving survey was used to obtain catch-and-release rate and harvest rate information from shore-based anglers. The roving surveys were undertaken on the same days as the progressive counts for fishing effort, but they did not cover the interval of the progressive count. The roving survey travel direction for each survey day was randomly

selected, and the start location was the termination point of the progressive effort count. The roving surveys covered at least one complete circuit of the fishery during each survey day.

An access point survey was used to obtain catch-and-release rate and harvest rate information from boat-based anglers. Eleven access points (public boat ramps) were identified. Information about the physical features of the access points; prior knowledge of the fishery; and the expert opinions of maritime and fishery compliance officers, local fishing guides and tackle store owners were used to categorize each access point as either high or low usage. Unequal probability sampling was then used to allocate two access points for coverage on each survey day; with the exception of 6 December 2014, when three ramps were sampled to improve coverage of a large boat-based fishing tournament. The daily selection probability for each of the three high usage access points was 0.3, and each of the eight low usage access points was assigned a daily selection probability of 0.0125. It was not cost effective to cover private access points during the survey. We assumed that the behaviors of anglers using private and public access points were similar.

All fishing parties interviewed during the roving and access point surveys were asked to provide information about their fishing trip and catch. These data included (a) trip duration, (b) primary target species of the fishing party, (c) the number and species that were caught-and-released, (d) the reason why those fish were released and (e) the fishing method. Harvested fish were identified and measured (FL, mm) by creel clerks. Any refusal to provide information or to show harvested fish was recorded.

### *Estimation procedures*

All calculations for determining estimates of catch and effort were based on statistical methods and equations from Pollock et al. (1994) and (Forbes et al. 2015c).

### *Fishing effort*

Fishing effort (party hours) was estimated separately for boat- and shore-based fisheries. Daily progressive counts were multiplied by the length of the survey day to estimate the fishing effort for each day sampled. Fishing effort estimates for each base-level stratum were made by multiplying the number of possible sample days in that stratum with the mean daily effort estimate for that stratum. Fishing effort estimates for each survey period were obtained by summing the day-type stratum effort estimates. Seasonal estimates were calculated by summing the survey periods.

For comparisons among studies, the estimates of fishing effort were converted from party hours to fisher hours. This procedure was performed separately for boat- and shore-based fisheries for each base-level stratum by multiplying the fishing effort (party hours) and the daily average of the mean number of anglers per fishing party. Variances were additive when strata were combined. Standard errors (SE) were calculated as the square root of the variance.

### *Catch-and-release rates and harvest rates*

The mean of ratios estimator was used for estimating shore-based catch-and-release rates and harvest rates, because interviews were based on incomplete trips (Jones et al. 1995; Hoenig et al. 1997; Pollock et al. 1997). The mean of ratios has a large variance when high harvest rates resulting from very short, incomplete fishing trips are included in cal-

culations (Hoenig et al. 1997). Plots of party-based catch-and-release rates, harvest rates and the length of the incomplete trip were examined to identify an appropriate level of truncation for these shore-based interviews (Hoenig et al. 1997). Twenty party minutes was used as the truncation criterion, thus resulting in the removal of six (2.4%) shore-based interviews.

The ratio of means estimator was used for estimating catch-and-release rates and harvest rates for the boat-based fishery (Jones et al. 1995; Pollock et al. 1997). Each access point that was sampled on a survey day was given equal weighting in the calculation of daily catch-and-release rates and harvest rates.

Catch-and-release rates and harvest rates and their variances for each survey period were weighted to compensate for the different sizes in day-type strata. Similarly, weighted mean catch-and-release rates and harvest rates and their variances were calculated for the summer season by using weighted means that compensated for the different sizes of the two survey periods (Pollock et al. 1994). These weighting procedures were applied to data from both the shore- and boat-based fisheries.

#### *Catch-and-release and harvest*

Catch-and-release and harvest estimation for both boat- and shore-based fisheries were undertaken by multiplying fishing effort (party hours) with the mean daily catch-and-release rate or harvest rate (fish/party-hour) for each base-level stratum (Pollock et al. 1994; Steffe and Chapman 2003). Catch-and-release and harvest totals for each survey period were obtained by summing the appropriate day-type stratum estimates. Seasonal estimates of catch-and-

release and harvest were made by summing the survey periods. Variances and SEs were then calculated.

#### *Targeting behavior, fishing methods and reasons for catch-and-release*

Weighted frequency distributions were constructed to describe the targeting preferences of anglers, the reasons for their catch-and-release practices and the fishing method used. Weighted frequency distributions were initially used for each base-level stratum on data aggregated at the PSU level (i.e., day). Within each PSU, the weighted response from each fishing party was given equal weighting. The fishing party response was derived by giving equal weighting to the responses of individual anglers within that party. Seasonal weighted frequency distributions were constructed by integrating the data from the base-level strata and weighting them to account for the different number of days in each base-level stratum. These weighted frequency distributions were created for each of the boat- and shore-based fisheries. The reasons why anglers practiced catch-and-release were categorised into whether released fish were undersized (below the MLL), oversized (above maximum length limit), legal voluntary (harvest eligible but voluntarily released) or over bag limit (exceeding possession limits). The fishing method used was categorised into bait, lures or a combination of bait and lures (where anglers used multiple methods).

#### *Standardised parameters*

To assess variability among fisheries for Murray cod, estimates of effort, harvest and discard were standardised per unit of surface area. The surface area (ha) of the survey area was calculated with ArcMap

(Environmental Systems Resource Institute 2009). Boat-based anglers are able to effectively fish the entire surface area of Lake Mulwala; however, shore-based anglers are restricted to the lake margins and the distance to which they can cast or wade from shore. Therefore, the surface area used to calculate effort, discard rate and harvest density for the shore-based fishery in Lake Mulwala was defined as the area extending between the shoreline and 50 m from the shore. The estimates of effort, discard rate and harvest were divided by the appropriate surface area (either boat- or shore-based) to obtain effort/ha, fish discarded/ha and fish harvested/ha.

The size structure of harvested Murray cod was standardised by calculating the relative stock density for each fishery (Neumann and Allen 2007). The relative stock density was the proportion of Murray cod that we deemed to provide a memorable fishing experience (i.e. > 700 mm, at which length Murray cod are a highly sought-after sport-fish; Forbes 2011) in the legally harvested population (i.e., > 550 mm, the lower bound of the existing harvest slot limit).

We propose a new standardised parameter of harvest specificity as the proportion of harvested Murray cod in the total harvest of all species combined, which provides a relative measure of importance. Harvest specificity differs from targeting behavior because it is independent of angler opinion, perceptions and attitudes.

To obtain effort-, discard- and harvest-density; relative stock density; and harvest specificity in these systems, equivalent to those calculated for Lake Mulwala, we re-analysed data from similar surveys of recreational fisheries conducted during 2012–2013 in the Murrumbidgee River between Ber-

embed Weir and Yanco Weir (Forbes et al. 2015c) and during 2006–2008 in the Murray River downstream of Lake Mulwala to the South Australian border (Brown 2010). These standardised data allowed for comparisons among boat- and shore-based fisheries in each waterbody for the three month summer season.

## Results

Roving surveys produced 253 successful interviews of shore-based fishing parties, comprising 493 anglers. Access point surveyors successfully interviewed 296 boat-based fishing parties and 627 anglers. A total of 681 Murray cod were recorded as being captured during the surveys, 46 of which were harvested.

### *Boat-based fishery*

Thirty-three Murray cod ranging from 540 to 760 mm were measured during interviews with boat-based anglers in Lake Mulwala, and 94% (31 fish) were within the current harvest slot limit. Of these, 52% of Murray cod (17 fish) retained by the boat-based fishery were ineligible for harvest at the previous 600 mm minimum length limit (i.e., harvested fish were > 550 mm lower slot bound but < 600 mm). One Murray cod was undersized (i.e., < 550 mm), and one was oversized (i.e., > 750 mm; Fig. 1). The boat-based released component (i.e., the number of fish released as a percentage of fish harvested plus those caught-and-released) for Murray cod in Lake Mulwala was 88.1%. Most Murray cod releases in the boat-based fishery were mandatory because the fish were undersized (93.7%); however, 6.2% of harvest eligible Murray cod were voluntarily released, and 0.1% were released because they were oversized (Fig. 2).

Sixty-five percent of the summer fishing effort in Lake Mulwala was expended in the boat-based fishery (Table 1), and 98% of boat-based fishing parties targeted Murray cod (Fig. 3). Boat-based anglers predominantly used lures, and a smaller proportion used bait (Fig. 4). The summer boat-based catch-and-release rate of Murray cod in Lake Mulwala was 0.256 ( $\pm$  0.064 SE) fish/angler-hour, and the harvest rate was 0.029 ( $\pm$  0.011 SE) fish/angler-hour (Table 2). The boat-based catch-and-release rates and harvest rates for species other than Murray cod were minimal ( $<$  0.003 fish/

angler-hour; Table 2). Subsequently, the boat-based catch-and-release and harvest estimates for species other than Murray cod were low (catch-and-release  $\leq$  200 fish; harvest  $\leq$  89 fish; Table 3). The boat-based catch-and-release for Murray cod in Lake Mulwala was 8,486 ( $\pm$  2,769 SE) fish, and the harvest was 1,145 ( $\pm$  454 SE) fish (Table 3).

The boat-based fishery in Lake Mulwala had lower effort density (16.6 angler-hours/ha) than did the Murrumbidgee River (20.0 angler-hours/ha) and the Murray River (26.4 angler-hours/ha; Table 4). The discard density varied from 2.4 fish/ha in Lake Mulwala

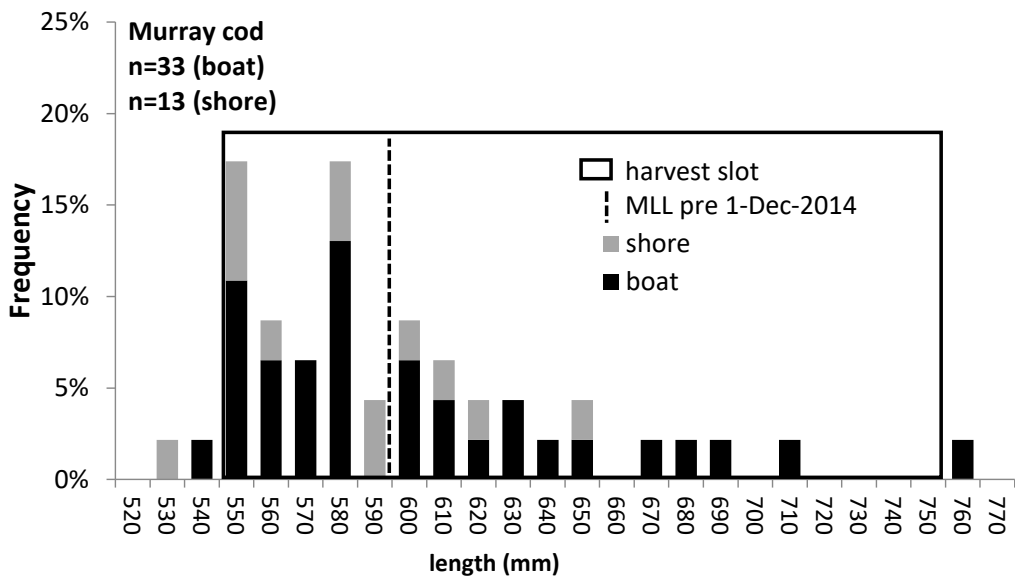


Figure 1: Length frequency distributions for Murray cod harvested by boat- and shore-based anglers from 1 December 2014 to 28 February 2015 in Lake Mulwala. The current 550–750 mm harvest slot is boxed, and pre-December 2014 minimum legal length (MLL) given as a dotted line.

Table 1. Effort estimates (angler-hour; with SEs) for the 2014–2015 summer boat-based and shore-based fisheries in Lake Mulwala.

Day-type	Boat		Shore		Total	
	Total	SE	Total	SE	Total	SE
Weekday	17,259	4,954	17,316	3,924	34,575	6,320
Weekend	41,696	23,590	14,855	3,827	56,551	23,898
Total	58,955	24,104	32,171	5,481	91,126	24,719

Table 2. Murray cod, carp, golden perch, trout cod and redfin release rates and harvest rates (fish/angler-hour, with SE) for (a) boat-based, and (b) shore-based fisheries, taken by recreational anglers during the 2014–2015 survey period in Lake Mulwala.

Day-type	a) Boat-based fishery				b) Shore-based fishery			
	Release rate		Harvest rate		Release rate		Harvest rate	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Murray cod	0.256	0.064	0.029	0.011	0.115	0.019	0.011	0.003
Carp	0.003	0.002	0.001	0.001	0.007	0.004	0.037	0.007
Golden perch	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0	0
Trout cod	<0.001	<0.001	0	0	0.001	0.001	0	0
Redfin	0	0	0	0	<0.001	<0.001	0	0

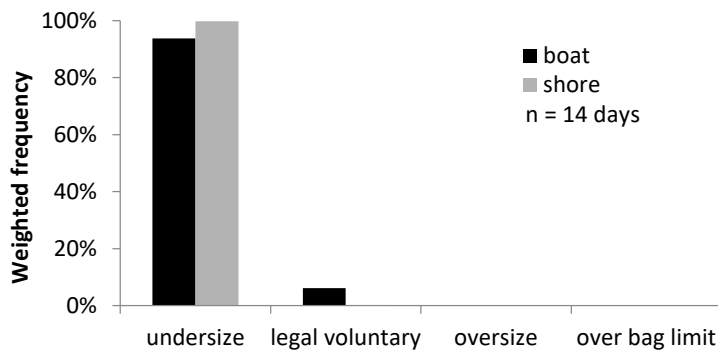


Figure 2: Weighted frequency distribution of reasons for Murray cod catch-and-release for boat- and shore-based fisheries during the 2014–2015 survey period in Lake Mulwala. The total number of sampling days is represented by n.

to 13.8 fish/ha in the Murrumbidgee River (Table 4). Harvest density varied from 0.2 fish/ha in the Murray River to 1.1 fish/ha in the Murrumbidgee River (Table 4). The boat-based harvest specificity in Lake Mulwala (92%) and the Murrumbidgee River (71%) was higher than that in the Murray River (16%; Table 4). The relative stock density for boat-based fisheries varied from 27

in the Murrumbidgee River to six in Lake Mulwala (Table 4).

*Shore-based fishery*

Thirteen Murray cod ranging from 530 to 650 mm were measured during interviews with shore-based anglers in Lake Mulwala, 92% (12 fish) of which were within the current harvest slot limit. Of these, 62% of Murray

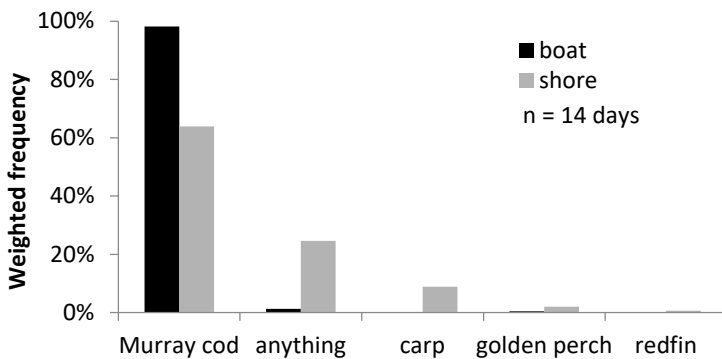


Figure 3: Weighted frequency distribution of angler species-specific target preferences for boat- and shore-based fisheries during the 2014–2015 survey period in Lake Mulwala. The total number of sampling days is represented by n.

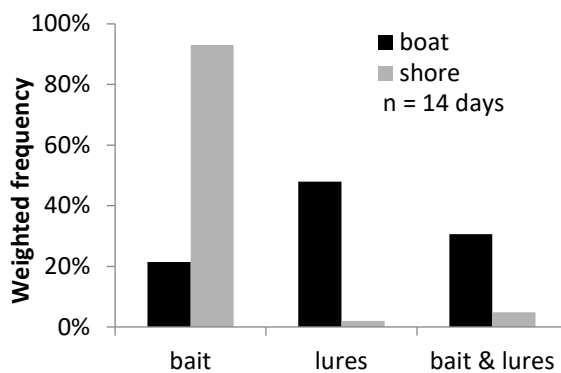


Figure 4: Weighted frequency distribution of the fishing method used by boat- and shore-based fisheries during the 2014–2015 survey period in Lake Mulwala. The total number of sampling days is represented by n.



Table 3. Recreational catch-and-release (a) and harvest (b) estimates (number of fish; with SEs) for Murray cod, carp, golden perch, trout cod and redfin taken by boat-based and shore-based anglers during the 2014–2015 survey period in Lake Mulwala.

Day-type	a. Catch-and-release						b. Harvest					
	Boat		Shore		Total		Boat		Shore		Total	
	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<b>Murray cod</b>												
Weekday	4,524	1,742	1,849	656	6,373	1,862	495	221	161	90	656	238
Weekend	3,962	2,152	1,929	674	5,891	2,255	650	397	197	86	847	406
Total	8,486	2,769	3,778	941	12,264	2,924	1,145	454	358	125	1,503	471
<b>Carp</b>												
Weekday	69	57	60	60	129	83	13	13	981	415	994	415
Weekend	15	15	36	32	51	36	76	40	515	179	591	183
Total	84	59	96	69	180	91	89	42	1,496	452	1,585	454
<b>Golden perch</b>												
Weekday	29	20	0	0	29	20	13	13	0	0	13	13
Weekend	171	108	4	4	175	108	0	0	0	0	0	0
Total	200	110	4	4	204	110	13	13	0	0	13	13
<b>Trout cod</b>												
Weekday	0	0	0	0	0	0	0	0	0	0	0	0
Weekend	36	36	38	38	74	52	0	0	0	0	0	0
Total	36	36	38	38	74	52	0	0	0	0	0	0
<b>Redfin</b>												
Weekday	0	0	0	0	0	0	0	0	0	0	0	0
Weekend	0	0	6	6	6	6	0	0	0	0	0	0
Total	0	0	6	6	6	6	0	0	0	0	0	0

cod (8 fish) retained by the shore-based fishery were ineligible for harvest at the previous 600 mm minimum length limit. One Murray cod was undersized (i.e., < 550 mm; Fig. 1). The shore-based released component for Murray cod in Lake Mulwala was 91.3%. In addition, 99.8% of Murray cod released in the shore-based fishery were undersized, and 0.2% of harvest-eligible Murray cod were voluntarily released (Fig. 2).

Thirty-five percent of the summer fishing effort in Lake Mulwala was expended in the shore-based fishery (Table 1). Shore-based

fishing parties were more generalist in species targeted than boat-based fishing parties and showed 64% targeting of Murray cod, 25% with no preference (where target species was ‘anything’) and 9% targeting carp (Fig. 3). Ninety three percent of shore-based anglers used bait, whereas 2% used lures (Fig. 4).

The summer shore-based Murray cod catch-and-release rate in Lake Mulwala was 0.115 ( $\pm$  0.019 SE) fish/angler-hour. The catch-and-release and harvest rates for other species were  $\leq$  0.007 fish/angler-hour (Table 2). The shore-based harvest rate of Murray

Table 4. Quantitative characteristics used to assess variability among Murray cod fisheries in Lake Mulwala, the Murrumbidgee River and the Murray River. Data from the Murrumbidgee River were re-calculated from Forbes et al. (2015b). Murray River data were re-calculated from Brown (2010).

	Mulwala boat-based	Mulwala shore-based	Murrumbidgee boat-based	Murrumbidgee shore-based	Murray boat-based	Murray shore-based
Surface area (ha)	3,561	201	1,019	1,019	13,424	13,424
Harvest specificity	92%	19%	71%	3%	16%	3%
Relative stock density	6	0	27	25	21	0
Effort density (angler-h/ha)	16.6	160.1	20.0	10.3	26.4	13.3
Discard density (Murray cod/ha)	2.4	18.8	13.8	2.3	3.2	0.6
Harvest density (Murray cod/ha)	0.3	1.8	1.1	0.1	0.2	0.1

cod was 0.011 ( $\pm$  0.003 SE) fish/angler-hour. The shore-based catch-and-release of Murray cod in Lake Mulwala was estimated at 3,778 ( $\pm$  941 SE) fish. The shore-based harvest estimate for Murray cod was 358 ( $\pm$  125 SE).

The shore-based effort density varied from 160.1 angler-hours/ha in Lake Mulwala to 10.3 angler-hours/ha in the Murrumbidgee River (Table 4). The discard density varied from 18.8 fish/ha in Lake Mulwala to 0.6 fish/ha in the Murray River (Table 4). The harvest density varied from 1.8 fish/ha in Lake Mulwala to < 0.1 fish/ha in the Murray River (Table 4). The shore-based harvest specificity was higher in Lake Mulwala (19%), than in the Murrumbidgee and Murray rivers (both 3%; Table 4). The relative stock density for shore-based fisheries varied from 25 in the Murrumbidgee River to zero in Lake Mulwala and the Murray River (Table 4).

### Discussion

The regulatory change from a minimum length limit of 600 mm to a harvest slot of 550–750 mm for Murray cod resulted in a

temporary harvest bias toward fish of 550–600 mm in Lake Mulwala. In addition, most Murray cod captures resulted in mandatory release because the fish length was below the existing lower slot limit, and few large fish were captured, a finding consistent with angling surveys for this species in riverine environments (Brown 2010; Forbes et al. 2015c). The role of smaller fish in the recreational fishery was highlighted by previous research indicating that a HS of 400–600 mm may decrease the risk of decline and improve catch rates compared to a range of HSs (including the current HS) and minimum legal lengths (Koehn and Todd 2012). Despite their ability to grow to a large size, small Murray cod (i.e. < minimum legal length) are typical in reservoir and riverine recreational fisheries; thus, the performance of management interventions and the fishery in general may also require evaluation in reference to a recreational fishery dominated by catch and release of Murray cod < 550 mm.

Overall, lowering the minimum length limit to 550 mm initially provided access

to more harvest eligible cod in the reservoir examined. However, whether this harvest influences long term sustainability cannot be determined by this study and requires ongoing monitoring. Furthermore, the initial high harvest of Murray cod created a 'gold rush' and likely led to unsustainably high angler expectations in this reservoir. As fish populations adjust to the HS, angler expectations and satisfaction may become unrealistic, because harvest rates of fish 550–600 mm are likely to decline from the initially high rates in the first season after the regulation changes (Connelly and Brown 2000; Arlinghaus 2006). As a result, replication of this survey in Lake Mulwala would be required to provide information on long term impacts and effectiveness of the HS limit in this fishery.

The Murray cod HS was introduced to allow a more natural age structure (Gwinn et al. 2015), because populations truncate at the minimum legal length (Nicol et al. 2004). This truncation was thought to be a result of fishing pressure removing many harvest eligible fish from the population (Nicol et al. 2004). However, the harvest of recently eligible fish in Lake Mulwala also suggest that fewer fish may grow through the slot and attain a protected length (i.e., > 750 mm). In particular, Lake Mulwala is thought to experience reasonable growth rates with fish likely to remain in the HS for approximately 3 years (Anderson et al. 1992; Ye et al. 2000; Nicol et al. 2004). Growth rates in other areas, particularly rivers, are thought to be much slower, and the time in the HS could be more than 5 years in some waters (Anderson et al. 1992; Gooley 1992). As a result, waterbody-specific growth rates and further recreational catch and harvest data are needed to adequately assess the effects of

HS introduction over the large scale where the regulation has been imposed.

The sustainability of the initial harvest of 550–600 mm Murray cod and the long term success of the HS will be highly dependent on the ability of the regulation to achieve its goals across multiple state jurisdictions. The ability of the HS to achieve goals across this large scale is especially challenging for Murray cod fisheries, because they are found in waterbodies with varying productivity and fishing pressure (Rowland 2005; Koehn and Todd 2012) as well as reservoirs with management goals, which may conflict with the optimal conditions required for strong recreational fisheries (Kingsford 2000). Similar regulations applied over large spatial scales in other fisheries (e.g., walleye in Alberta, Canada) have had mixed success, with reports of outcomes (e.g., prevention of fishery decline or collapse) not being met on the local scale or in certain waterbodies (Sullivan 2003). In particular, fluctuations in reservoir water levels and the impacts on fisheries may need to be considered in assessing fishery management interventions. These considerations may include the identification of suitable reservoir and riverine sites for ongoing monitoring of the fishery. In instances where monitoring identifies unsustainable practices, managers should consider adaptive management strategies or differing legislation based on local science (Sullivan 2003).

The social trend of voluntarily releasing harvest-legal Murray cod (Douglas et al. 2010) was less apparent in Lake Mulwala as < 10% of harvestable cod were released (Fig. 2). Overall, the percentage of Murray cod released (mandatory and voluntary) in the current study (89%) was less than that reported in the Murrumbidgee River (95%;

Forbes et al. 2015c), greater than that identified during a nationwide survey (77.6%; Henry and Lyle 2003) and similar to the 90.0% release rate reported for the Murray, Goulburn and Ovens rivers (Brown 2010). Mortality of released fish can be a major concern in the sustainability of recreational fisheries. Murray cod are thought to be sensitive to recreational fishing mortality because of their longevity (Allen et al. 2009; Douglas et al. 2010). Murray cod catch-and-release mortality is estimated to range from 2% in the Murray River (Douglas et al. 2010) to 15% in Lake Mulwala during a delayed-release summer fishing tournament (Hall et al. 2012). Such mortality rates and the high incidence of catch-and-release fishing could generate additional mortality in excess of our harvest estimates. Given the high fishing pressure exerted in Lake Mulwala, the high incidence of catch-and-release and the longevity of Murray cod, multiple recaptures are possible, but the rate of recapture and implications of cumulative capture on mortality are not understood (Douglas et al. 2010; Forbes et al. 2015c).

Variability in standardised parameters was evident between Lake Mulwala and the river sites, possibly as a result of fluctuations in abundance, population size structure, shifts in fishing effort or changing length-based harvest restrictions. Harvest specificity varied between Lake Mulwala and the river sites with the reservoir site having very high proportions of Murray cod harvest. The difference in harvest specificity would likely be the result of the recent introduction of the HS but also reflect the importance of Murray cod harvest for this reservoir fishery (Howitt et al. 2004). Murray cod have higher growth rates in reservoirs than rivers, which may contribute to different popula-

tion structures between these waterbody types (Forbes et al. 2015a). Thus the different growth rates and population structures may contribute to the differences in standard parameters (e.g., relative stock density and harvest density) between Lake Mulwala and rivers. Furthermore, reservoir management practices (e.g., fluctuating water levels) may influence angling effort, harvest, abundance and recruitment (Chizinski et al. 2014; Nagid et al. 2015). Lake Mulwala is subject to excessive aquatic weed growth, which is managed by reducing the lake level to expose banks for a sustained period (~ 3 months) over autumn and winter. The impacts of this procedure on the lake productivity and fishery are not understood, but studies in other regions of the world suggest both positive and negative impacts of drawdown on recreational fisheries (Chizinski et al. 2014; Nagid et al. 2015).

The differences in effort density identified between Lake Mulwala and river sites may be related to the proximity of the reservoir to population centers and the convenient and safe access to angling sites (compared with river sites which were more remote). In Lake Mulwala, most of the total discard of Murray cod came from the boat-based fishery. In contrast, the shore-based fishery in Lake Mulwala was a more diverse, multi-species fishery. Shore-based fishers almost exclusively used bait, an effective method to capture a range of species in the Murray-Darling Basin (Rowland 1989; Brown 2010), whereas boat-based anglers mainly used lures, which can be a selective method for Murray cod (Forbes 2011). In addition, Murray cod are less active during daylight hours in summer months and prefer habitats that include structural woody debris, deeper water and overhanging vegetation

(Koehn 2009; Koehn et al. 2009; Thiem et al. 2018). These habitats are more accessible to boat-based anglers, thus possibly explaining why shore-based anglers were less focused on Murray cod and had increased harvest of less habitat-specific, generalist species such as carp.

This study used fishery-dependent survey techniques to identify the change from a minimum length limit to a harvest slot limit, which resulted in a strong harvest bias toward newly harvestable Murray cod. Analysis of data from this and other surveys for Murray cod also revealed that populations of this species are characterised by an abundance of undersized fish and few large individuals, thus justifying the implementation of the harvest slot limit and its objectives to increase the number of larger fish (Gwinn et al. 2015). In order to provide longer term evaluation of the HS in Lake Mulwala, this survey should be repeated at regular intervals so changes in catch, effort and harvest can be evaluated. However, close monitoring will also be required in both reservoir and riverine fisheries across large areas to ensure that the HS achieves the desired outcomes, particularly which fish survive harvest, grow beyond the upper slot limit and provide enhanced angling opportunities and reproductive advantages afforded by these large fish. Furthermore, managers may need to be responsive to changing angler and fishery needs. Working around lake management will be especially important during times of low inflow or high demand on water resources. Therefore, continued monitoring of recreational fisheries for Murray cod is vital as populations adjust to changing harvest restrictions, fishing effort, reservoir management practices and environmental conditions. Such moni-

toring should ensure that sampling effort and design are sufficient to separate variability caused by differences among fisheries (as identified in this study) from desired changes caused by the harvest slot limit.

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## The Skottowe manuscript and the Cook connection

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### Abstract

Thomas Skottowe was Commandant of the Penal Settlement at Newcastle from 1811 to 1814. A keen naturalist, he made extensive notes on the local flora and fauna and had them illustrated by one of the convicts at the Settlement, Richard Browne. The resulting manuscript was acquired by David Scott Mitchell and donated to the State Library of New South Wales as a gift to the people of the State. In 1988, the Skottowe manuscript was published as part of Australia's Bicentennial celebrations. Thomas Skottowe's father was Lord of the Manor in Great Ayton, Yorkshire, where the navigator James Cook spent much of his childhood. He was instrumental in helping Cook gain an education and perhaps in encouraging him to enlist in the Royal Navy. The significance of the manuscript lies, in Sir David Attenborough's words, not in the scientific information it contains, but in "something much rarer — the glimpse it brings to our jaded and only too knowledgeable eyes of a land full of marvels seen with wonder and innocence" [Foreword, *The Skottowe Manuscript*, 1988].

### Historical background

The expedition led by Lieutenant-Governor William Paterson in June and July 1801 to survey the mouth of the Hunter and to travel as far as possible up-river had, amongst the other purposes outlined by Governor King, that of loading the colonial schooner *Francis* with "the best coals that can be procured" and dispatching it to Sydney "without loss of time."<sup>1</sup> Under the command of Lieutenant James Grant, that most serviceable of colonial vessels the brig *Lady Nelson* set off for Newcastle with a party of eight comprising Paterson himself, the surgeon Dr John Harris, the French cartographer Ensign Francis Barrallier, the naturalist and artist John Lewin, a pilot and second mate, a sawyer and an Indigenous man variously referred to as Bungery or Bongary.

The party was quick to act in carrying out King's instructions. Having left Sydney on 10 June and reached the mouth of the Hunter after four days, Paterson was able to dispatch the *Francis* back to Sydney as early as 24 June with a cargo of coal samples and various kinds of wood. King lost no time in moving to exploit Newcastle's coal deposits. In July 1801, he sent Corporal John Wixstead with a party of eight privates and 12 convicts to form a post and begin mining operations.

Things did not go well. Accused by disloyal subordinates of offering an inducement to a female convict to sleep with him and of supplying convicts with spirits, Wixstead was the subject of a "court of enquiry" consisting of Ensign Barrallier (who made a second journey to Newcastle in October–November 1801) and the surgeon Dr Martin Mason. The "court," convening in October, found Wixstead guilty of "imprudence"

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<sup>1</sup> *Historical Records of New South Wales [HRNSW]*, 1896, 4: 390–391.

and reduced him to the rank of private.<sup>2</sup> Mason took over the superintendence of the Newcastle post in the role of magistrate. Things then went from bad to worse. Mason remained at the settlement for three months, until his harsh and tyrannical rule made a mutiny by the convicts almost inevitable. He was recalled by Governor King in early 1802, whereupon the post was abandoned and all soldiers and convicts returned to Sydney. So ended what is usually referred to as the First [Penal] Settlement.

Nothing more happened until March 1804, when Governor King appointed Lieutenant Charles Menzies of the Royal Marines as Commandant of the settlement, which King had been ordered by the Secretary of State for the Colonies to re-establish “without loss of time.”<sup>3</sup> This Second Settlement was a great deal more successful than the First, lasting until the early 1820s, when the remaining convicts were removed to Port Macquarie, where a Penal Settlement was opened in 1821. In addition to the general Commission given him by Governor King, Menzies was instructed to use the convicts, among other tasks, to get “as many coals as possible” and “to enforce a due observance of religion and good order.” Though he remained Commandant in Newcastle for only a year, Menzies established the Second Settlement on a sound basis, King reporting that he had “brought it to a forward degree of perfection” (Flowers, 1967). Resuming his post in the Royal Marines in March 1805, Menzies went on to a career of great distinction, playing a notable part in the wars against Napoleon. In 1852 he was appointed

aide-de-camp to Queen Victoria and ended his military career as General Sir Charles Menzies KCB KH.

### Commandants and artists

Among Menzies' successors as Commandant, two in particular were in the fortunate position of having among their charges a convict who had been transported for the crime of forgery, and who — having re-offended while in Sydney — was punished by being sent to what the historian John Turner described as “Sydney's Siberia” (Turner, 1980), namely the Penal Settlement at Newcastle. These convict forgers, for obvious reasons, proved to be quite accomplished artists, and this talent was put to good use by the Commandant of the time.

The better-known of the forger/artists was Joseph Lycett, by profession a portrait and miniature painter. Convicted of forgery at the Salop (Shropshire) Assizes in 1811, he was sentenced to transportation for 14 years. As it happened, the transport *General Hewitt* on which Lycett's journey to Sydney took place was also carrying Captain James Wallis of the 46<sup>th</sup> Regiment, himself an amateur artist, who was travelling to New South Wales with his regiment. After commanding a company of grenadiers of the 46<sup>th</sup> Regiment in a skirmish against hostile Indigenes on Sydney's outskirts, Wallis was appointed in 1816 Commandant of the Newcastle Penal Settlement, for which he embarked on 8 June in the *Lady Nelson* with a detachment of his regiment. Meanwhile, in the course of his employment as a clerk in the police office, Joseph Lycett had managed to acquire a small printing press and in May 1815 had flooded Sydney with hundreds of skilfully forged five-shilling bills drawn on the postmaster. He was again convicted

2 *Corporal Wixstead and the Fate of Newcastle's First Settlement in 1801*, n.d.

3 *HRNSW*, 1896, 5: 362

of forgery and sent to Newcastle. After enduring the severity of the strict regime imposed by Lieutenant Thomas Thompson, Commandant since February 1814, Lycett found that his fortunes improved considerably once Wallis succeeded Thompson in June 1816.

A keen amateur artist, Wallis had come to Newcastle equipped with paints and brushes, and quickly set Lycett to work, not only in recording views of Newcastle but in drawing up architectural plans for a church known as “Christ’s Church” or “Christ Church.” When the latter was completed in 1818, it was Lycett whom Wallis commissioned to paint an altar piece. In return for his work, he was granted a conditional pardon on Wallis’ recommendation and was able to leave the Newcastle Penal Settlement for Sydney. Three of the views of Sydney painted by Lycett were sent by Governor Macquarie to Lord Bathurst, and by way of reward Lycett was granted an absolute pardon in November 1821. The following year, he left for England and carved out a modest career there as an artist until his death in Birmingham in 1828.

The lesser-known forger/artist in the Newcastle Penal Settlement was one Richard Browne. Just as Lycett had been set to work by Commandant Wallis, Browne had been commissioned to produce drawings and paintings by an earlier Commandant, Lieutenant Thomas Skottowe, who was in charge of the Settlement from December 1811 to February 1814. Born in Dublin in 1771, Richard Browne was sentenced to transportation in 1810, presumably for the crime of forgery, and was sent directly from Ireland to New South Wales, where he arrived in July 1811. In October that year he was sent to Newcastle for committing a second offence.

During his time in Newcastle he formed a liaison with a female convict named Sarah Coates, with whom he had at least two daughters who were born in Newcastle. On the completion of his sentence in 1817 he lived in Sydney, where he was designated “free by servitude” (Hyde, 2012). He died in Sydney in January 1824.

Just how it was that Thomas Skottowe came to commission Browne as an artist and illustrator is not recorded, nor is there any record of artworks created by Browne before his period of penal servitude. It seems most likely that Skottowe selected Browne purely on the basis of his conviction for forgery, on the assumption that his keen eye for detail and skill in the visual reproduction of objects would meet the requirements of the task. In the event, Skottowe’s faith in Browne’s ability proved to be justified. As his most characteristic work is generally considered to date from the emancipist period of his life between 1817 and 1821, it seems that his work for Thomas Skottowe served as his apprenticeship as an artist. After his sentence in Newcastle was completed, he lived in Sydney selling watercolour illustrations of natural history subjects, particularly birds, and of Indigenous Australians. As would later be the case with Joseph Lycett, Browne contributed many of the original watercolours for James Wallis’ *An Historical Account of the Colony of New South Wales and its Dependent Settlements* (London, 1821).

### Thomas Skottowe and the manuscript

Thomas Britiffe Skottowe was born in Great Ayton, Yorkshire, in or about 1787, the son of Thomas Britiffe Skottowe IV (1767–1841) and Sarah Lydia Pockocke (1768–1844). The Skottowe family (the surname is of Scandinavian origin) had a long record of distin-

guished government service, Thomas Skottowe III having held the office of Register and Secretary of the Province under the Appointment of His Majesty in Charleston, South Carolina, at the outbreak of the American Revolution. Thomas Skottowe IV was Lord of the Manor of Great Ayton and owner of the nearby Aireyholme Farm. It is most likely that his son, later to become Commandant of the Newcastle Penal Settlement, was born at Ingleby Manor House, Great Ayton.

Having enlisted as an ensign (equivalent to second lieutenant) in the 73<sup>rd</sup> Regiment, our Thomas Skottowe was ordered to the colony of New South Wales under the regiment's Commanding Officer, Lieutenant-Colonel Lachlan Macquarie, sailing from St Helens, Isle of Wight, on 25 May 1809 and arriving in Sydney on 1 January 1810. He was promoted to (first) lieutenant and made Commandant of the Newcastle Penal Settlement the following year. While in New South Wales, Skottowe, amongst other dalliances, formed a liaison with Mary Ann McCarty,<sup>4</sup> who already had a son from an earlier association on Norfolk Island. On 28 August 1811, a month after Skottowe had left Sydney to take up his post at Newcastle, Mary McCarty gave birth to a son, named by the couple Augustus John (*discussed below*). Mary did not join Thomas in Newcastle, at least not immediately, as Augustus was baptised in St Philip's Church, Sydney, on 20 September 1811.

Unlike Commandant Wallis, Skottowe was not himself an artist, but as a keen naturalist he may well have arrived in Newcastle armed with a stock of paintbrushes and pig-

ments in the expectation of either finding there a person capable of illustrating the native flora and fauna or, in default of this, doing the best he could on his own. Indeed, for a keen naturalist of that era not to have travelled with a stock of artists' materials would be the equivalent, in a more modern period, of a tourist travelling without a camera. In any case, Richard Browne found himself equipped with the necessary prerequisites to undertake the commission that was given him by Thomas Skottowe.

Intensely interested in the flora and particularly the fauna of Newcastle and its region, Skottowe wrote extensive notes on animals, birds and fish, leading to the production of a manuscript entitled *Select Specimens from Nature of the Birds, Animals, &c, &c, of New South Wales, Collected and Arranged by Thomas Skottowe, Esqr*<sup>5</sup> (1813). The manuscript at one time was in the possession of a certain A. Cahill, who gave it to his son Frank Cahill on 3 August 1852. It was acquired by the great bibliophile and philanthropist David Scott Mitchell from an unknown source before 1907, when he bequeathed his collection to the people of New South Wales, forming the Mitchell Library.

The Skottowe Manuscript was dismembered by the Library in June 1979 for conservation reasons. The binding from which it was removed appears to date from the late nineteenth or early twentieth century and is possibly English. A facsimile edition of the manuscript was published as a Bicentenary project in 1988 by the Newcastle-born publisher David Ell in conjunction with the bookshop Hordern House, a firm specialis-

<sup>4</sup> In the entry on Thomas Skottowe on the *People Australia* website, Mary Ann McCarty's surname is incorrectly given as McCarthy.

<sup>5</sup> See 56 pages of the 1813 MS on-line at the State Library of NSW, at <http://archival.sl.nsw.gov.au/Details/archive/110320794> [Ed.]



ing in rare books. Along with an accompanying volume containing a commentary by the cultural historian Professor Tim Bonyhady and a foreword by Sir David Attenborough, the manuscript was published in a limited edition of 550 numbered copies. The editors acknowledged the assistance given by the distinguished mammalogist Dr John Calaby who acted as natural history consultant.

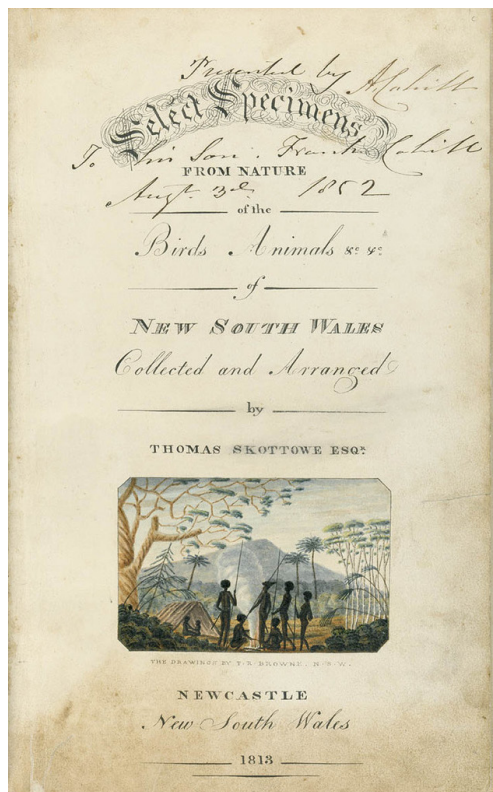


Fig. 1: Title page of the 1813 MS. (Courtesy Mitchell Library, State Library of NSW)

Attenborough's foreword opens:

Lieutenant Thomas Skottowe stationed, at the beginning of the nineteenth century, on the rim of an almost unexplored continent reacted in just the same way as many of us do today on seeing a beautiful bird or an extraordinary mammal. He felt

an urgent desire to record it, perhaps even to tell others about it. He knew, doubtless, that by doing so he could rekindle his initial delight and enjoy himself all over again. So he set about compiling this book [Foreword, *Skottowe Manuscript*, 1988].

Though a keen amateur naturalist, Skottowe was — as Sir David remarks — not a particularly knowledgeable one. Moreover, as Louise Anemaat has pointed out, “[t]he quality of drawings by convict artists is often variable. Some are poorly executed” (2019: 209). This is sometimes the case with Richard Browne’s depictions, particularly of the local fauna, which are, in Sir David’s words, “less than scientifically accurate.” He goes on to observe, however, that “the skill needed to portray the true proportions of a totally unfamiliar animal is much greater than those of us may suppose who, these days, take our natural history notes by pressing the button of a camera” (Foreword, 1988).

Lieutenant Thomas Skottowe remained in New South Wales after the departure of the larger part of his regiment, but was ordered to Ceylon (Sri Lanka)<sup>6</sup> with the last of the 73<sup>rd</sup> Regiment and departed the colony on the colonial brig *Kangaroo* on 18 April 1815. He was accompanied neither by his son Augustus nor by his common-law wife Mary Ann McCarty, who may again have been pregnant by him. He was promoted to the rank of captain while in Colombo, and served there and in Kandy until December 1817, after which he returned to his family in England — probably for reasons of failing health, since he died at the age of 33 while on leave of absence “for the recovery of his health” (“Thomas Britiffe Skottowe”). He

<sup>6</sup> Not Calcutta, as stated on the [findagrave](#) website (“Thomas Britiffe Skottowe”).

was buried on 18 November 1820 in St Bartholomew Churchyard, Tweedmouth, Berwick-upon-Tweed. His son Augustus John (1811–1898) emigrated to Ontario, Canada, where he took the name John Augustus McCarthy and had numerous descendants.

### The Cook connection

James Cook (1693–1779) was a Scottish farm labourer who came as a young man to live in the village of Marton, near Middlesbrough in Yorkshire, where he found employment as what was known as a “day labourer.” He and his locally-born wife Grace Cook, *née* Pace, were married on 10 October 1725 and had eight children, four of whom died in childhood. Their second son, born on 7 November 1728, was baptised in St Cuthbert’s Church, Marton, on 14 November that year<sup>7</sup> and given his father’s name of James. In 1736, the family moved a few miles from Marton to Aireyholme Farm at Great Ayton, where the Lord of the Manor, Thomas Skottowe IV, had offered James senior the position of farm manager or “bailiff.” The Cooks lived on the farm in an estate cottage until James senior retired in 1755. Thomas Skottowe, impressed by the promise shown by James junior, paid for him to attend the charity school founded in 1704 by the landowner Michael Postgate. Having received only the most basic of schooling in Marton, James Cook junior began his formal education in Great Ayton, where between 1736

and 1740 he was taught reading, writing and arithmetic.

In 1745, at the age of 16, James Cook junior moved some 20 miles to the fishing village of Staithes, to be apprenticed as a shop-boy to a grocer and haberdasher. After 18 months, proving to be unsuited for shop work, he travelled to the nearby port town of Whitby. Here he was taken on as a merchant navy apprentice, plying coal along the English coast. As part of his apprenticeship, he applied himself to the study of mathematics, navigation and astronomy, and from his subsequent career must have done so with considerable success. After his three-year apprenticeship, Cook began working on trading ships. Having passed his examinations in 1752, he progressed through the merchant navy ranks, being promoted that year to the position of mate on a collier brig. Although offered command of that vessel, he decided instead to volunteer for service in the Royal Navy and did so in 1755.

It was in that same year of 1755 that James Cook senior, aged 67, retired from the position of bailiff on Aireyholme Farm. He then either built, re-built or bought (it is not clear which of these three was the case) a cottage in Bridge Street, Great Ayton. Some sources have suggested that the land on which the cottage was built might have been purchased for the Cooks by Thomas Skottowe senior as an inducement for James junior to join the Royal Navy. It was common at the time for landowners to provide encouragements for young men to volunteer for service in the armed forces at a time when Britain was re-arming for what was to become the Seven Years’ War. Whatever the case may be, it is clear that the naval career of the man to become Captain James Cook FRS owed a great deal to the support and encour-

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<sup>7</sup> The Captain Cook Birthplace Museum website gives Cook’s date of birth as 27 October 1728, and his date of baptism as 3 November that year. These are the dates found in the Parish Register of St Cuthbert’s Church, Marton. They are based on the Old Style (O.S.) dating system, which was changed to the New Style (N.S.) system when England moved from the Julian to the Gregorian calendar under the *Calendar (New Style) Act* of 1750.



agement he received as a youngster from Thomas Skottowe of Aireyholme Farm.

### The cottage

James Cook senior and his wife Grace lived in the Bridge Street cottage until Grace's death in 1765, after which James continued to live there on his own. It is probable that James junior had called on his parents while on leave in 1757, and it is known that in December 1771 he visited his widowed father. He managed to persuade James senior to move from the cottage in 1772 and live with James junior's sister Margaret [Fleck] at Redcar, where James senior died in April 1779 — the same year as his son. The house passed through a number of hands until, in 1933, its then owner, a Mrs Dixon (who did not live in the house but was well aware of its significance), decided to put it up for auction. She made it a condition of the sale that the house should stay in England, in order to prevent its purchase by Americans, but was later persuaded to change "England" to "the Empire."

A bid of £800 by the Australian businessman and philanthropist Russell (later Sir Russell) Grimwade was able to secure the purchase, being much greater than the highest local offer of £300. Russell Grimwade arranged for the house to be dismantled and packed into 253 cases and 40 barrels for shipping from Hull. It arrived in Melbourne in April 1934 and was reassembled in Fitzroy Gardens, as Grimwade's donation to the people of Victoria for the centenary anniversary of the settlement of Melbourne in October 1834. The relocated house was originally known as Captain Cook's Cottage, but this misleading nomenclature was later corrected, the house now being referred to as Cooks' Cottage.

In the year 2020, the Australian Government's decision to celebrate the 250<sup>th</sup> anniversary of Captain James Cook's arrival in Australia has become a subject of bitter controversy. Some Australians, particularly those of Indigenous heritage, see the event as an occasion of mourning rather than as a reason to celebrate Cook's achievements. A few have taken their protests to the extent of vandalising statues of Cook by spraying them with paint and daubing them with slogans. It is not the intent of the present article to express an opinion on this matter, other than to comment on the sad irony of the fact that the vandalising of Cooks' Cottage in Melbourne and its daubing with the word "Shame" (see Figure 2) appears to have been somewhat misplaced, given that Captain James Cook never lived in the cottage and that he set foot in it, at most, on only two possible occasions. What remains valid, however, is the testimony offered by this story of encouragement of local talent wherever found, to the power of education and science: these at their best are what extend our understanding of human culture and the natural world.



Fig. 2: Cleansing the graffiti from Cooks' Cottage, Melbourne, *The Age*, 24 January 2020.

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# The history of blue pigments in the Fine Arts — painting, from the perspective of a paint maker

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## Abstract

In this text, I will introduce you to the colour blue, how and why we see it and when we, as a species, started to discover and use its various versions. I only cover blue pigments as opposed to dyes. Many of the blues that I discuss are known by several names depending on locality, the age in which they were used and, at times, slight variations of their chemical makeup. I do not look at blue dyes mainly due to their inherent lack of lightfastness (and, therefore, usefulness to the artist).

## Introduction

The largest expanse of colour that any human is likely to have seen, or ever will, is the blue of the sky followed by the blue of the sea. Why then was this colour the last to be named by *Homo sapiens* and one of the least to have been reproduced in paint? “The first new blue pigment discovered in 200 years” (Garfield 2017) — headlines from just a handful of years ago. One has to ask how flight, aeronautics, and nanotechnology have all been discovered in the last 100 years and yet we have only discovered one new blue in twice that time.

Is this recalcitrant frontier a sign that we already know all that there is to know about colour, or are we blissfully unaware of a plethora of unfound hues? An insight into these questions may come from examining the history of blue. To do this, we need to look no further than the discipline of Fine Arts which has unknowingly documented the discovery of blue across the millennia.

## How we see colour

Before delving into the intricate past of human endeavour to produce a likeness of

what was seen daily looking skyward or the mottled hues of the never-ceasing oceans, it is worth understanding just how we see colours.

In much the same way our ears tune in to sound, or we use a radio to tune in to a radio station, our eyes detect different wavelengths of electromagnetic radiation or energy. The various wavelengths falling on our eyes’ rods and cones send a signal to the brain commensurate with the particular wavelengths which, if everything is working correctly, we interpret as colour.

We can gain a better understanding of how colour works by understanding what happens when colours are combined: blue is a primary colour in both Additive and Subtractive colour mixing. In other words, along with red, it is not possible to add other colours together to make blue. As a quick aside, Daniel Nelson asked in 2018, “what two colours combine to make blue?” and hypothesised that cyan and magenta mix to make blue. While this is true, many would counter that cyan is indeed a blue; hence, in mixing magenta with it, one is only chang-

ing the hue of a blue to another blue rather than “making blue.”

Additive colour mixing occurs when different colours of light are immitted from an energy source in the visible spectrum. An example of this is an LCD screen where differing amounts of red, blue and green light are combined to form a vast array of colours. All three colours together produce what we call white light or a light containing all the wavelengths of the visible light spectrum (i.e., sunlight). Subtractive colour mixing can be most easily understood using the example of mixing paints. In the presence of sunlight (i.e., all wavelengths of the visible spectrum or white light), when two colours, such as blue and yellow, are mixed together, their combination will result in a reflection of the resultant wavelengths of the yellow being reduced by the blue, the combination of which produces what we perceive to be green, which lies between yellow and blue on the spectrum.

### Did we always “see” colour?

Now that we know how we see colour, we may wonder why we have so few blues and why it has taken so long to discover a new one. As a matter of fact, it appears that we may not have always “seen” blue, or at least may not have always given it its status as a colour.

It is well known that, as humans, we have far fewer receptors for the colour blue in the eye, compared with red and green. This was thought to be due to the fact that there was very little food coloured blue; hence, we as humans did not need to concern ourselves with this colour that much. Specifically, it is widely believed that early man could only recognise black, white and red and then later yellow and green. In fact, many theo-

ries posit that humans did not really know that blue existed until relatively recently.

Jules Davidoff, who worked with the Himba tribe from Namibia as recently as 2006, found that not only did the tribe not have a name for blue but they also found it very hard to distinguish it. In a series of tests to detect a blue square, when presented with 11 squares, 10 of which were green and one blue, the surveyed tribe members were unable to distinguish the blue square that most people in the “outside” world would readily pick from the line-up (Robertson et al. 2006).

Indeed, when one thinks of it, back beyond 6,000 years ago there was very little that was blue. The blue we see in the ocean is due to the molecules of water absorbing more of the red end of the spectrum and therefore producing what we perceive to be a blue hue, this of course can vary considerably depending on impurities in the water. High iron content can give the water a brown hue, as can tannin from leaves and trees leaching into a water course. However it is not possible to harness the blue of water to tint or colour, for instance, for use in a paint.

One may claim, “Of course the sky is blue!”, yet we can respond, “Hold on: we know that is not true!” — the sky appears blue because the sunlight is diffracted by tiny particles in the stratosphere. Subsequently, some of the sunlight is diffracted into the blue spectrum of visible light by particles which are very close to the same size as the wavelength of blue, which explains why we perceive the sky as blue. Theories for this phenomenon were first described by Lord Rayleigh,<sup>1</sup> Richard Gans, and Peter

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<sup>1</sup> See Rayleigh scattering, [Ed.]

Debye and, more accurately, by Gustav Mie. Intriguingly, their work was based on earlier work carried out by Horace-Bénédict de Saussure and Alexander von Humboldt who developed and used a “cyanometer,” which consisted of squares of paper dyed in graduating shades of Prussian blue (mixed with white or black) and laid out on a circle that was then held up at a particular distance from the viewer and used to compare to the colour of the sky at that specific place and time.

Looking wider afield, peacock feathers appear to have blue in them; once again, this is not caused by a pigment absorbing and re-emitting particular wave-lengths as a colour, but rather by diffraction, or the slight bending of light waves known as structural colour. The wings of a blue-winged wasp and the wings of the blue morpho butterfly are all light diffractors, which can be best thought of as acting a little like layers of slits or grates that diffract the light to produce a blue. I will discuss this further with reference to phototronic pigments.

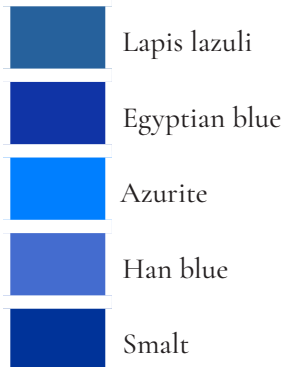
### A timeline of blue pigment discovery

While there is evidence of very early use from around the world of naturally occurring ochres and earths of red and Yellow. Blacks made from charcoal as a result of fire and whites in the form of calcium carbonate and other compounds. All colourants that were readily found or easily dug up. These “pigments” are found in caves around the world from France to Australia and date back millennia. However we can see from above that there were no naturally occurring blues that were able to be found and easily ground into a paste and applied to a cave

wall.<sup>2</sup> We will now look at when the first blues were found and how.

Listed below, for completeness, are the blue pigments in general use over time. They are listed according to their Colour Index pigment number, which is a general classification of colour by chemical type. A more detailed list, maintained by The Society of Dyers and Colourists (UK) and The American Association of Textile Chemists and Colourists (US), provides more specific five-digit numbers.

### Ancient blues



### *Lapis lazuli PB29 and Egyptian blue — PB31*

Some of the earliest existing examples of the use of blue for adornment is provided by the Egyptians, who used lapis lazuli for ornaments and ceremonial artefacts. The original ultramarine blue made from lapis lazuli (Italian *oltremarino*; ultra: beyond, *marino*: sea) was so called as the lapis was transported from Afghanistan literally “beyond the seas” (from a Eurocentric perspective, of course), and it was originally

<sup>2</sup> There are no blues in the Indigenous art works presented in B. J. Gillam, Figure-ground and occlusion depiction in early Australian Aboriginal bark paintings, *JProcRNSW* 152: 251–267, 2019. <https://royalsoc.org.au/images/pdf/journal/152-2-07Gillam.pdf> [Ed.]



employed by the Egyptians in solid form for ornamental use in jewellery. But there is no record of them having successfully formulating it into a paint, which was left to the clever Italians many centuries later. Due to the processes of collection and manufacture through a series of manual kneading, washing and filtering, it proved to be a highly expensive pigment. There are many stories in later years of well-known artists not finishing pictures or saving their tiny amounts of ultramarine for the final application and only on especially important icons.

Although the Egyptians were never able to incorporate lapis lazuli into a paint successfully, there is little question that it was they who first manufactured a blue pigment, using a chemical reaction. This pigment, now known as Egyptian blue, was used in paint in artwork and ornaments, and the Egyptians indeed referred to their discovery as artificial lapis lazuli: “The term for Egyptian Blue in the Egyptian language is *ḥsbd-irjt* which means artificial lapis lazuli (*ḥsbd*)” (Pagès-Camagna 1998).

I argued that this is the first record of a manufactured blue, yet this applies if one does not consider the incredible amount of work that goes into refining lapis lazuli. As recorded in the 15<sup>th</sup> century by Cennini (who devotes a several pages to detail its precise handling extensively, including who should do the work), “You must know also that it is rather the art of maidens than of men to make it because they remain continually in the house and are more patient and their hands are more delicate. But *beware* of old women.” (Cennini, 1899). On a more serious note, the manufacture of lapis lazuli is mainly mechanical, as it involves taking a semi-precious stone and crushing and purifying it.

Egyptian blue is the earliest blue pigment that we are aware of whose formation is definitely based on a chemical reaction. This reaction takes place when silica (sand) is heated in the presence of a copper compound and an alkali for several hours. Egyptian blue, when studied at a microscopic level, consists of blue crystals, with impurities of unreacted quartz and small particles of glass. Some people thus refer to Egyptian blue as a frit.

Egyptian blue’s reaction can thus be described as  $\text{Cu}_2\text{CO}_3(\text{OH})_2 + 8 \text{SiO}_2 + 2 \text{CaCO}_3 \rightarrow 2 \text{CaCuSi}_4\text{O}_{10} + 3 \text{CO}_2 + \text{H}_2\text{O}$

As we will see with many other blues, the colour is derived from copper. However, looking at the formula, the starting compound is highly similar to that of azurite, which was also to be found in those times.

#### *Azurite — PB30*

Like lapis lazuli, azurite is a naturally occurring mineral, and, when ground and washed, it produces a light blue powder reminiscent of a clear blue sky. Azurite was most likely also used when lapis lazuli was not on hand, namely earlier than Egyptian blue; however it does not appear as highly prized as lapis lazuli, as it is a light blue rather than the rich dark blue of lapis. It was still used in painting between the 14<sup>th</sup> and the 17<sup>th</sup> centuries in China, Japan and Egypt and was a major blue pigment in the Middle Age in Europe. Verditer blue and blue bice are synthesised versions of a basic copper carbonate, similar in chemical composition to azurite. It is believed that these blues superseded azurite predominantly due to cost (Bristow 1996).

#### *Han blue*

Han blue was a manufactured barium copper silicate pigment found since the Chinese

Han Dynasty (208 BC–220 CE). It is similar in chemical makeup ( $\text{BaCuSi}_4\text{O}_{10}$ ) to the Egyptian blue  $\text{CaCuSi}_4\text{O}_{10}$ . It has also been referred to as Chinese blue, but the name Han blue is preferred to avoid confusion with other more common blues recognised as Chinese blue. Synthesised Han blue has a similar chemical makeup to the rare mineral effenbergerite. (Eastaugh et al. 2004)

Subsequently, if we are to believe modern pigment history, there was somewhat of a hiatus between the Egyptians' discovery of *hsbd-irjt* (Egyptian blue) earlier than 3,000 BC, Han blue by the Chinese around 200 BC and the next blue in more modern times over 2,000 years after that. Or was there?

### Other possible early blues

Thomas Katsaros, in his 2019 lecture at the Symposium on the History of Technology and Research of the Colour Blue at the Herakleidon Museum in Athens, argued that in ancient Greece there was at least knowledge of other blues as found in the records of Theophrastus of Eresos — the successor to Aristotle at the Lyceum — who wrote on stones in 315 BC listing, among other things, the colours of the painters of his time and recorded three types of cyanus (blue): Cypriot, Scythian and Egyptian. While it was generally accepted that Chrysopastos (Cypriot) cyanus was lapis lazuli, doubt remains as to what the Scythian cyanus was: possibly sapphire? While there is no certainty as to the exact meaning, the jury is still wondering what blues Theophrastus was referring to; Thomas Katsaros posits that at least the Greeks believed that there was more than just lapis lazuli and Egyptian blue at that time (azurite being included with Egyptian).

### Vivianite

Vivianite is also known as blue ochre and earth iron blue. Its molecule is a phosphate of divalent iron with a significant amount of water:  $\text{Fe}^{2+}_3(\text{PO}_4)_2(\text{H}_2\text{O})_8$ . Vivianite has been used for millennia by artists although sparingly due to its scarcity in an agreeable blue state and its known propensity to change colour unavoidably. It is sometimes confused with azurite because it too changes colour over time, but, unlike azurite that changes into the green of malachite, vivianite tends to continue its process past the green and through to a deep blue-black (as described below). It is found in many places around the world — specifically, in ancient wetlands or where deposits of peat are now found, rich in organic matter but lower in oxygen and calcium concentrations.

As is evident from his 1921 book *The Manufacture of Earth Colours*, Josef Bersch understood vivianite's chemical composition and was cognizant of its ability to oxidise; however, he still thought it to be stable. Eastaugh et al. (2004) touch on the pigment altering to a yellow, which produces an overall green pigment (p. 266); however, the changing colour of vivianite is best explained by Alfredo Petrov (2008) in *A Scientific Study of the Absorption of Evil by Vivianite*, where he describes the various states of vivianite and how it transmorphs into metavivianite:

Some people think vivianite darkens by oxidation — absorbing oxygen from the atmosphere — and then flakes apart along the cleavages by “drying out,” i.e. losing some of its 8 waters. They optimistically hope that both of these processes can be hindered by a thin coating of lacquer (which is why some specimens in old collections were varnished), or by dipping



in oil, or sealing it in a glass jar. They are correct that both oxidation and water loss are taking place, but not in the way they imagine and not in any way that could be prevented by a coating of lacquer no matter how thick! To somewhat oversimplify and paraphrase the process, when photons (particles of light energy) enter a transparent vivianite crystal, they can knock a proton (a hydrogen nucleus) out of one of the 8 water molecules, which converts the water into a hydroxyl ion (OH) which has a negative charge. This extra negative charge is balanced by oxidation of one iron atom, whose valence state changes from 2+ (ferrous) to 3+ (ferric). Notice that no interaction with the atmosphere was involved — no oxygen entered the structure from outside, and no water molecule escaped to the outside — we are dealing with a completely internal reaction (oxidation by deprotonation). The liberated hydrogen (the proton) easily migrates through the crystal lattice, as in other species of proton-conducting crystals (which are currently undergoing intense study for potential industrial uses like fuel cells). No coat of lacquer is going to prevent this.

Hence, while this is an intriguing colour, it is not one that is likely to see too many artists wishing to use it due to its inevitable colour shift.

### *Smalt — PB32*

Concerning colourant in paint, early cobalt blue was actually glass containing cobalt and potassium (known as smalt), which was ground and used as a colourant (smalt, PB32) The earliest recording of its use has been found in paintings by Hans Holbein the Younger (1497–1543).

There are many other examples in China and Japan of blues made from either both copper or/and cobalt — or at least that is what we know now is their main colour constituent. However, following the accepted Western timeline, cobalt blue as a pigment (as opposed to a frit or ground glass) was yet to be discovered. Hence, we move on to Prussian blue, the next blue to be discovered.

### **Modern blues**



### *Prussian blue — PB27*

It was not until the very early 1700s that a purely synthesised pigment was recorded as having been made in what we know as Prussian blue. Swiss dye-maker Johann Jacob Diesbach, working in the Berlin laboratory of his friend Johann Konrad Dippel, was attempting to create red Florentine

lake — carminic acid which is extracted from cochineal and precipitated by alum, iron sulphate, and potash.

When Diesbach mixed what he thought was potash with the iron sulphate, instead of the strong red he was expecting, he observed a light pale colour. In attempting to concentrate the product, he first found it went purple, and then a deep blue. Diesbach had unknowingly, and by accident, produced the first batch of Berliner Blau, called many other names such as Paris Blue, Antwerp Blue but what we universally now know today as Prussian blue.

Digging a little deeper into this story, Alexander Kraft, who believes that the most probable year of discovery was 1706, has pieced together more details from several sources, namely letters and diaries from the time. He found out that of one of Dippel's contemporaries, a younger friend named Senckenberg, recorded that Dippel had told him, concerning Prussian blue, that "he was preparing a large amount of a 'sal volatile' by dry distillation of calcined sal tartari (potash) and dried ox blood." Dippel's assistant had not disposed of the remaining mixture but rather stored and labelled it only as sal tartari instead of noting it had other ingredients. This is the "potash" that Diesbach used to make his discovery. Then he set about selling this newfound colour to some local artists unbeknown to his friend Dippel only to find out that, once his source of what he thought to be potash ran out, he could no longer make the colour. He then reported his problem to Dippel, who suggested the use of bovine blood with potash.

This story makes one consider that, had Dippel not been aware of the mislabelling of the jar and exactly what was in it, the formula might have been lost; or, had the

jar been labelled correctly, Diesbach might not have used it at all or discovered Prussian blue, and he would have just continued to make a boring old red! It took nearly another 20 years for the formula to become public, and, even then, both recorded early copies of the process continued to include the superfluous red cochineal dye. It is apparent no one had worked out the true formula in that time: how much longer might it have been before it was discovered?

Spare a thought for these poor guys who really had very little knowledge with which to work, very few books, no internet of things, just a hunch and their observational skills. We can only try to imagine what it would have been like to work in a cold stone building, trying to solve a problem and really not knowing where to start. They lived in a time when the realm of science was the domain of gentlemen who could afford the time and expense to experiment. Today, we might class them as great thinkers or even as lunatics! Working by daylight or candlelight, life was very basic by our standards today, a furnace was just that — with little or no idea as to the actual temperature to which compounds in an experiment were being heated, accuracy would have been very difficult. (The first mercury thermometer was not developed until 1714.)

Even under the most controlled conditions of the time, many things were left to chance. One can imagine lab benches with little on them in the way of apparatus, sunlight filtered through smog-coated windows being the only illumination, and suit-clad menfolk working away, hypothesising and experimenting with no boundaries and very little clue as to what they were doing — a little like a child playing with a chemistry set before reading the instructions! And, bang,

here is a brand-new colour when you were not even expecting it! Hence, I guess it is not a surprise to learn that Prussian blue was discovered by accident.

Prussian blue is not only interesting for the way it was discovered but also because it has played a role across many industries. It is probably best known for its use in the blue of blueprints (since the mid-1800s), in which a sheet of paper is coated with a mixture of ammonium iron citrate and potassium ferrocyanide. The original drawing (done on a thin paper, such as a tracing paper) to be copied is then laid on top of the coated paper and exposed to intense light. The light combines the two compounds, producing Prussian blue in the areas exposed to light and not protected by the drawn line on the design above. The coated sheet is then washed, and the unexposed areas washed clean to show the colour of the paper through, as the white of the print. The exposed areas are coated in the combined compound being insoluble Prussian blue, resulting in a blue background, thus a blue print. A far easier and more precise way to make copies than was the pre-existing practice of tracing them by hand. Even when carbon copies and copying machines were invented, large-scale technical and architectural drawings were still reproduced in this way for some time.

For anyone who has visited a machine shop, Prussian blue is mixed with oil as “marking blue” or “engineer’s blue” to show high spots or areas that rub when “mating” machine parts.

In medicine, Prussian blue is used to very effectively remove thallium and radioactive caesium from the body. In fact, it is included in the World Health Organization’s list of essential medicines, namely those consid-

ered essential to any basic healthcare system. Strangely enough, while Prussian blue is used as a life-saving antidote to heavy metal poisoning, when combined with acid and a bit of heat, it gives off life-ending cyanide. “By itself it is only slightly toxic; however, it can produce extremely toxic hydrogen cyanide gas in hot acid if heated to decomposition or exposed to strong ultraviolet radiation.” (McCann 1979, p.145)

For those with a technical interest, variations on the hue can be produced by varying the reagents; an example of this is Turnbull’s blue. Prussian blue continues to be used by artists today although not to the extent of other blues which have come after it. There are three variants of Prussian blue, and only one of them will work in a water-based system such as acrylic or watercolour, which still needs to be incorporated in a well-balanced formulation. Many see Prussian blue as not as clean or brilliant as its successors. Nonetheless, it is still highly employed by artists and industry alike, although most paint manufacturers now offer a blend to achieve the colour rather than the original pigment.<sup>3</sup>

### *Cobalt blue — PB28*

I started with Prussian blue because it was the first modern synthesised blue pigment. However, the use of the cobalt as a colourant dates back to the eighth and ninth centuries and, in fact, far earlier when it was used to colour ceramics and jewellery, but as a colourant in paint, it was not commercially produced for another century after Prussian blue: around 1807 in France (where it

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<sup>3</sup> Use of Prussian blue spread quickly around the world, even into Japan, despite its *sakoku* trade policy, where it is seen in Hokusai’s *The great wave off Kanagawa* (1830–1834), as Davies (2017) discusses. [Ed.]

was discovered in 1802). It is the effect of the element cobalt in rich blue in the now ubiquitous blue and white ceramics from China (although, apparently, early on, the blue was seen as too ornamental for local Chinese tastes; hence it was not used much for local production but rather for export). The amazing blue stained glass that we see in churches and cathedrals across Europe owes its distinctive lightfast blue to the element cobalt as well, which is somewhat ironic when considering that the word “cobalt” is derived from “Kobold”, the name of a devilish sprite well known in German folklore for mischief-making. Miners in the Saxony region discovered the silver-like ore which after smelting formed a “useless” lump and produced noxious and lethal fumes. The irritated miners thus dubbed the ore Kobold, and the name stuck. This was around 1500 AD.

Nearly 200 years later, a Swedish chemist, Georg Brandt, at Uppsala University, began researching the rejected substance. Suspecting that the core of the material was in fact a previously unknown element, Brandt tested his theory on an ore from Sweden, separating the metal via fire assay, thus isolating the same substance that the Saxony miners had stumbled upon and discounted. Brandt stuck with the miners’ name for the material and called the newly discovered element cobalt.

As a synthesised pigment, a purer alumina-based version of cobalt blue was discovered by French chemist Louis Jacques Thénard in 1802. Leithner of Vienna is also recorded as having developed a cobalt arsenate as early as 1775. Cobalt blue is a favourite of artists: although more expensive than copper-based blues, it gives a vibrant but opaque blue, slightly leaning to the green

bias, and is very stable when formulating and lightfast in use. Furthermore, when used in standard proper artist practice, it is quite safe, as most modern versions have no free bio-soluble cobalt.

#### *Cerulean blue — PB35 (PB36)*

As cobalt blue was being released to artists in the early 1800s, a new blue was in development, once again making use of cobalt: the compound originally composed of cobalt magnesium stannate (1789). In antiquity, the term “caeruleum” was used to describe blue pigments in general, particularly mixtures of copper and cobalt: the main chemicals in azurite or malachite and smalt. Cerulean blue production was then further perfected by a process developed by Andreas Höpfner in Germany in 1805 by heating that roasted cobalt and tin oxides together. However, the colour only appeared available to artists in a catalogue from the 1860s under the name of caeruleum. Cerulean blue is an inert, lightfast pigment that can act as a drier in oil paints. It is quite stable in both watercolour and acrylic and is referred to as PB35 cobalt stannate. PB36, which is a cobalt chromate, is also used and sold as Cerulean blue for those who prefer a slightly greener or cooler hue.

#### *Artificial ultramarine — PB29*

We now have a bit of a backtrack in our timeline!: Artificial Ultramarine Blue. The original ultramarine blue made from lapis lazuli was employed by the venerable Egyptians in solid form for ornamental use in jewellery, as remarked above. Due to the processes of collection and manufacture through a series of manual kneading, washing and filtering, it proved to be a highly expensive pigment. While paint made on

remarkably high-quality lapis is a romantic idea to produce, it was still feeble in strength in comparison to what was to come and vastly expensive to produce even now.

Finding a way to make artificial ultramarine (lapis lazuli) was going to assure its inventor fame and fortune, but, even with that promise, it was still a long time till the birth of artificial ultramarine blue. Sir Arthur Church (1915) recorded that, “[i]n the year 1814, a blue colouration, subsequently proved to be due to ultramarine, was noticed in the soda (black ash) furnaces of St. Gobain.” Artificial ultramarine blue was not born until 1824, when the Societé d’Encouragement offered a reward of 6,000 francs to anyone who could develop a synthetic alternative to ultramarine. It was a troublesome birth. Two men came forward within several weeks of one another: Jean-Baptiste Guimet, a French chemist, and Christian Gmelin, a German professor from the University of Tübingen. The prize was fiercely contested. Gmelin claimed that he had arrived at a solution a year earlier but had waited to publish his results. Guimet countered by declaring that he had conceived his formula two years before, but, like Gmelin, had opted not to publicise his findings. The committee awarded the prize to Guimet, and the artificial blue became known as “French ultramarine.”<sup>4</sup>

This new method of production was based in part upon chemical analyses of natural ultramarine (lapis lazuli), and in part on a study of the conditions which produced the first observed accidental manufacture at St Gobain. This very rich red-blue was developed and revolutionised the way artists could now mix their purples and violets, while also allowing for a full new range of

subdued greens and shadow hues. Modern ultramarine blue is a soft pigment that quite often does not need much milling to disperse into a paint formulation. It is non-toxic, with generally accepted good lightfastness. However, recent research conducted during the restoration of Michelangelo’s work in the Sistine chapel has thrown some doubt on the lightfastness of lapis lazuli in oil paint (lapis blue and ultramarine are very similar in chemical composition). Specifically, it seems that sulphur, which is one of the constituents of the colour, has been moving out of the pigment molecules, resulting in fading. Certainly, most colour chemists would have struck occasions where they have observed sulphur off gassing from formulations, which smells very unpleasant. Clearly, this is a space to watch.

It would be remiss of me not to add in Yves Kline blue here — if only for completeness of the story. Kline’s blue was just artificial ultramarine which was underbound — namely, presenting too much pigment and not enough binder — which gave a striking finish extremely rich in colour and texture, which is how the raw pigment presents. However, it does not take much of an imagination to work out what happened to those works: by producing a coating that did not have enough binder, the resulting colour was not going to hold on well. This still happens today, as there can be found more than one story of gallery staff coming in each day to find more ultramarine pigment on the floor to be cleaned up below a Kline artwork.

#### *Indanthrone blue — PB22 and PB60*

Indanthrone blue (PB22 and PB60, also known as indanthrene blue), was first patented in 1901 by Rene Bohn. It belongs to

<sup>4</sup> See Mertens (2004) for details of this rivalry. [Ed.]

the class of pigments described as “vat pigments.” It is a very red shade, ranging from blue to indigo pigment. However, due to the high cost relative to the artificial ultramarine pigments, uptake and use have been limited.

#### *Phthalocyanine blue — PB15*

Phthalocyanines were discovered in 1907 by Braun and Tchermiac in London. Without understanding the importance of their finding, they noted the results, but did not follow them up. Then, in 1927, the Swiss chemists Von der Weid and de Diesbach (no relation to our Prussian blue inventor that I could find) accidentally obtained a form of copper phthalocyanine whilst trying to produce phthalonitrile. Then, in 1928, at Scottish Dyes Ltd., iron phthalocyanine was found as an impurity during the preparation of phthalimide, a fine white solid produced by reacting phthalic anhydride and urea. A crack was spotted in one of the glass linings of the reactors which was leading to an unwanted blue impurity in what was supposed to be a whiteish end product. The Scottish dyers had the foresight to follow through and find out what was going on. With experimentation, they produced iron phthalocyanine, and, in 1929, Scottish Dyes was granted a patent for the preparation of phthalocyanine produced from phthalic anhydride, a metal salt and ammonia.

Since then, several phthalocyanine variations have been produced on various metals, together with a metal-free version, the most popular being the green tone based on copper, which is used across many industries, as it is very lightfast, incredibly strong in tint strength and very stable in formulations. It is worth noting that while at present there are many producers around the

world, this type of blue was first marketed by ICI in 1935 under the name Monastral blue, which is still available today.

#### *Manganese blue — PB33*

A synthetic green-blue pigment is formed “when an aqueous solution of permanganate of potash yields, with baryta-water, a violet mixture which afterwards becomes colourless and deposits a blue precipitate.” (Eastaugh et al. 2004, p.44). This was first mentioned in the late 1800s. Manganese blue only became commercially available in the 1930s when IG Farbenindustries AG patented it in 1935. However, its production appears to have been phased out in the 1990s probably due to the higher cost when compared to other pigments on the market, such as cobalt and phthalocyanines. Furthermore, it contained barium and was deemed to be toxic. Therefore, at present, any artist-paint manufacturer who offers the colour produces a blend to arrive at the same hue.

#### *Fluorescent blue*

Although most artists do not use fluorescent pigments due to their fugitive nature, I will mention them here for completeness and because how they were developed is an interesting story. In the summer of 1933, Rob Switzer had taken a summer job before he started medicine at UC Berkeley. In a terrible twist of fate, he suffered an accident which saw him spend a prolonged period in hospital, followed by doctor’s orders to rest in a dark room. Rob and his brother Joe had a love of magic: during Rob’s time of convalescing confined to darkened rooms, he and Joe found that their parents’ pharmacy provided an Aladdin’s cave of compounds that glowed under black light, which gave



them the idea to enhance their magic show with the addition of fluorescent costumes, which earned them a prize for best illusion at a magicians' convention in Oakland. Rob and Joe were to go on and build the company now known as Day-Glo Color Corp., and in 1957, they were awarded a patent to produce the first commercial fluorescent pigment.

As early as 1944 artists started using fluorescent colours, which were dyes and not very stable (De Winter 2010); however, they became more popular in the 1960s as they became commercially available in more stable paint forms. Blue was not one of the first fluorescent colours developed but did start appearing in catalogues for fluorescent pigments by the late 1960s.

#### *Pearlescent, Iridescent and Interference blue*

Pearlescent pigments are made by coating mica with metal oxides and titanium dioxide and may contain other blue pigments. The pearlescent pigment does not contain any pearl but rather has a lustre similar to that of a pearl that gives it its name. The colour, however, can be considered to be homogenous. This is in contrast to iridescent blue pigments which are produced in a similar way yet appear to the observer to “change” colour around a limited spectrum. Interference colours go one step further and tend to emit two definite homogenous colours, depending on the angle of view.

In each of the above cases, the observer sees colours which are developed through the result of interference between rays of light. The light is reflected off the top and the bottom of particular layers (platelets or flakes) within the pigment, which collide or combine to form particular colours. The

angle at which the pigment is viewed will dictate what colour is observed.

“The development of pearlescent pigments only started in the 20<sup>th</sup> century using mercury and arsenic salts, but there were no substantial advancements until the invention of mica coated with metal oxides in 1963. From that point onward, new discoveries were made in this field, as the production of aluminium-based pearlescent pigments in the 1990s.” (Rossi and Russo).

#### *Mayan blues — PB82 and PB84*

A fairly recent addition to the modern range of pigments, the MayaCrom and MayaPure blues (PB82 and PB84) are a recreation of an ancient blue pigment composed of palygorskite clay and indigo which was used by the ancient Mayans throughout Mesoamerica between the 6<sup>th</sup> and the 8<sup>th</sup> centuries. Research has shown it to be very stable when exposed to acids, alkalis, and chemical solvents. Artefacts recovered from a well at Chichen Itza along with over 100 skeletons gave further weight to the theory that Maya blue was an essential colour in Mayan culture. It is believed that, at some time in the Mayan history, blue was produced by burning incense, which was found to contain palygorskite and indigo, during sacrificial ceremonies and applied to the sacrificial victims just before their still-beating heart was cut out and they were thrown into the well as an offering to the rain god (Arnold et al. 2008).

Using multiple modern analysis techniques, the chemical makeup of the blue was discovered and then recreated by a group at the University of Texas around 2006. Unfortunately, it seems at writing, the company that was to commercially produce the pigments is now defunct. I have formulated



artist colours on these recreated pigments, and while they are generally not as strong as other synthesised pigments, such as the phthalocyanines, they do have a wonderful hue for painting. Formulating can be a tedious process and takes time as they are based on clays and time needs to be given to wet these out sufficiently to avoid post-thickening.

### *Yin Min blue*

In 2009 the discovery of Yin Min blue, the first truly new blue pigment in two centuries, was the result of a happy accident in the research for new materials that could be used in electronic applications. In the course of research by an Oregon State University team led by chemistry professor Mas Subramanian, his then-graduate student Andrew E. Smith took manganese oxide mixed with other compounds — yttrium (Y) and indium (In) — and heated it at high temperatures to test for structure. They noticed that one of their samples turned out into a very vivid brilliant blue colour. Despite not being specifically developed for artistic purposes, the characteristics of this newly created inorganic pigment undoubtedly make it possible for it to have applications in art.

One of the most remarkable structural characteristics of this pigment is that it absorbs red and green wavelengths of light while at the same time only reflecting the blue wavelengths in the light spectrum. This new inorganic pigment has been described as an intense blue colour with high solar radiation (IR) reflecting properties. As has been observed, the resulting vibrant blue appears to be very durable, and its core compounds are said to be so stable that “the colour does not fade” (Subramanian 2018). The initial application and use intended for

this pigment may concern a variety of commercial products, such as paint coatings for buildings and roofs. Specifically, the coat of paint would help to keep buildings cool by reflecting infrared light.

In artistic terms, Yin Min blue (or YInMnBlue, as it is quoted in research notations) has a brilliant, almost shimmering look with a, maybe, very slight red undertone. Research notes from evaluation testing of samples indicate a higher optical reflectance (vividness) than other blues in the colour spectrum due to the compounds in the structure of the pigment particles. Another crucial factor to consider, and in direct relation to health and safety, is that none of this pigment’s compounds is toxic, which cannot always be said for copper or cobalt. Yin Min Blue has just as vivid an appearance, providing an alternative to ultramarine blue with the added benefits of refracting infrared wavelengths, which makes it highly lightfast, in archival terms, with no toxic compounds — specifically, a very safe pigment to use either in paint form or dry. Yin Min has gone through initial approval in the US to be used in artist paints only in bound form in July 2020.<sup>5</sup>

### **Forthcoming blues?**



Quantum blue

### *Deepwater blue*

Presently, I have no more information than the one referenced below from Ruth Siddall’s article; however, I have made contact with Professor Dobson and, on his return from hiking in Scotland (whilst socially distancing I am sure), I hope to find out

<sup>5</sup> To read further, see Kupferschmidt (2019). [Ed.]

more about his discovery, however I find this quote from a recent article very exciting. “Here in UCL Earth Sciences, we are attempting to develop synthetic structures which mimic the unusual ferric iron structure of ringwoodite but which are stable at atmospheric pressure. So far we have shown that we can make blue pigments from iron-bearing oxides and are now investigating how much  $\text{Fe}^{3+}$  the structures can take before they become unstable. That will determine just how blue we can make them. The prospects are bright ... blue.”

#### *Phototonic blue*

The concept of phototonic colours, a colour produced through the modulation of light pigments a form of structural colours, is not new; as discussed previously, the way we see the sky is a form of structural blue. Birds, insects and flowers have been using this form of colouring forever — the wings of the morpho butterfly being a perfect example of a bright blue caused by light diffraction, which is the bending of light rather than generation or absorption and reflection or generation or reflection. The latest iteration of this exciting method of producing colour has been reported in 2019 as taking place at Wageningen University in the Netherlands where they have produced photonic pigments, which they refer to as suprapigments — free-standing water-dispersible spheres entirely made of silica, an abundant, (photo)chemically stable and non-toxic material, with an ordered, macroporous structure that interacts with incident light to endow the pigments with a colour. Theoretically, these colours should be very stable and very lightfast — an utter dream for formulators, artists and hopefully

conservators alike. In theory; they could be a real game changer!

#### *Quantum blue*

From his lecture at the Symposium on the History, Technology and Research of the Colour Blue at the Herakleidon Museum in Athens in 2019, Jason Hartlove, CEO of Quantum Dot Leader Nanosys put the question: “What if paint pigments could actively emit light instead of merely absorbing it? A new type of nanotechnology called Quantum Dots is changing the way artists work with colour and light. Quantum Dots are tiny nanocrystals — 10,000 times narrower than a human hair — that can be tuned to actively emit light at any colour in the visible spectrum. This exciting new material is enabling artists to explore a new mode of expression — painting with light. Light-emitting pigments open new artistic possibilities for unique colour combinations and surprising perceptual manipulation through additive light mixing.”

Artist Olga Alexopoulou is already working with quantum dots. It will be interesting to watch how quantum dots evolve over time and just how the artistic community will embrace and use them to create work we cannot probably even imagine at present.

#### **Conclusion**

Ancient or Modern blue pigments — one does not need to be a paint maker or an artist to appreciate how we see them or indeed the various ways they came into use. An understanding of the development of one of the three basic primary colours, however, is a window into human development over the ages. With hopefully more to come.

It seems that we are not at the end of the discovery of all things blue, but partway

along the course; therefore, next time you look up at a never-ending blue sky or across the vast plain of the ocean, your inner artist will realise that you are not really seeing blue ... or are you?

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## Point Counterpoint: Gas as a Transitional Fuel

The Editor

### Abstract

A new section to air scientific disagreements. Here, seven pieces and one response on the use of natural gas as a transitional fuel on the road to a renewable future.

On 12 February, 2020, Alan Finkel, the then Chief Scientist of Australia, addressed the National Press Club in Canberra on the topic of “Planned obsolescence — managing the transition to the electric planet.”<sup>1</sup> Eventually, this talk resulted in the disagreements we print here.

On reading the *Sydney Morning Herald* of Tuesday 25 August, I found reference to a letter from 25 scientists to Alan Finkel, arguing against his argument for natural gas as a “transition” fuel on the de-carbonising path to a renewable future. Three of the signatories are FRSNs — Matthew England, Trevor McDougall, and Steven Sherwood. I wrote to them asking for a copy of their letter and permission to republish in the *Journal*: “It seems to me that documenting such debates and their eventual resolution is important, both historically and scientifically.”

They responded with their letter and permission. The next day Alan Finkel’s response appeared, and I received permission to republish that too. Then, on Thursday, Penny Sackett, a past Chief Scientist, published a piece in the *Herald*, not really in response to the previous two pieces (it had

apparently been written earlier), arguing a different case.

She gave permission (as did the *Herald*) for us to republish her piece. Finally, Richard Bolt, a member of Alan Finkel’s Stakeholder Advisory Group, published a piece in the *Herald* of 3 September refuting the 25 scientists. I sought and received his permission, and the *Herald*’s, to reprint the piece.

Andrew Blakers, an engineering professor at ANU, was interviewed on radio on 17 September. I sought a discussion paper from him, below.

Peter Rez, a physicist at Arizona State University, contributed a piece supporting the Chief Scientist, but Andrew Blakers disagrees with this analysis, as can be seen in the Debate between the two at the end.

Here, then are seven pieces arguing for and against the case for natural gas as a transition fuel on the path to renewables. There have been other pieces pro and con, not least when the Government, absent a proper energy or emissions policy,<sup>2</sup> announced their “gas-fired recovery plan” on 15 September.<sup>3</sup>

1 <https://www.chiefscientist.gov.au/news-and-media/national-press-club-address-orderly-transition-electric-planet>

2 For an historical perspective, see R. E. Marks, “Australian energy policy and conservation,” *IFAC Energy Systems. Management and Economics*. Tokyo 1989. <https://www.agsm.edu.au/bobm/papers/japan89paperwp.pdf>

3 <https://www.pm.gov.au/media/gas-fired-recovery>



## A letter from 25 scientists to the Chief Scientist, Alan Finkel

Dr Finkel,

We are writing to you as Chief Scientist with our concerns about your strategy for dealing with climate change, and to offer any scientific advice that you might find useful on climate change issues.

With the Black Summer bushfires and yet another mass bleaching of the Great Barrier Reef fresh in our minds, meeting the climate change challenge is more urgent and daunting than ever. The Paris Climate Agreement, to which Australia is a signatory, provides the global framework for addressing this challenge. It calls for nations to take action to keep global temperature rise to “well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C.”

In your February speech to the National Press Club entitled “The Orderly Transition to the Electric Planet,”<sup>1</sup> and in other publications and presentations, you have emphasised the importance of transitioning to renewables such as solar and wind, and that they should become the backbone of a 21<sup>st</sup> century clean economy. We strongly support this approach, and agree that renewables firmed by batteries and pumped hydro comprise a very effective approach to tackling the emissions reduction challenge.

Our concern, however, relates to the scale and speed of the decarbonisation challenge required to meet the Paris Agreement, and, in particular, your support for the use of gas as a transition fuel over “many decades.”

Unfortunately, that approach is not consistent with a safe climate nor, more specifically, with the Paris Agreement. There is no role for an expansion of the gas industry.

There are multiple lines of evidence to support our position on gas:

- We are already committed to a temperature rise of 1.3°C or 1.4°C from past greenhouse gas emissions, primarily from the combustion of coal, oil and gas (WMO 2020).<sup>2</sup> At this point it would take a global social, political and technological miracle to keep the world under 1.5°C (Huppmann 2019).
- Exceeding even 1.5°C will have escalating impacts on Australia (Reisinger et al. 2014)
- The combustion of natural gas is now the fastest growing source of carbon dioxide to the atmosphere, the most important greenhouse gas driving climate change (Friedlingstein et al. 2019; Peters et al. 2019)
- Global methane emissions from fossil fuel sources and from agriculture are accelerating (Saunio et al. 2020; Jackson et al. 2020). On a decadal timeframe, methane is a far more potent greenhouse gas than carbon dioxide. In Australia, the rapid rise in methane emissions is due to the expansion of the natural gas industry.<sup>3</sup> The rate of methane leakage from the full gas economy, from exploration through to end use, has far exceeded earlier estimates (Hmiel et al. 2020).
- Existing and planned fossil fuel infrastructure is more than sufficient to push the

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1 Australia’s Chief Scientist, National Press Club Address: The orderly transition to the electric planet (12 February 2020) <https://www.chiefscientist.gov.au/news-and-media/national-press-club-address-orderly-transition-electric-planet>

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2 See Table 2.2 in Rogelj et al. (2018)

3 <https://ageis.climatechange.gov.au/>



world past 2°C, pushing even the upper bounds of the Paris Agreement’s temperature goals well out of reach (SEI 2019).

- To meet the upper Paris goal (“well below 2°C”), we must achieve net zero emissions by 2040–2050. This requires a rapid phase-out of existing fossil fuel infrastructure, leaving no room for expansion of the gas industry.
- While in principle CCS (Carbon Capture and Storage) could extend the life of fossil fuels — for example, for use in the production of hydrogen — CCS technology is still far from being technologically and economically viable. The renewable energy-based alternatives are already technologically ready, less expensive, and more widespread, capable of delivering economic and employment benefits across regional and rural Australia.

The undeniable conclusion from this analysis is that the time has passed for any new fossil fuel infrastructure, including the proposed expansion of the gas industry in Australia. All types of fossil fuels, including gas, contribute to climate change and all must be phased out as quickly as possible to meet the Paris Agreement targets, helping to keep Australians safe now and into the future (Reisinger et al. 2014).

We reiterate that we very much appreciate your efforts and leadership in facilitating the rapid expansion of the renewable energy sector. This is a major step forward. But we must now make urgent progress towards a prosperous net-zero emissions economy by 2040–2050.

As always, we stand ready to provide advice on the science of climate change and to support your efforts to expand and accelerate the actions needed to do our part

in the global effort to meet the goals of the Paris Agreement.

Yours sincerely,

Professor Nerilie Abram, Australian National University

Professor Nathan Bindoff, University of Tasmania

Professor John Church FAA FTSE, UNSW Sydney

Professor Matthew England FRSN FAA, UNSW Sydney

Professor Jason Evans, UNSW Sydney

Honorary Professor John Finnigan FAA, Australian National University

Dr Joelle Gergis, Australian National University

Adjunct Professor Dave Griggs, Monash University

Professor Clive Hamilton AM, Charles Sturt University

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## The Chief Scientist's response



**Australian Government**

**Chief Scientist**

Dear Colleagues,

I write in response to your letter of 24 August 2020 in which you raised concerns relating to the potential expansion of natural gas usage in Australia.

I take this opportunity to thank you for acknowledging that I share your vision for the rapid development of Australia's renewable electricity sector. It is rewarding to see the contribution renewables have already made to reducing emissions.

To your point about my position regarding the supporting role that natural gas will play in the transition to a low emissions electricity supply, I can only reiterate what I said in my National Press Club address in February 2020. Namely, that the adoption of more renewable electricity will be faster, more economical and more reliable if natural gas fired electricity generation continues to be available in the near to medium term.

There will be times when supply from renewable electricity generators will be inadequate to meet demand and occasionally such periods will last many days and affect adjacent jurisdictions. Natural gas fired electricity can pick up where batteries and pumped hydroelectricity run short. Furthermore, natural gas fired electricity has an important firming role to play as and when existing coal-fired stations close due to age or competition.

Emissions from using natural gas to generate electricity are significantly lower than when using coal to produce the same amount of electricity, even when upstream fugitive emissions of methane are included in the analysis.

In addition, the rapid ramping rate of natural-gas-fired electricity — in its supply firming role — means that it does not need to operate for nearly as many hours per year as slow ramping coal fired electricity would need to operate to meet shortfalls in the combined solar and wind generation.

The combination of lower emissions per megawatt-hour and a smaller number of operating hours means that natural gas fired electricity can make a valuable contribution to reliability during our transition to a low emissions electricity system. In my address to the National Press Club I also referred to the important role of an expanded transmission line network, large-scale batteries and pumped hydroelectricity in smoothing the variable renewable electricity supply, with any residual role of gas fired generators being ultimately met by fuelling them from clean hydrogen.

Responding to one of your other points, I have not commented on an expanded role of natural gas for industry. My focus has been on the use of natural gas fired electricity generation alongside renewable energy to offer redundancy and reliability for our

electricity supply, as has been successfully demonstrated in South Australia, the United Kingdom and California.

The policy issues surrounding electricity supply are complex; the reliability of supply, the cost of electricity, and environmental issues all need to be addressed.

In summary, we need to use all of the tools available to us to achieve a low cost and secure transition to a low emissions electricity supply.

I thank you again for taking the time to write to me to express your position.

Yours sincerely



Dr Alan Finkel AO Australia's Chief Scientist

To:

Professor Nerilie Abram, Australian National University

Professor Nathan Bindoff, University of Tasmania

Professor John Church FAA FTSE, UNSW Sydney

Professor Matthew England FAA, UNSW Sydney

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Professor John Wiseman, University of Melbourne



## Gas is not a transition fuel to a safe climate. That ship has sailed.

Penny D. Sackett

Climate Change Institute, Australian National University

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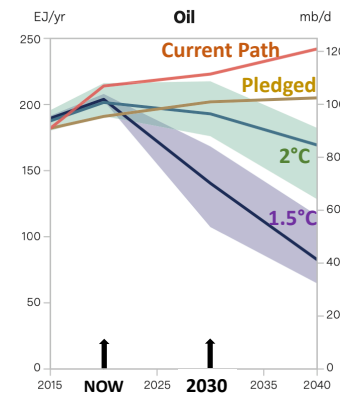
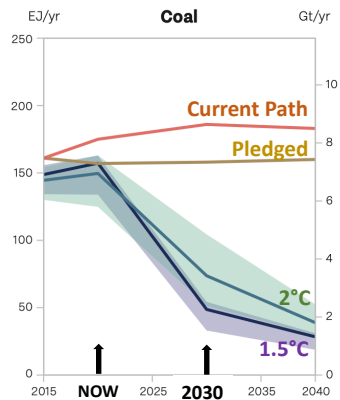
If gas-fired electricity emissions can be lower than that from coal-fired plants, should Australia expand its fossil gas industry as a means of combating climate change? The answer is a clear no if we want to avoid the worst climate change outcomes.

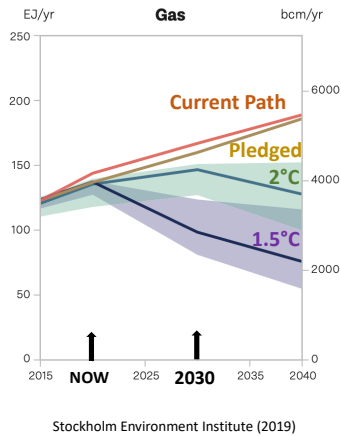
Science has repeatedly demonstrated that the most important action to limit global warming to well below 2°C is to begin to reduce all fossil fuel consumption — coal, yes, but oil and gas too — in this decade.

The primary difficulty is the large mismatch between what is required to meet that stated climate goal of the Paris Agreement and what nations have actually pledged to do. Worse still, the current policies of many countries, Australia included, would increase their national production of fossil fuels, increasing emissions above their own weak pledges.

This so-called “production gap” is the subject of a recent multi-institutional, multi-national report led by the Swedish Environment Institute (SEI 2019). Its analysis shows that governments are planning to produce about 50 per cent more fossil fuels by 2030 than would be consistent with a 2°C pathway and 120 per cent more than would be consistent with a 1.5°C pathway. This means that plans for fossil fuel development or extension that are already on the table must be shelved to hold warming to the Paris target range.

Consistent with other research, the report demonstrates that to have a 66 per cent chance of holding warming to well below 2°C, coal, oil and gas production must all decline significantly in the next decade. That is why increasing gas development to displace coal is no longer a viable approach to maintaining a reasonably safe climate.





Over the past 30 years, coal-to-gas “fuel-switching” has played a role in reducing emissions in the United States and Britain. However, the latest information from the US Energy Information Administration (2019) shows that the US energy grid has decreased its emissions from a shift to non-fossil fuel sources by almost as much as a shift to gas. Despite the shale boom, non-carbon energy sources have now overtaken any other single source of fossil fuel in supplying energy to the US grid.

In Britain, renewables played a large role in reducing emissions in the electricity grid. Between 2006 and 2016, the renewables share of electricity production rose from 2 per cent to 25 per cent, even excluding large hydro. While the 1990s’ “dash for gas” was responsible for the largest cumulative amount of avoided greenhouse emissions in Britain since 1990, the situation is different now (Hausfather 2019). In 2017, the transition to renewable energy was the largest driver in its electricity sector’s emission reductions. In second place was lower electricity demand (think what we could do with energy efficiency in Australia), while coal-to-gas switching came in third.

The world we live in has already changed dramatically with global average temperatures now 1.1°C above pre-industrial levels. Cyclones and storm surges are more intense. Droughts are more damaging. Fire seasons are longer and bushfires more fierce. Billions of animals died in last year’s Australian bushfires alone. Entire species are becoming extinct at rates far above normal. The point of no return may have already passed for Arctic sea ice — in 15 years, globes in school-rooms may show white ice at only one pole.

At 2°C of warming, heatwaves would be even more severe and more deadly to humans, animals and agriculture. Sydney and Melbourne would need to brace for 50°C days. The fire weather that produced Australia’s Black Summer would become at least four times more likely, the amount of water available to feed dams and rivers in NSW would be reduced by 30 per cent from what was typical mid last century, and coral reefs around the world would almost certainly be eliminated.

We have all the tools to avoid that future of 2°C of warming. What has been lacking is coherent, science-based action that does not add yet more fuel to the climate fire. Today, when the enormous human, economic and ecological costs of even 1.1°C of warming are so clear, when prices of renewable energy have plummeted, and several non-fossil energy storage options are available, gas is not a transition fuel to a safe climate. That ship has sailed.

Planned and rapid coal-to-renewables switching is now the responsible path. Gas will have a role in the near term, certainly, but the science is clear. The role of gas needs to be a significantly declining one, not a growing one, if we are to avoid the worst of climate change so that Australia’s future is safe, sustainable and competitively modern.

*Penny Sackett was Australia's chief scientist from 2008 to 2011. She is an honorary professor at the Climate Change Institute, Australian National University. This was first published in The Sydney Morning Herald, of 27 August 2020. Reprinted with permission.*

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## The Chief Scientist's critics are wrong about natural gas

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Several scientists have criticised the views of Chief Scientist Alan Finkel on the role that natural gas should play in reducing our carbon emissions to meet our Paris Agreement commitments. But they have misinterpreted his statements and taken a position that would make it harder to cut our emissions.

Finkel is not proposing to replace coal-fired power with natural gas-fired power, or expand the direct use of gas in industry. Rather, he anticipates that coal power will be replaced with wind and solar power. He argues that increasing their contribution requires they be backed up with gas-fired power, to keep the lights on when the output of wind, solar and storage falls too low.

Our national grid is a complex and hair-trigger system. Supply and demand is balanced second by second from western South Australia through Victoria and NSW to northern Queensland. If the supply-demand gap grows too much and too quickly, the grid is vulnerable to rolling blackouts and cascading failure. This is not a price the public will pay to reduce our emissions. Our jobs and homes depend on highly reliable power supplies.

Finkel's critics are concerned that using natural gas as a back-up means we won't meet our emission reduction targets, but the opposite is true. It will accelerate emission reductions, because an increasingly renewable and reliable power supply will allow coal generators to be closed early and safely.

Gas use is modest when used for back-up power, so will produce low emissions while bringing forward much larger emission cuts from the coal closures.

Conversely, relying on renewables without natural gas will keep coal plants operating for longer, to keep the lights on when the output of renewables and storage drops too far. This would be a perverse result and a risky gambit. Coal-fired power is not designed for intermittent operation and becomes more prone to failure when used that way. It's a recipe for more emissions and blackouts.

There is a common belief that natural gas for back-up power can be avoided by stronger transmission links, more electricity storage through pumped hydro and batteries, and more efficient and flexible use of energy. These are all important but won't be enough. During prolonged and widespread periods of low sun, low wind and high demand, renewable output will be low, storages will be depleted and there won't be surplus power to share between states across their transmission links. And there are limits to electricity customers' ability and interest to adjust their usage.

Again, relying on these options without back-up power from natural gas will make blackouts more likely. This scenario played out in California on August 14 and 15, 2020, prompting calls to delay the planned closure of gas-fired power plants.

Australian states have already seen the reliability of power compromised on hot summer days, due to increased use of air-conditioning and the variability of renewables. As the renewable share grows, that summer risk will grow. And as we electrify more heating in homes and businesses, it will also become a winter problem — particularly when the weather is calm, cloudy and cold.

Once renewable power grows enough to close all remaining coal-fired power stations, we can begin to produce a serious surplus from which zero-emissions hydrogen can be made. This will allow back-up power stations to convert from natural gas to hydrogen and reduce their emissions from low to zero.

To reach a renewable surplus will take years with all hands on deck: particularly onshore wind, offshore wind and large solar farms, supplemented with rooftop panels and bio-energy. It will be a large and complex transformation, in which cleaner, targeted and transitional uses of fossil fuels will be essential.

The build-up of methane in the atmosphere, including from leaking pipelines, would be tackled by this approach. Gas-fired back-up power will make a very small contribution to the problem, and would help reduce methane releases from coal mining as power stations close.

The Chief Scientist's response to his critics was dismissed by one as an engineering solution that wouldn't meet our climate goals. In fact, it's a crucial way to meet those goals at the quickest pace and the lowest cost.

*In 2019, Bolt was a member of the Stakeholder Advisory Group to Chief Scientist Alan Finkel for the development of a national hydrogen strategy. He was also a member of the Advisory Panel to the Energy Security Board on the post-2025 design of the national electricity market. This piece was first published in the Sydney Morning Herald of 3<sup>rd</sup> September 2020. Reprinted with permission.*



## Gas as a transition fuel is a bit-player

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In Australia, natural gas has small importance as a transition fuel to a low emissions economy. Domestic gas consumption will fall substantially during the 2020s.

The global electricity system is rapidly transitioning towards low-cost renewable energy (Blakers et al. 2019) (Fig. 1). About two-thirds of net global annual generation capacity additions are solar photovoltaics (PV) and wind energy systems (Fig. 1). Australia is a global renewable energy pathfinder. In Australia, solar PV and wind comprise virtually all new generation capacity. The deployment rate of new renewables is 10 times faster per capita than the global average and 4 times faster per capita than in Europe, China, Japan or the USA (Fig. 2). The Australian National Electricity Market (NEM) has passed 25% renewable electricity and is tracking to 50% in 2025 (Blakers, Baldwin and Stocks 2020). South Australia will pass 60% solar and wind in 2020. Rapid falls

in emissions from the electricity sector are causing economy-wide emissions reductions.

Both South Australia and the NEM as a whole have highly reliable electricity supply. The wholesale market price in South Australia so far this year is around \$50 per MWh, which is similar to Queensland but below NSW and Victoria, which have about 15% wind and solar and a price of \$60–70/MWh. High levels of wind and solar are correlated with stable electricity supply and lower electricity prices.

Balancing energy demand with 50–100% variable wind and solar during every second of every year is straightforward at low cost, using off-the-shelf methods:

- energy storage
- legacy coal and gas plant
- demand management, and
- strong interconnection over large areas using high-voltage transmission lines (Blakers et al. 2017).

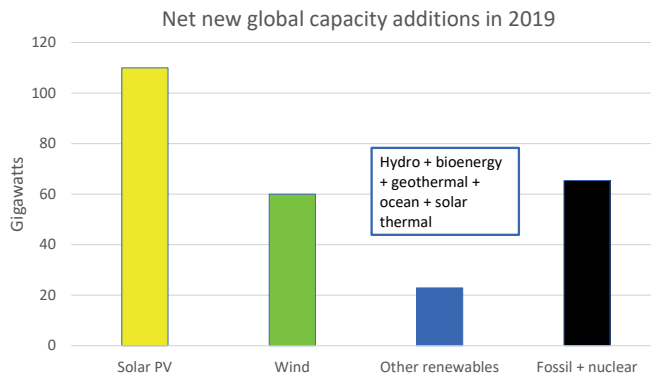


Figure 1: Net new global generation capacity additions showing the dominance of solar and wind.

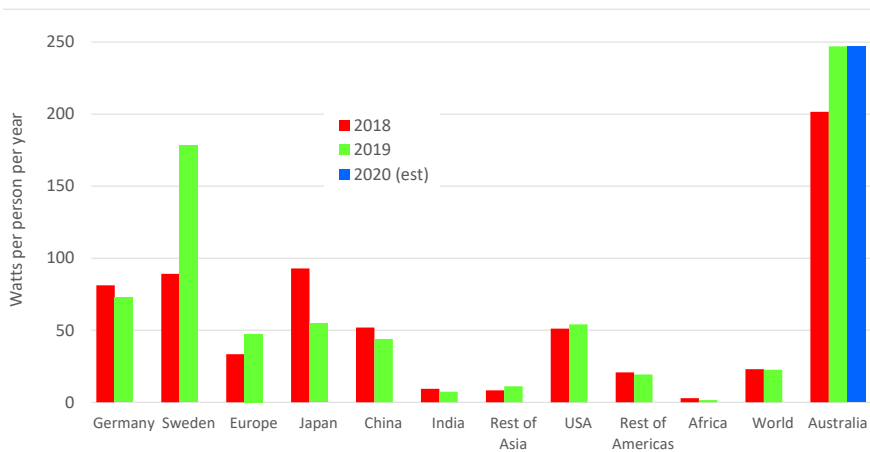


Figure 2: Deployment rate of renewables (principally solar PV and wind) in various regions in terms of Watts per person per year. (IRENA 2020)

Energy storage is mainly hydro (water held in dams in the Snowy Mountains and Tasmania), pumped hydro (like Snowy 2.0) and batteries (home, utility and electric vehicles).

Demand management can include switching off aluminium smelters for a few hours, paying people to reduce air conditioning loads during a stress period, avoiding charging electric vehicles during evening peak periods, moving water heating to daytime, or even paying some factories to have a holiday if an occasional wet windless week in winter is forecast.

Strong transmission helps because sunny or windy weather in one place can offset lack of generation in another place. This hugely reduces the cost of balancing.

Storage and demand management react far faster (sub-seconds to minutes) than legacy coal or gas plant and will garner most of the associated ancillary market payments. New Gigawatt-scale pumped hydro, batteries, transmission and demand management are being developed right now.

The Federal Government has proposed an intervention in the market to build a Gigawatt-scale gas generator in NSW to help cover stress periods in the grid.<sup>1</sup> Such a generator will have to compete with the other methods mentioned above as well as existing coal and gas generators. Its duty cycle, emissions and revenue will probably all be small.

Gas for energy has a limited future. Gas only produces 8% of NEM electricity (Open-NEM 2020). Electric heat pumps are starting to push gas out of air and water heating in buildings. Solar and wind will squeeze most gas out of the Perth, Pilbara, Darwin and mining electricity grids in the 2020s. The latest A.C.T. reverse auction produced a wind price around \$40/MWh (Mazengarb 2020). Both PV and wind will reach \$30/MWh by 2030, at which price it undercuts gas at \$5-6/GJ for industrial heating (given the losses in the latter) (Blakers and Stocks 2020).

However, gas for chemical production (fertilisers, plastics etc) will continue into

<sup>1</sup> <https://www.pm.gov.au/media/gas-fired-recovery>

the 2030s, until sustainable and low-cost alternatives are fully commercialised.

Methane is a far more potent Greenhouse gas than CO<sub>2</sub>. Leakage of 4% of the natural gas equalises coal and gas in Greenhouse terms when viewed over a 20-year time frame (Swann 2020). No one knows what the real leakage rates of methane are in Australia, and detailed research is urgently needed to find out.

To achieve zero oil, gas and coal in the economy (= 85% reduction in total emissions) we need to triple electricity production to meet the needs of transport, heating and industry (Lu et al. 2020). Wind and solar are being deployed at a rate of 6–7 GW per year in Australia, and this only needs to double to 13 GW per year to reach zero fossil fuels in 2050 (Blakers, Baldwin and Stocks 2020). For context, in 2017, the deployment rate was only 2 GW per year. The net cost will be about low or negative because wind and solar are cheap and getting cheaper.

The most important help the renewable energy industry needs from Government right now is far faster deployment of new and upgraded transmission lines to get the new wind and solar power to the cities.

In summary, electricity production will rapidly increase to replace fossil fuels used for heating, transport and industry, and this new electricity will come overwhelmingly from solar and wind. Natural gas will have a steadily diminishing role in Australian domestic energy.

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# The Chief Scientist is right, and why.

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## Abstract

Australians are responsible for some of the highest values of CO<sub>2</sub> emissions per person. To lower CO<sub>2</sub> emissions the most effective policy is to eliminate coal from power generation. In principle all electrical power generation in Australia could be provided by renewables. The mismatch between renewables and actual electrical demand means that extensive storage in the form of pumped hydroelectric will be required. However considerable reductions in CO<sub>2</sub> emissions can be achieved by using nuclear power or combined cycle gas turbines for baseload and open cycle gas turbines for peak loads. Other options include combinations of renewables and rapid response gas turbines. At the present time more than 1/3 emissions come from transportation, so further progress can only be achieved with the electrification of ground transportation. This will require a considerable increase in both electrical power generation and storage if the aim is to rely totally on renewables.

## Introduction

If emission of carbon dioxide is a big sin, then Australians are among the world's biggest sinners. The 16.2 t annual per capita emission of CO<sub>2</sub> by Australia is now higher than the United States,<sup>1</sup> generally considered to be the country with the most profligate lifestyle and lack of environmental consciousness. Energy demand and associated CO<sub>2</sub> emissions are greater in places with harsh, cold, climates. The heavily populated parts of Australia have particularly mild climates as measured by the degree days of heating and cooling, especially when compared with much of the US and Canada or Northern Europe (Rez 2017). So why does Australia have such an abysmal record?

	Cooling 27°C	Heating 21°C
Adelaide	102	2014
Melbourne	63	2718
Sydney	62	1212
Brisbane	102	900

Table 1 Degree Days of Heating and Cooling (www.degreedays.net)

The reason is the extensive use of coal in electrical power generation. What makes it worse is that Australia is a major exporter of coal and promotes its sale to developing nations in Asia. So if Australia wants to reduce CO<sub>2</sub> emissions, it has to eliminate coal from power generation. The “Letter from the 25 Scientists” in this issue talks about meeting commitments under the Paris agreement and managing entirely by using renewables: wind, solar, and hydroelectric power. However, for energy and electrical power, physical laws rather than laws passed by legislatures and international agreements limit what can be done.

<sup>1</sup> <https://www.cia.gov/international>



## Electricity use

As a start, let's look at electricity use in Australia at the present time. South Australia, Victoria and New South Wales show broad peaks in the winter months; for Queensland the peak is in the summer. The 1–2 day summer spikes in New South Wales, Victoria and South Australia correlate with maximum temperatures and are a consequence of increased use of air conditioning. This correlation is not so apparent for Queensland, where it's not just daytime high temperatures, but elevated nighttime low temperatures, that drive the demand for air conditioning. It's also apparent that the constant baseload accounts for most of the demand. In the analysis that follows, one option we will also consider is meeting the baseload with nuclear power. To see how large the effect it is instructive to compare the CO<sub>2</sub> emitted per person for France and Germany. Despite having more renewable generating capacity in the form of solar and wind than coal and natural gas, the Germans are responsible for almost twice as much CO<sub>2</sub> per person per year than are the French.

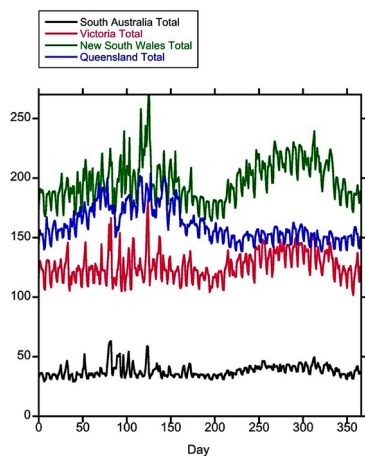


Fig. 1. Total Electrical Demand in GWh per day for Australian states for a year.

To a first approximation most of the population live in major urban areas separated by a distance of about 400 miles. In many respects this is similar to the Western United States. A simple analysis shows that transmission losses are proportional to the product of power transmitted and distance (Rez 2017). That means that electrical power trading between the states is in the range of a few hundred MW, out of total power demand in the range of GW, as can be seen from the data from the Open National Electricity Market Site.<sup>2</sup> That means we really should consider each state separately, unless a lot of extra transmission lines are installed.

## Meeting demand

The problem with solar and wind is that they do not match actual electrical demand. Solar, especially in Queensland, can be dependable, since most days are sunny. However, the peak in solar output is around midday, while the demand peaks are partly in the early morning and mainly in the early evening.<sup>3</sup>

The output from solar is falling off steeply just as the demand is increasing. Right now the increased evening demand is being met by ramping up the output of coal-fired power plants. Given that they rely on a steam Rankine cycle, their start-up time and response time is slow, and so they are not ideal for meeting this sudden increase in electrical demand. Open-cycle gas turbines are a better option, and would provide the needed fast response with about half the CO<sub>2</sub> emissions.

<sup>2</sup> <https://opennem.org.au/energy/nem>

<sup>3</sup> We are assuming rooftop solar here, as this represents output from northward-facing flat PV panels. It's hard to tell from the utility solar data how much has been curtailed to try and better match actual demand.

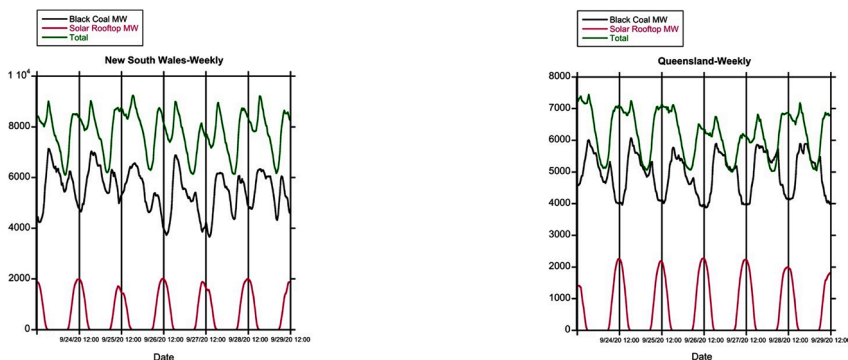


Fig 2. Electrical Demand for New South Wales and Queensland showing how solar peaks in the middle of the day and how coal is used to meet the evening peak demand.

### Using solar and wind only

But what if we wanted to manage entirely from solar power? The issue of how to meet the evening demand becomes even more critical, especially in the winter months with reduced hours of daylight. This is an issue everywhere, not just Australia. Peaks are driven by domestic demand, which is at its highest when people come home in the evening or when they get up in the morning.

There are three choices:

1. Eliminate the evening demand, have everyone go to bed at sunset! (This is what people did before artificial lighting.)
2. Given the rapid fall off in solar output, provide lots of gas turbines that can be quickly ramped up to meet the evening demand. They'd also play a large role in meeting the morning demand in winter.
3. Over-generate during the day and store the excess electrical energy for use in the evenings and at night.

So how much storage would be needed? Based on this week in September, if Queensland were to rely on solar alone, it would

need about 21 GW of solar generating capacity and 150 GWh of storage, taking account that storage isn't perfect and that one might get out about 80–90% of the energy that has been put in. That is almost as much as the daily electrical energy used. If the aim is to reduce CO<sub>2</sub> emissions, then the mismatch between solar and demand can be reduced by using nuclear to meet the baseload. In that case, 13GW of solar generation are needed and 90 GWh of storage. Also peak electrical energy demand is on hot days and nights in the summer, not relatively mild days in September. This would increase daily electrical demand and storage needs to approximately 200 GWh.

However, not every day, even in Queensland, is sunny so one must store enough to get through the days with reduced solar generation. Looking at the variation of solar with time of the year, we can see that there were 13 one-day periods and 7 two-day periods with half the peak solar output. The longest period was almost a week, although this was in winter and the reduced solar generation might be partly compensated by the availability of wind at that time.

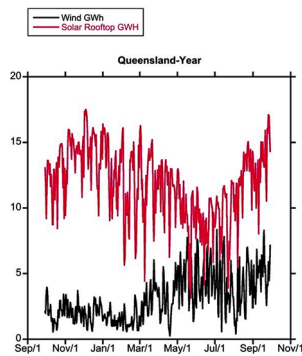


Fig. 3. Solar and Wind Power generated in GWh per day throughout the year.

If solar is relatively dependable, but does not cover the peak demand well, then wind, by comparison, is very unreliable, but can cover peak demand periods. South Australia has more wind than the other states but even for one week in September there’s one day with no wind. Note the rapid fall in wind energy on the third day, comparable to the fall in solar energy as the sun goes down.

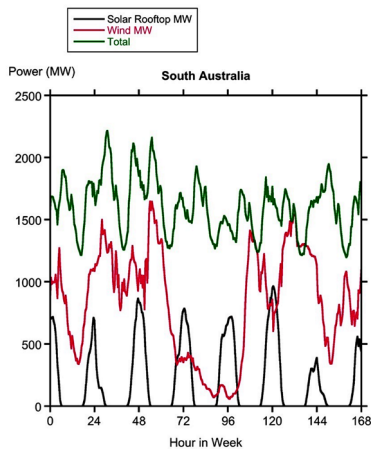


Fig. 4. Variation by the hour of solar and wind output in MW for South Australia.

Examining the annual variation of wind energy throughout the year, it’s apparent that there are about 50 periods when the wind energy is 15 GWh or less, about half

the 30 GWh output when presumably the wind turbines are generating their rated power. There’s even one period where the wind energy is less than 15 GWh for 14 days. If the wind speed,  $v$ , isn’t high enough for the wind turbine to generate its rated power, generally 11–12 m/sec, then the output is only proportional to  $v^3$ . This means in practice wind is either “on” or almost “off,” which is again apparent from Fig. 5.

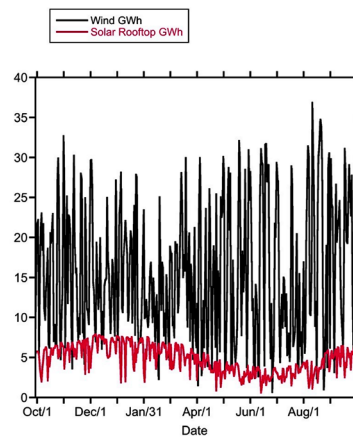


Fig. 5. Annual variation in solar and wind electrical energy in GWh per day for South Australia

### How much storage?

So to rely on wind and solar means either having lots of open-cycle gas turbines available to fill in the gaps, or having some form of energy storage. To assess how much energy storage is needed I wrote a code where one could multiply the amount of wind and solar generated at present in each state and store the excess in a “bank” (or energy storage unit). Energy could also be withdrawn from the “bank” and the aim of the exercise was to come up with a plausible mix of solar and wind that would minimize the amount of energy stored. The results are given as Table

2 below. Ideally this would have been done for data points in half-hour intervals throughout the year, to take account of the variation of solar throughout the day that was discussed above, but the data from the National Energy Market<sup>4</sup> only gives energy per day so the result isn't quite as accurate as I would like, but the order of magnitude is probably correct. The analysis was done assuming solar and wind were going to meet all the electrical demand, or assuming the baseload was met with some appropriate low emission generation source like nuclear (France) or hydro-electric power or a combination of both (Sweden). Hydro electric could also be used for peaks, which makes it the most desirable of the renewable energy sources since not only can it match real time demand, large scale hydro electric also comes with a store of energy in the form of reservoirs.

As can be seen from Table 2, the energy storage requirements for these four Australia states add up to about 11.4 TWh. The energy storage required in each state is in the range of hundreds to thousands of GWh. The only practical way to meet this storage need is pumped hydro electric, but that depends on having suitable topography for the two reservoirs with a sizeable elevation difference (hydraulic head). Snowy 2 with 380 GWh is a commendable first step, but this will have to be replicated about 30 times to meet the total storage demands. Battery banks like the 129 MWh installed at the Hornsdale wind farm are too small to make a difference. A quick calculation shows that it can only store the equivalent of 25 minutes of output. As the late Dave MacKay (2008) said "every big counts." Using nuclear or hydro for base load as shown in Table 3 reduces the requirement

by a factor of about 2.5, except in Queensland. That is because there is some need for inter seasonal storage, some of the excess electrical energy generated in summer has to be stored for use in winter. However, given that Australia has a third of the world's uranium and thorium reserves, it would make sense to use this locally available resource.

### Transport emissions

Of course, this analysis does not address the CO<sub>2</sub> emissions resulting from consumption of liquid hydrocarbons by the transportation sector. Even now in Australia these emissions are slightly greater than the CO<sub>2</sub> emissions associated with coal burning and accounts for about 6 t per person per year out of the 16 t CO<sub>2</sub> emission per person per year. An electric vehicle can be at least 4 times as efficient at using stored energy. Dividing the energy available from liquid hydrocarbons used in ground transportation<sup>5</sup> by 4 gives about 175 TWh per year, almost as much as the electrical energy used at present. In practice vehicles will be mainly charged at night, so it will increase the baseload. This is not good for renewables like solar and wind, but is favourable for nuclear.

### The need for storage

In conclusion, it is impossible to make solar and wind supply Australia's electrical energy needs without extensive storage. This will only be exacerbated with the electrification of ground transportation. The development of hydro and pumped hydro-electric is predicated on climate and topography. In most countries hydro-electric power has been fully developed. Furthermore pumped hydro requires not just one, but two reservoirs at dif-

<sup>4</sup> <https://opennem.org.au/energy/nem>

<sup>5</sup> <https://www.eia.gov/international>

	S. Australia	Victoria	New South Wales	Queensland
Wind	2.4	5.5	5.5	2.5
Solar	1.9	6.5	14.5	13.5
Storage	800 GWh	2800 GWh	5270 GWh	2550 GWh

Table 2. Proportions of solar and wind given as multiples of the current solar and wind generation, and storage requirements, for the four Australian states to manage totally from solar and wind renewables.

	S. Australia	Victoria	New South Wales	Queensland
Baseload	30 GWh	105 GWh	164 GWh	138 GWh
Wind	0.5	0.82	0.6	1.4
Solar	0.6	1.4	3.1	1.7
Storage	300 GWh	1245 GWh	2100 GWh	2050 GWh

Table 3. Proportions of solar and wind given as multiples of the current solar and wind generation, and storage requirements, for the four Australian states using solar and wind for peaks only and generating baseload demand from other low CO<sub>2</sub> sources such as nuclear or hydro.

ferent elevations. However, Blakers et al. (2017) claim that it is possible to develop pumped hydro storage capacity of sufficient magnitude with multiple relatively small units mainly in Victoria and New South Wales. They correctly point out that this is possible because inter seasonal storage needs are quite low in Australia, unlike in Northern Europe. However we differ in the magnitude of power hydro electric storage required. I can't comment on the cost estimates, but is it realistic to develop a thousand 1.6 GWh pumped hydro-electric storage systems, mainly in remote areas? How long would this take?

If the aim is to reduce CO<sub>2</sub> emissions, a considerable reduction could be achieved by using nuclear instead of coal for the baseload. (Again, compare France and Germany.) Solar and wind would then have to meet much less of the demand, and as shown in Table 3, the need for storage would be much reduced. Even if the peak load were met by open-cycle gas turbines, the CO<sub>2</sub> emissions per person for electrical power generation would be

reduced from about 10t per person per year to 0.7t per person per year. Copying the United States and substituting combined-cycle natural gas for coal for the baseload while using open-cycle turbines for peaks would reduce CO<sub>2</sub> emissions from power generation to about 3t per person per year.

### Conclusion

Managing totally off renewables (Blakers et al 2017) is an interesting theoretical possibility, but would be very hard to implement in practice, with lots of excavation in remote mountainous areas. As they say “The perfect is the enemy of the good.” The Chief Scientist is right: in practice natural gas will be needed for power generation in Australia.

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## Discussion between Andrew Blakers and Peter Rez

### Abstract

The two authors respond to each other's articles, above.

### Andrew Blakers responds to Peter Rez's article

To undertake this kind of analysis you need to include the following:

- Hour-by-hour solar, wind and demand data over 5–10 years for many places in each state. This represents what is actually happening
- Both PV and wind are cheaper than one alone
- Add in legacy hydro and bio
- Additional high voltage DC (HVDC) and AC transmission to even out supply and demand between states (a “copperplate”). We find a 5× reduction in storage needs when we do this rather than try to balance state-by-state. The cost of the transmission is modest but the effect is large.
- Storage (0.5 TWh). We chose to model off-river pumped hydro, of which there are 3000 good sites in Australia — look at our atlas at <http://re100.eng.anu.edu.au/global/index.php>. This sets an upper bound on storage cost. If batteries and demand management reduce the overall cost, then good.

Our 2017 paper did all these things (Blakers et al. 2017), which represent what is actually happening.

Prof. Rez did not. His comment is wrong: “The development of hydro and pumped hydro-electric is predicated on climate and topography. In most countries hydro-electric

power has been fully developed. Furthermore pumped hydro requires not just one, but two reservoirs at different elevations.”

Our results are clear and reproducible: the cost of balancing a 100% grid (over and above the cost of PV/wind energy supply) is low (<A\$25/MWh). This is far below the cost of gas generation.

Gas is only supplying 8% of generation in the national electricity market (and declining). Facts on the ground show that PV, wind and storage is squeezing gas.

See Blakers et al. (2020).

### Peter Rez responds

Ideally I would have used hour-by-hour data for many years. I grabbed what was available and did what I could in the limited time available. I've looked at the Blakers paper (Blakers et al. 2017) again and have now come to the conclusion that there are serious problems.

Prof. Blakers claims that he can get by with a total storage of somewhere between 225 and 750 GWh; let's call it about 500 GWh. The reason I went through those detailed analyses on mismatch between demand and solar and demand and wind is to establish what could be considered as minimum storage necessary. Let's take solar. Just looking at the shape of the peak and how it slots between the demand peaks shows that as a minimum one would need to store approximately the amount of electrical



energy used in a day. For the 4 states that's about 600–700 GWh. Taking account that not every day is sunny would only increase this amount. For wind the problem is different: it's the need to allow for long periods (up to a week or more) with low wind velocities and minimal outputs. Don't think that taking wind from widely separated areas is that much help: the correlation between wind in S. Australia and Victoria is 0.72, and even when one compares New South Wales (where there isn't much wind) with S. Australia it's as high as 0.4. In other words wind is mainly determined by the passage of weather systems (you'll see the same elsewhere in the world).

HVDC buys one a factor of about 2 (see Rez 2017, Chapter 5); maybe it's cheaper to put in one HVDC line rather than 2 equivalent AC lines. The real advantage of long-distance transmission is using solar generation at points 2000 miles west to match an evening peak. But that's not what we're talking about: these states are on a North–South axis. When I played with my crude program, I found that amalgamating the states brought the storage down from about 11TWh to 9TWh either with 5.0× wind 10.4× solar or 7.6× wind and 6.4× solar. To be honest, the notion that the 4 eastern states of Australia can manage off 0.5 TWh storage seems implausible, so I think there's something wrong with his code.

If anything, my crude analysis underestimates the storage required, as it takes each day as a block rather than following supply and demand on an hourly basis (very important for solar as shown above).

As for costs, one doesn't know what they will be until someone actually goes out and asks for bids (preferably on a fixed-price contract).

If Prof. Blakers is right, then Australia should be able to manage on Snowy 2 with a few extra transmission lines. So what's stopping you? (Though I'd check his code carefully first: as I said, I think the estimates for storage required are implausibly low.)

As for the wonders of all the solar that has already been installed, see Fig. 1D showing the effect on Australian CO<sub>2</sub> emissions. It's precisely zero. Until Australia gets off coal, nothing is going to change.

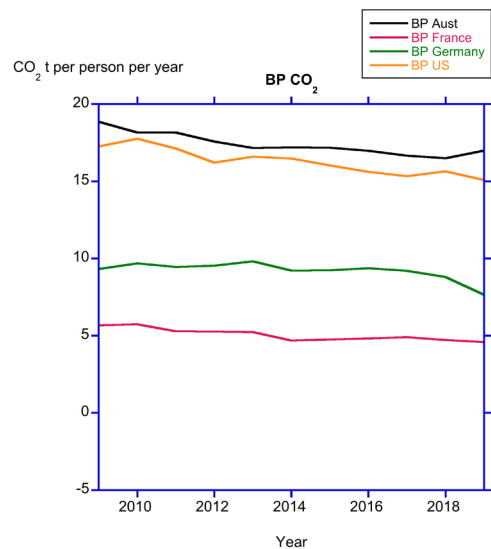


Figure 1D CO<sub>2</sub> emissions

### Peter Rez continues

Let me summarise where we are at:

I agree in principle it would be possible for Australia to live entirely off renewables; where we differ is the magnitude of pumped hydro required (I think it's 10 to 15 times more than Prof. Blakers' estimate). I don't know whether the topography allows for the 9–15 TWh of pumped hydro that I think is more likely to be necessary. I'm a bit confused by Prof. Blakers' 2017 paper. The critical number, the amount of pumped storage

in GWh or TWh, is not clearly spelled out. In the text there's vague talk of numbers between 225 GWh and 750 GWh, in his Fig 4 16 TWh per year (what does that mean?) is mentioned.

If the objective is to lower CO<sub>2</sub> emissions, then the increased adoption of solar PV, despite Prof. Blakers' cheerleading, hasn't done much (if anything). (See attached graph, Fig. 1D). It didn't do anything in Germany either. The most important thing is to eliminate coal from power generation. That hasn't happened in Australia, which is why Australia's CO<sub>2</sub> emissions per person remain high. Australia also has a high contribution from transportation. It would be interesting to see how much the extractive industries contribute.

It's very easy to get into a situation where the widespread adoption of rooftop PV actually increases CO<sub>2</sub> emissions when it displaces nuclear power or combined-cycle gas from the baseload.

The one thing that is guaranteed to work is to substitute nuclear power for coal. The position really hasn't changed that much from when I wrote my book (Rez 2017): the French CO<sub>2</sub> per person per year is substantially less than the German CO<sub>2</sub> per person per year. The British Petroleum data show a fall in German CO<sub>2</sub> for 2019 (Fig. 1D, BP 2020), but I'm going to wait for the more rigorous U.S. Energy Information Agency data to try and understand what's going on.

The costs of renewables are all up-front capital costs. I wouldn't take any notice of numbers for costs produced by me, Prof. Blakers or anyone else who lives in an ivory tower. Take a concrete proposal and send it out for bid with real contractors and companies who have "skin in the game."

In many countries there are various individuals promoting the view that reducing or even eliminating CO<sub>2</sub> emissions in a modern industrial society is going to be cheap, with the painless substitution of renewables for fossil fuels. Any reduction in CO<sub>2</sub> emissions is going to be hard, potentially costly and time-consuming, and these costs have to be weighed against potential benefits. I think the Chief Scientist understands this, and I would urge him to consider all the options and not accept what Prof. Blakers says.

### Andrew Blakers responds

Robert, one difference between us is that my colleagues and I have actually done the hard yards: a detailed hour-by-hour analysis taking all key parameters into account.

Another is that we look at facts on the ground: PV and wind are rapidly taking over the AU electricity grid — far faster than in the USA and elsewhere — because they are cheap.

As I said, Prof. Rez needs to include the following, and until he does so then he will get an inflated answer for storage needs:

- Hour-by-hour solar, wind and demand data over 5–10 years for many places in each state. This represents what is actually happening with widely distributed solar & wind
- Both PV and wind are cheaper than one alone
- Add in legacy hydro and bio
- Additional HVDC and AC transmission to even out supply and demand between states (a "copperplate"). We find a 5× reduction in storage needs when we do this rather than try to balance state by state. The cost of the transmission is modest but the effect is large

- Storage (0.5 TWh). We chose to model off-river pumped hydro, of which there are 3000 good sites in Australia — look at our atlas at <http://reeroo.eng.anu.edu.au/global/index.php>. This sets an upper bound on storage cost. If batteries and demand management reduce the overall cost, then good.

Table 3 in our 2017 paper clearly sets out storage needs for 17 scenarios. All around 0.5 TWh. None is around 9–15 TWh (Blakers et al. 2017).

With respect to Snowy 2.0: this system has nearly enough energy storage (350 GWh, compared to the 500 GWh requirement) but not nearly enough power (2 GW, compared to 20 GW). In other words, we can't get the water out fast enough.<sup>1</sup> It would be unwise to put too many eggs in this basket by adding many more tunnels and gensets — better to spread the storage power around.

Australia has no nuclear and is not going to get any.

Gas is only 8% of annual generation in the NEM and declining (OpenNEM). Renewables are tracking towards 50% in 2025.

- Facts on the ground (Blakers et al. 2020):
- Solar and wind are 99% of new capacity in Australia because they are cheap
- Emissions in the electricity sector are falling rapidly. Overall emissions are also falling
- Australia is installing renewables 4× faster per capita than EU, USA, China or Japan and 10× the global average. USA has a great deal to learn from Australia
- So far in 2020, Tasmania (100% hydro & wind) and South Australia (60% wind & solar) have the cheapest electricity in Australia. See this at <https://opennem.org.au/energy/nem/?range=7d&interval=30m>

“In the year to June 2020, emissions per capita and the emissions intensity of the [Australian] economy were at their lowest levels in 30 years. Emissions per capita were lower than 1990 by 44.7 per cent while the emissions intensity of the economy [CO<sub>2</sub> per \$] was 64.7 per cent lower than in 1990.” (AG 2020, p. 3)

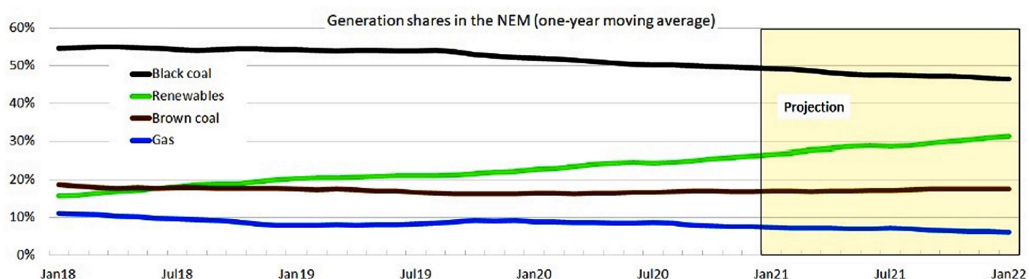


Figure 2D Australian energy shares

<sup>1</sup> This is a distinction between energy (measured in GWh) and power (measured in GW): in the economist's language, almost enough stock but not enough flow. [Ed.]

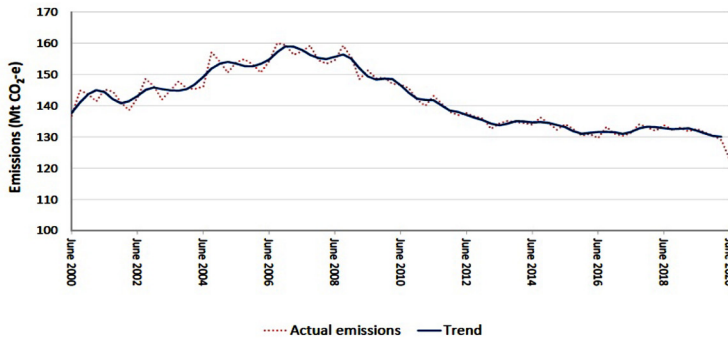
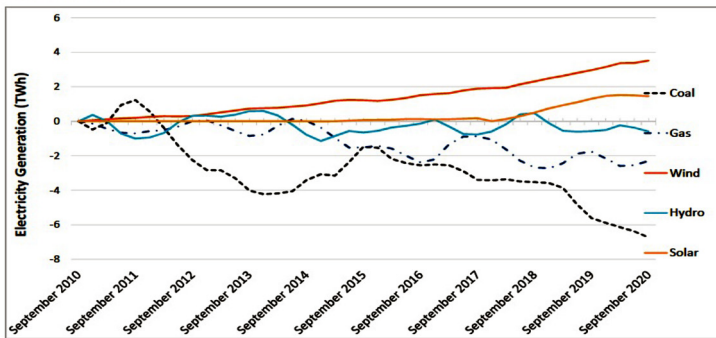


Figure 3D CO<sub>2</sub> emissions — AU

Figure 8: Change in electricity generation in the NEM (trend), by fuel, by quarter, September 2010 to September 2020



Source: Australian Energy Market Operator (AEMO, 2020), obtained using NEM-Review software

Figure 4D Electricity fuel changes — AU

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## Thesis abstracts

### Improving health providers' management of smoking in Australian Indigenous pregnant women

Yael Bar-Zeev

Abstract of a thesis for a Doctorate of Philosophy in Behavioural Science submitted to the University of Newcastle, Callaghan, Australia

Globally, tobacco use is the leading cause of morbidity and mortality, causing an annual death rate of seven million people. In Australia, tobacco use is responsible for 9% of the total burden of disease. Smoking during pregnancy remains a significant public health problem for specific population groups, causing miscarriage, stillbirth, low birth weight and more. Psychosocial interventions such as behavioural counselling have been shown to be effective. Clinical guidelines in Australia recommend using the 5As approach: Ask about smoking status; Advise briefly to quit; Assess nicotine dependence and motivation to quit; Assist as needed (including behavioural counselling and nicotine replacement therapy [NRT] if required); and Arrange follow-up and referral to smoking cessation support services. NRT is recommended if the woman is unable to quit using only behavioural counselling, with oral NRT considered as first line.

Aboriginal and Torres Strait Islander pregnant women have the highest smoking rates in Australia at 43%, facing multiple barriers to quitting smoking, including lack of adequate support from health providers. Health providers also face many barriers to support pregnant women to quit smoking, on an individual and systematic organisa-

tional level. To date, very few interventions have tried to improve health providers' management of smoking with Aboriginal and Torres Strait Islander pregnant women. Those that have either did not use rigorous research methods or suffered from multiple implementation challenges.

The aim of this thesis was to explore health providers' practices regarding smoking cessation care during pregnancy, barriers to the provision of smoking cessation care and methods for improving health providers' care, and to test an evidence-based behaviour change intervention to improve health providers' provision of smoking cessation care to pregnant Aboriginal and Torres Strait Islander women.

As part of this thesis, a national cross-sectional survey of 378 general practitioners (GPs) and obstetricians was conducted about their knowledge, attitudes and practices providing smoking cessation care to pregnant women. Data from this survey revealed low levels of provision of several smoking cessation care components ("Assess," "Assist" and "Arrange"), with only 15.6% of GPs and obstetricians reporting "often and/or always" performing all of the recommended 5As. Overall, 25% of GPs and obstetricians reported "never" prescribing NRT, with nearly 50% reporting

they would “never” prescribe combination NRT (NRT patch plus an oral NRT). GPs and obstetricians reported that they lacked time, resources and confidence in their ability to prescribe NRT during pregnancy, and lacked optimism that their intervention would be effective.

Semi-structured qualitative interviews were conducted with 19 GPs, aiming to explore their management of smoking during pregnancy in greater depth and what would enable them to improve their smoking cessation support to pregnant women. Participants reported they lacked communication skills to provide pregnant patients adequate support for quitting, focusing on providing information on smoking harms and discussing treatment options only with patients who reported an interest in quitting. Lack of time, NRT cost, previous negative experiences with NRT and safety concerns, being unfamiliar with the Quitline process and uncertainty over its suitability (specifically for Aboriginal and Torres Strait Islander peoples) were all perceived as additional challenges. Participants reported needing clear detailed guidelines, with visual resources they could use to discuss treatment options with patients.

A narrative review of the current guidelines regarding NRT use in pregnancy was performed, while considering the existing evidence base on NRT safety, efficacy and effectiveness during pregnancy. Animal models show that nicotine is harmful to the foetus, especially for brain and lung development, but human studies have not found any harmful effects on foetal and pregnancy outcomes. Previous studies have used NRT doses that might have been too low and not have adequately accounted for the higher nicotine metabolism during

pregnancy, and thus not sufficiently treating withdrawal symptoms. Nonetheless, studies of efficacy and effectiveness in the real world suggest that NRT use during pregnancy increases smoking cessation rates. Current national clinical guidelines from Australia, the United Kingdom, New Zealand and Canada recommend that if women are unable to quit smoking with behavioural interventions alone, they should be offered NRT in addition to behavioural counselling. The guidelines also impose many restrictions on NRT prescription during pregnancy and do not provide practical detailed guidance on when to initiate NRT and how to titrate the dosage. Pragmatic suggestions for clinical practice were made, including an approach for initiating and titrating NRT dosage during pregnancy and for discussing the risks versus benefits of using NRT in pregnancy with the pregnant patient and her partner.

A systematic review and meta-analysis reviewed the data from all published interventions aimed to improve health providers' smoking cessation care during pregnancy. Overall, 16 studies describing 14 interventions were included — 10 used a quasi-experimental design (pre–post), with only six studies using a randomised controlled trial (RCT) design. The review found that the median number of intervention components reported by studies was two (range 1–6). The most common intervention components used were training (93%,  $n=13$ ), educational resources (64%,  $n=9$ ) and reminders (57%,  $n=8$ ). Studies used a variety of outcome measures, with different data collection methods, affecting the ability to synthesise the data. Specifically, the “Assist” or “Provide smoking cessation support” component of care was ill defined with vast variability



between studies. Meta-analysis of the different smoking cessation care components (according to the 5As) showed a small significant increase in the provision of all smoking cessation care components. The review suggests that use of a behaviour change theory to guide intervention development, and inclusion of audit and feedback, increases the likelihood of intervention effectiveness in improving health providers' provision of certain smoking cessation care components.

Informed by these studies, a multi-centre community-based participatory research study was undertaken. This study aimed to assess a collaboratively developed educational resource package to aid health providers' smoking cessation care in pregnant Aboriginal and Torres Strait Islander women. A panel of eight experts with complementary expertise provided input and suggestions to aid simplicity and usefulness of the resources. Staff members from three Aboriginal medical services in New South Wales, Queensland and South Australia scored each of the patients' resources using the "Suitability of Material" scoring method, finding that all received adequate or superior scoring. Average readability was grade 6.4 for patient resources (range 5.1–7.2; equivalent to ages 10–13 years) and 9.8 for health provider resources (range 8.5–10.6; equivalent to ages 13–16 years). Content analysis from focus groups with health providers from the three Aboriginal medical services revealed four themes including "Getting the message right," "Engaging with family," "Needing visual aids" and "Requiring practicality under a tight timeframe." Results were presented back to a Stakeholder and Consumer Aboriginal Advisory Panel (SCAAP), and resources were adjusted accordingly for

inclusion in the ICAN QUIT in Pregnancy multi-component intervention.

Thereafter, a step-wedge cluster randomised pilot study was conducted: the ICAN QUIT in Pregnancy intervention. This intervention aimed to improve health providers' provision of evidence-based, culturally responsive smoking cessation care to pregnant Aboriginal and Torres Strait Islander smokers. Six Aboriginal medical services were randomised into three clusters for implementation. Clusters received the intervention staggered by one month. The intervention included a three-hour training webinar for health providers, educational resource packages for health providers and pregnant women, free oral NRT for pregnant women and audit and feedback on health providers' performance. Of 93 eligible health providers, 50 consented to the trial (54%), 45 completed the pre-intervention survey (90%) and 20 completed the post-intervention survey (40%). About 42% ( $n=39$ ) of health providers participated in the webinar training. Mean knowledge composite scores improved significantly from pre to post (78% vs 84% correct,  $p=0.011$ ). The mean NRT-specific knowledge composite score also improved significantly (68% vs 79% correct,  $p=0.004$ ). The mean attitude composite score improved significantly (3.65 [SD 0.4] to 3.87 [SD 0.4];  $p=0.017$ ). The mean NRT-specific attitudes composite score also improved significantly (3.37 [SD 0.6] to 3.64 [SD 0.7];  $p=0.005$ ). None of the practices improved significantly, including the prescribing of NRT.

In summary, increasing health providers' provision of smoking cessation care to pregnant Aboriginal and Torres Strait Islander women is a significant priority in Australia. This body of work highlights that currently,

health providers are lacking in their provision of smoking cessation care, specifically in their support for pregnant Aboriginal and Torres Strait Islander women to quit smoking. Particularly, the provision of the “Assist” smoking cessation component was low, including the prescription of NRT. Multiple barriers exist and include lack of knowledge, skills (especially communication skills), time, resources and lack of optimism. Guidelines do not provide clear guidance, including the optimal timing for initiating NRT and titrating the dosage. The pilot intervention tested within this thesis showed promising initial results, with health providers significantly improving their knowledge and attitudes, although this did not translate into improved practices. Several strategies might enhance the

effectiveness of the intervention and should be tested in a larger and adequately powered trial. The complex nature of tobacco smoking, and considering its historical and social context in Aboriginal communities, suggests that wider and more intensive interventions are needed.

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## Intrinsic and extrinsic aspirations and psychological well-being: a meta-analysis and latent profile analyses of life goals

Emma Bradshaw

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Australian Catholic University, Sydney

Goal Contents Theory holds that intrinsic life goals (personal growth, relationships, community giving, and health) and extrinsic life goals (wealth, fame, and image) differentially relate to psychological well-being. Intrinsic life goals, or aspirations, inherently satisfy basic psychological needs and therefore promote optimal functioning, while an emphasis on extrinsic aspirations represents a reliance on external contingencies

which, at best, only indirectly satisfies basic psychological needs. Despite abundant evidence supporting goal contents theory, positive links between extrinsic aspiring and well-being, observed particularly in Eastern European countries, have led some authors to contend that extrinsic aspirations may not be damaging in all contexts. In addition, the frequently observed positive correlation between intrinsic and extrinsic aspirations

suggests that they are not universally divergent. Indeed, consistent unexplained heterogeneity in the results indicates there are unobserved sources of heterogeneity in the data, suggesting there may be subgroups with distinct patterns of aspiring.

In Chapter 2 of this thesis, a meta-analysis of more than 1,000 effect sizes showed support for the universality of goal contents theory across countries, age groups, and socioeconomic statuses. In Chapters 3, 4, and 5, bifactor structural equation modelling (B-ESEM) was combined with latent profile analysis (LPA) in three large, independent samples from Hungary, Australia, and the United States of America, and derived three replicable profiles of aspiring. Chapters 4 and 5 showed that profile membership predicted additional variance in well-being, even in highly conservative tests that control for the aspirations that

comprise the profiles. The profiles also differed in the breadth of their care for others. From Profile 1 to Profile 3, increasingly more (and more distal) others are central in the configurations of aspiring, starting with the self (Profile 1), then close others (Profile 2), and then the world in general (Profile 3). These studies make a unique contribution to the literature by synthesizing the available evidence and by identifying replicable latent profiles of aspiring that account for variance in well-being and other-oriented-ness over and above the constituent variables.

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## Institutional influences on education investment and pro-social behaviour

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

This thesis consists of three chapters. It studies, as a broad theme, the effectiveness of several institutional changes on individual decision-making based on experimental evidence. Chapter 1 is self-contained, with results purely based on a laboratory experiment. Chapter 2 and Chapter 3 are based on one field experiment in education. Chapter 2 describes the experimental set-

tings and presents the overall results of the experiment, whereas Chapter 3 extends the analysis and focuses on treatment effects on women and men respectively.

Chapter 1 shows how reward or punishment opportunities change contributions in a public goods game with 'privileged' members, where 'privilege' indicates that one's per-unit contribution to the public

good produces a higher monetary return than is the case for others in the group. The main finding is that reward opportunities strongly increase group contributions in such groups while punishment opportunities do not. Reward also mitigates contribution decay over successive periods and improves social welfare.

Chapter 2 mainly studies how rank incentives (i.e., relative performance information) in a milestone-based online assignment system affect students' academic performance. I find that rank incentives increase the likelihood of a student putting more effort in the online assignment. Rank incentives also have positive effects on low-performing students' exam marks while they have negative effects on high-performing students' exam marks. The positive effects seem driven by increased self-perceived stress, increased effort, and decreased procrastination. The negative effects seem driven by increased self-perceived happiness and reallocation of effort.

Chapter 3 studies how rank incentives and milestone information (i.e., information with reference to achievement milestones corresponding to different amounts of points earned) affect men's and women's academic performance differently. Women with access to the rank incentives experience a 0.19 standard deviations decrease of marks in the first midterm, compared to women without this access. In the absence of relative performance information, men with access to the milestone information experience a 0.26 standard deviations increase of marks in the final exam, compared to men without the access. The negative effects on women seem driven by their increased stress level, whereas men's improved exam performance seems driven by increased effort.

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## “Black America Cares:” The response of African Americans to the Nigerian Civil War, 1967–1970

James Farquharson

Abstract of a thesis for a Doctorate of Philosophy submitted to the  
Australian Catholic University, Sydney

Far from having only marginal significance and generating a “subdued” response among African Americans, as some historians have argued, the Nige-

rian Civil War (1967–1970) collided at full velocity with the conflicting discourses and ideas by which black Americans sought to understand their place in the United States

and the world in the late 1960s. Black liberal civil rights leaders leapt to offer their service as agents of direct diplomacy during the conflict, seeking to preserve Nigerian unity; grassroots activists from New York to Kansas organised food-drives, concerts and awareness campaigns in support of humanitarian aid for Biafran victims of starvation; while other pro-Biafran black activists warned of links between black “genocide” in Biafra and the US alike. This thesis is the first to recover and analyse at length the extent, complexity and character of such African American responses to the Nigerian Civil War. Drawing on extensive use of private papers, activist literature, government records and especially the black press, it charts the way African Americans conceptualised, over time and in complex ways, their varied understandings of issues such as black internationalist solidarities, territorial sovereignty and political viability, humanitarian compassion and great power *realpolitik*, as well as colonial and neo-colonial influence in Africa.

The thesis initially explores the longer twentieth-century history of African American engagement with Nigeria by way

of establishing context, before providing in-depth analysis of the key initiatives and events that comprised African American engagement with the civil war. Chapters move chronologically and thematically to discuss direct diplomatic efforts to broker peace, African American responses to alleged genocide in Biafra, the rise and fall of pro-Biafran political support, and the latter’s loss to what emerged as a stronger political bloc of those supporting Nigerian political unity. Situated methodologically and historiographically at the intersection of scholarship on black internationalism and the international history of the Nigerian Civil War, this thesis demonstrates the way the civil war not only provoked intense activism, but did so in ways that fundamentally connected with the central ideas, themes and concerns of the black freedom struggle in the United States.

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## Sounding out the past

Andrew Harrison

Abstract of a thesis for a Doctorate of Philosophy submitted to  
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This thesis explores the relationship between music composition and historical narrative, and considers whether

creative works inspired by historical events offer an alternative perspective on the past.

To test this idea the thesis focuses on two significant, though unrelated, moments in history: Australia's involvement in World War One, and the shifting social and economic chronicle of Detroit since the mid-twentieth century. I address these two periods of history from a number of perspectives. Firstly, I analyse how other composers have creatively engaged with and reflected upon each moment. In particular, I examine the musical language of Australian composers who have been inspired by World War One, and American composers writing Detroit-focussed works, to show how their musical language underpins the histories they aim to reflect. I also assess critical responses to various works, demonstrating how the reception of music can differ depending on current social and political factors.

I then seek to establish my personal and creative connection to each of these historical narratives, outlining the historical research I undertook prior to writing compositions, *Gassed Shell (Severe)* and *Hum*. These works, premiered in Melbourne and Detroit respectively, represent a major component of the

thesis. Their scores are included in full. The connective tissue between these elements is a detailed exploration how my research informed and shaped my creative practice. Moreover, I provide insight into the musical techniques and decisions I made to fulfil my compositional intentions and, in turn, to gain fresh perspectives on the historical events. I seek to push beyond a conventional exegesis to self-reflexive analysis. In conclusion, I frame the music of composers dealing with the past through an interdisciplinary lens, drawing upon cultural anthropologist Clifford Geertz's idea of "thick description" to recontextualise these creative processes as akin to historical practice, and, as such, potential methods for obtaining new viewpoints on history.

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## Investigating undergraduate nurse responses to simulated interruptions during medication administration — a qualitative multi-method study

Carolyn Hayes

Abstract of a thesis for a Doctorate of Philosophy submitted to University of Technology, Sydney

**Aim:** The aim of this thesis is to explore undergraduate nursing student responses to interrupted medication administration

and to facilitate new insights into interruption management strategies.



**Background:** Medication administration incidents and errors are a significant patient safety issue that often occur as a direct result of the inappropriate management of interruptions and distractions. Undergraduate nursing students are mostly taught how to administer medications in a calm and uninterrupted environment. In the clinical environment, however, they are faced with the reality of administering medications amidst competing demands and multiple interruptions. Improving patient safety requires realistic, innovative and creative methods of teaching medication administration to undergraduate nurses.

**Design:** A qualitative multi-method research study was undertaken within a large Australian university. This study was designed to elicit student responses to a simulated role-play that purposefully placed students in an interrupted and pressured environment. Participants included second-year undergraduate nursing students ( $n=528$ ) and nursing faculty ( $n=8$ ). Data were derived from: student written reflective responses ( $n=451$ ), student semi-structured individual interviews ( $n=13$ ), student feedback surveys ( $n=28$ ), and faculty email questionnaires ( $n=8$ ). Data were subject to thematic analysis.

**Findings:** Student participants reported that they had gained a new understanding of the impacts of interruptions while administering medications. Improved awareness of management strategies and an increased level of confidence was revealed. Students identified that the role they played was significant to their individual experience and learning from the simulation. Some

roles were reported to have contributed to increased levels of stress and others were reported to facilitate enhanced patient and team-member empathy. Students expressed a desire to experience more complex scenarios during simulation experiences to enhance in their preparation for real-world clinical practice. Students also described the positive impact the written reflective experience had on their ability to consolidate and integrate prior and new knowledge and skills. Data collected from nursing faculty supported the findings from the student participant data.

**Conclusion:** Study findings highlighted that student confidence and understanding the impact of interruptions during the medication administration process improve if they are given the opportunity to practice in realistic and safe settings. Empathy for both patients and other members of the nursing team can be enhanced as a result of immersive role-play experiences. Simulated experiences that incorporate system and process complexities, together with opportunities for extended reflection to facilitate deeper learning, show promise in developing proficiency.

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## True Tracks: Indigenous Culture and Intellectual Property principles for putting self-determination into practice

Terri Janke

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Australian National University, Canberra

The appropriation of Indigenous arts and knowledge is not adequately protected by Australian intellectual property laws. Indigenous Cultural and Intellectual Property (ICIP) rights include free, prior informed consent, integrity, attribution and benefit sharing. Appropriation of culture is demeaning but also steals economic opportunities from Indigenous people.

The main argument of the thesis is that the True Tracks ICIP provide a framework for negotiating rights between ICIP holders and users. Part one examines the issues in law and policy. Part two presents case studies from my published papers. The case studies cover performing arts; Indigenous arts; records management; film protocols; and traditional knowledge and biological materials.

This PhD research is an important contribution to understanding how Indigenous arts and knowledge is treated in the Australian legal system, in policy and practice. It outlines the issues and problems and then focuses on the 10-step True Tracks Framework, that can assist negotiations, planning and implementation of projects that include Indigenous cultural expression and knowledge.

Seven published papers are presented which collectively provide valuable lessons for ICIP. They are laid out in three parts — the concepts are detailed in Part 1, with the inclusion of two chapters on Indig-

enous cultural heritage and the applications of the law. Part 2 presents case studies for the relevant fields and industries where ICIP rights are being applied. Part 3 makes recommendations for change with a solid paper on governance and infrastructure, arguing for self-determination through a National Indigenous Cultural Authority. In effect, this structure can be used locally and regionally to assist communities deal with the issues. The publications provide extensive analyses derived from long-term research and practice as a lawyer over the past 25 years working with Indigenous people, organisations, companies and government.

Three chapters are entirely new content. The Introduction chapter and the history and contextual chapter set the background for the work that has been done in the past, both in terms of critical writing in the literature and the many responses, reviews and developments that have taken place over the past 40 years.

The concluding chapter brings together a cohesive framework. The True Tracks ICIP framework has a proven track record for dealing with ICIP. This framework can be used and adapted in various industries including technology, tourism and business. This approach can assist Indigenous people assert their ICIP rights with the necessary supporting infrastructure and governance. The demand is growing for Indigenous

knowledge and arts, so the True Tracks framework provides a framework to negotiate, plan, manage and implement projects that involve ICIP.

Furthermore, the True Tracks ICIP framework can inform new law. But most importantly, the framework addresses the deeper relationship between Indigenous and non-Indigenous people and the value they place on each other's knowledge systems. The framework is called "True Tracks" because it is about creating meaningful

relationships and connections; and keeping tracks into the future to enable Indigenous descendants to actively manage and practice and strengthen their cultural life.

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## Cryptic drivers of methane and carbon dioxide emissions from disturbed coastal wetlands

Luke C. Jeffrey

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Southern Cross University, Coffs Harbour, NSW

Coastal wetlands represent important biogeochemical hotspots for carbon cycling and greenhouse gas (GHG) production. Large uncertainties remain in both the global wetland GHG emissions budgets, due to spatial and temporal heterogeneity, insufficient global data and previously unknown sources. This thesis resolves some of the complexities surrounding key GHG emissions and drivers, from a range of disturbed coastal wetland ecosystems. By utilising novel methods, capturing high temporal and spatial resolution data, and uncovering

cryptic un-accounted for emissions pathways, this thesis represents an important contribution to the global carbon budgets from previously understudied southern hemisphere systems.

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## *Murruwaygu: Following in the footsteps of our ancestors*

Jonathan Jones

Abstract of a thesis for a Doctorate of Philosophy submitted to University of Technology, Sydney

This research considers one particular element of Koori artistic practice in south-east Australia — the unique and continuing use of the line by the region's male artists. Line-work is evident in a range of imagery, in various mediums, and throughout different generations. This study reveals the cultural importance and unbroken use of the line through changing social, political and cultural climates. The recognition of a continuing south-east aesthetic is significant, as the region has experienced prolonged colonisation, leading to a fragmentation of visual expressions and lack of art-historical research. In this context, the line represents the continuation of culture and the unbroken lineage of Koori knowledge.

This research is titled *Murruwaygu: following in the footsteps of our ancestors*. The Wiradjuri word “murruwaygu” refers to the designs carved onto trees and other cultural material unique to the south-east region: repeating lines, patterned chevrons and concentric squares, diamonds and rhomboids, with the inclusion of an occasional figure. Widely recognised as central to south-east identity, murruwaygu can be seen in artistic practices from pre-contact until today, establishing a clear cultural tradition that has endured massive change. This research charts this constant practice by investigating four distinct periods or generations. Referencing south-east kinship systems, each generation is represented by two artforms or artists.

Representing Mumala (grandfather) or first generation is pre-contact material — the carved and designed marga (parrying shield) and girran.girran (broad shield). The second or Babiin (father) generation features 19<sup>th</sup>-century Koori artists William Barak, a Wurundjeri man from the current Melbourne area, and Tommy McRae, from the upper Murray River near the contemporary border of NSW and Victoria. These artists documented their changing worlds with introduced materials like paper, pen and pencil, continuing line-work as a leading visual principle. The third or Wurrumany (son) generation focuses on self-taught senior Wiradjuri mission artists Uncle Roy Kennedy and the late HJ Wedge. Both use painting and printmaking that features line-work to document their life experiences of growing up on missions in NSW under segregation policies. Finally, the Warunarrung (grandson) generation is represented by professional and tertiary-educated contemporary Melbourne-based artists Reko Rennie (Kamilaroi) and Steaphan Paton (Gunai/Monero), who both work with new mediums while continuing line traditions.

Like these Koori artists, this thesis uses the line as its organising principle, both practically and metaphorically, to follow in the footsteps of our forefathers. Focusing on continuity and change, this research provides the first art-historical account of Koori men's art from pre-contact to today.

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## A creative study on data portraits: the visualisation process of self-surveillance as an indicator of datafication of social life

Ralph Kenke

Abstract of a thesis for a Doctorate of Philosophy in Design submitted to  
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This research is a practice-based speculative design enquiry into the emerging field of data portraiture. Humans' use of the networked digital environments that are now so much a part of life leaves a massive data trail of individuals' everyday interactions with these environments. An increasing quantity of this data trail remains invisible. Although we spend a significant amount of time participating in digital network activities, we have just started to discover the potential of visualising personal data as a graphical representation. The term "data portraiture" was developed by Donath (2014) to describe the practice of "artists" turning these data "pictures" into visible "portraits:" "Data portraits are depictions of people made by visualising data by and about them" and "their aim is to humanize the online experience" (187). Data portraits can reveal individuals' preferences, skills and talent, yet also record their mistakes, failure and history.

As a consequence, data portraits can indicate society's collective engagement in

self-surveillance and empower the public to debate the current datafication of social life. Data portraits can appear in different forms; some are graphs, while others are typographic displays that reveal recorded conversations, and some even take a sculptural figurative shape. These data trails can shape depictions of online behaviour, experiences and interests. Traditionally, "pictures" that depict individuals' physical likeness and infer their behaviour, experiences and interests are labelled "portraits" and created by artists. Network technology enables humans to share personal data on a large scale, thereby facilitating a global dialogue in a telematic society. This research into the emerging field of data portraiture seeks to understand the role of the "artist" as creative practitioner in interpreting qualitative data into image experiences, and to offer insights into the behaviour and interests of individuals engaging with such work. Through a number design iterations, this research investigates a potential visual format by initially using manually collected

quantitative data, before shifting to an automated process to record qualitative photography data of selfies shared on Instagram to successfully demonstrate what a “global image scenario” in a gallery has to offer.

Further, it reveals the importance of participant contribution to the “datafication” of social life and the emergence of “surveillance capitalism.” This study’s original contribution to knowledge focuses on the continuum of aesthetics and functionality, and,

throughout the implementation of prototyping, the exegesis reflects on the research’s case study and provides knowledge to the emerging field and design practice.

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## **Big Gubba Business: The making of the United Nations Declaration of the Rights of Indigenous Peoples, First Nations resurgence and the Australian connection**

Graeme Lyle La Macchia

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Australian Catholic University, Sydney

**I**ncorporating a significant component of Yarning-based oral history, Big Gubba Business investigates the making of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) from an Aboriginal Australian standpoint. This study examines the dynamics of the global Indigenous resurgence and interrogates the evolution of the Indigenous/UN relationship. First Nations engagement with the UN system and participation at the 1993 UN World Conference on Human Rights are explored in detail. Big Gubba Business also unravels the ongoing self-determination debate and the rise of the CANZUS bloc of resistant States. Having established the

political context and surveyed the cultural landscape, this study identifies and analyses the actions and achievements of Indigenous Australian representatives in the drafting, elaboration and eventual adoption of the UN Declaration on the Rights of Indigenous Peoples. Big Gubba Business finds that the principal value of the Declaration derives from its role as a rallying point and common cause for First Nations activists and theorists. The legacy of the Declaration project includes the building and embedding of a worldwide network of Indigenous organizations and an enhanced First Peoples political and intellectual presence on the world stage. It is hoped that Big Gubba Business



will serve to direct academic attention to this neglected domain of political activity and inform a wider public of the nature and importance of the Indigenous/UN relationship.

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## The impact of anthropogenic stressors on coral reef carbonate sediment metabolism and dissolution

Coulson Lantz

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Southern Cross University, Coffs Harbour, NSW

The balance in coral reef carbonate sediment metabolism may shift in response to global warming, ocean acidification (OA), and coastal eutrophication. To address this concern, this PhD thesis experimentally tested the individual and combined effects of these stressors on coral reef carbonate sediment metabolism and dissolution. The data produced show that warming and OA will be major drivers of carbonate sediment dissolution, while the effects of

coastal eutrophication will likely depend on the severity and duration of exposure. Altogether, these stressors will likely begin facilitating a net loss of carbonate sediment on coral cays by the end of the century.

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## The impact of detection of respiratory viruses on at-risk patient populations

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Abstract of a thesis for a Doctorate of Philosophy submitted to University of Technology, Sydney

Respiratory viruses are ubiquitous and are known to cause acute disease in otherwise healthy individuals and may be associated with severe morbidity and mortality in those with underlying chronic diseases. However, respiratory viruses do not always result in disease. The frequency and implications of asymptomatic carriage within at-risk patient populations remain poorly understood.

This thesis explores the development of a novel methodology for detection of respiratory viruses utilising exhaled breath captured in electret filter, using PCR-based detection. Evaluation of this methodology in different clinical cohorts was carried out, specifically exploring rates of asymptomatic detection in patients with bronchiectasis during stable phases and in patients intubated in the ICU, looking within the filter contained in the ventilator circuit. Finally, demonstration of the dynamics of the human respiratory virome in a cohort of patients undergoing lung transplantation, utilising the previously confirmed methodologies, completed this body of work.

The exhaled breath methodology was tested in the two clinical cohorts described above and demonstrated detection of both upper and lower respiratory tract viruses. Results correlated well with traditional

sampling methods. The major finding from these studies was the high rate of detection of respiratory viruses in the absence of symptoms and signs suggestive of acute respiratory infection.

Examination of the prospective lung transplant cohort also confirmed a significant rate of asymptomatic viral carriage and provided new insights into the dynamics of the respiratory virome. This project provides evidence that viruses are transplanted within the donor lung and remain detectable for many months after transplantation. There was no evidence, however, that detection of virus correlated with concurrent acute cellular rejection.

Taken together, these studies have allowed development of a novel clinical viral sampling methodology which may have important clinical and diagnostic ramifications. Ultimately, they have enhanced our understanding of asymptomatic viral infection. As well, the role of community-acquired respiratory viruses as transient members of the human respiratory virome has now been revealed for the first time.

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## Pulp Jungle Down Under: Horwitz Publications and the rise of the Australian paperback, 1945–1972

Andrew Nette

Abstract of a thesis for a Doctorate of Philosophy submitted to Macquarie University, Sydney

“Pulp Jungle Down Under” examines the largely unexplored field of mid-century Australian pulp fiction through a study of the now defunct Sydney-based publisher, Horwitz Publications. The dissertation covers the period from 1945, when the company published its first pulp fiction, to 1972 and the election of the reformist Labor federal government, which resulted in the removal of the last vestiges of Australia’s post-war censorship system, closing a historical period in which pulp had the ability to shock. Although best known for its cheaply produced, often lurid, softcover books, Horwitz Publications played a far larger role in mainstream Australian publishing than has been recognised, particularly in the expansion of the paperback from the late 1950s onwards. As this dissertation demonstrates, the company was adept at seeking out and exploiting the porous spaces that existed, sometimes only temporarily, between pulp and mainstream publishing: where mainstream literary forms were reconfigured to suit more sensational tastes, authorial reputation was fluid, and government regulation failed to keep pace with shifting reading tastes and social mores. Its dealings were

transnational, moving beyond London, the traditional focus of Australian overseas publishing efforts for much of the last century, to directly encompass the United States and other fiction markets. Horwitz Publications provides an Australian articulation of global pulp culture, continually mining international literary and publishing fashions and successes to create local analogues of popular pulp and mass-market publishing genres, giving them a makeover to align them with Australian cultural sensibilities, tastes, and the legislative environment. This dissertation also examines how Horwitz pulp paperbacks acted as a local conduit for vernacular modernist currents; the way they channelled modern thoughts, sensations and experiences, often in conversation with other parts of the globe, and the interaction of these with changing notions of culture, class and gender relations in Australia.

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## The role of cyclin F in Motor Neurone Disease

Stephanie L. Rayner

Abstract of a thesis for a Doctorate of Philosophy submitted to Macquarie University, Sydney

**M**otor Neurone Disease (MND) is characterised by the loss of motor neurons in the brain and spinal cord. Most patients with MND develop proteinaceous inclusions within affected neurons of the central nervous system, suggesting overall dysregulation of protein degradation systems. Our team identified mutations in *CCNF*, the gene encoding cyclin F. Cyclin F is a substrate binding component of a multi-protein ubiquitin ligase (denoted SCF<sup>cyclin F</sup>), which mediates the ubiquitylation of substrates in order to influence the cell cycle.

Overarching aims of this thesis concern the impact of *CCNF* mutations on the ubiquitin ligase activity of SCF<sup>cyclin F</sup> and the downstream impact within cells. Addressing these aims involved using a series of biochemical assays (including *in vitro* ubiquitylation assays, immunoprecipitations, proximity-ligation assays and mass

spectrometry). Results demonstrate that an MND-linked mutation in cyclin F leads to defective ubiquitylation activity, ultimately leading to the accumulation of proteins tagged for degradation.

Overall, the work provides insight into how the precise control of cyclin F ligase activity is dysregulated when cyclin F carries a disease-causing mutation. Furthermore, outcomes from this work provide novel links between cyclin F (a cell cycle regulator) and a devastating disease involving the degeneration of post-mitotic neurons.

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## Belief change without compactness

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**O**ne of the main goals of Artificial Intelligence (AI) is to build rational agents that are capable of taking rational decisions autonomously. For this, it is essential to devise mechanisms to properly represent

knowledge, and reason about the knowledge that an agent has about the world. However, an agent's knowledge is not static — it gets updated as the agent acquires new information. One of the big challenges involving

knowledge representation is how an agent ought to change its own knowledge and beliefs in response to any new information it acquires. This, in short, is the problem of belief change.

Standard approaches of Belief Change come in two flavours: a set of rationality postulates that prescribes epistemic behaviours for an agent, and a collection of constructions, or functions, to perform such rational changes. The two foremost paradigms of Belief Change are the AGM paradigm (for belief change in a static environment) and the KM paradigm (for belief change in a dynamic environment). Both these paradigms make strong assumptions about the underlying logic used to express an agent beliefs, such as Supraclassicality and Compactness. Relying on these assumptions, however, is rather restrictive, since many logics that are important for both AI and Computer Science applications do not have them. This thesis focuses on extending Belief Change to the realm of non-compact logics.

One of the side effects of dispensing with compactness is that standard constructions of both the AGM and the KM paradigms no longer nicely connect with the respective rationality postulates. In this work, I identify the reasons behind this breakdown. This in turn helps us identify some minimal conditions under which the existence of rational AGM and KM belief change operations is guaranteed. Subsequently we provide constructive accounts of AGM- and

KM-rational belief change operations without the compactness assumption, and we offer full accounts of belief change for both the paradigms. The main difference of our approach from the standard ones relies on the way epistemic preference of an agent is represented: instead of remainders and Grove's Systems of Spheres, we consider maximal complete theories and genuine partial relations over worlds.

Furthermore, we also consider the connection between AGM revision and non-monotonic reasoning (NMR) systems, often viewed to be two sides of the same coin. We demonstrate that the bridge between belief revision and NMR breaks down in the absence of compactness. We then identify the basis of this breakdown, and present a new non-monotonic system that appropriately connects with the AGM revision postulates even in absence of compactness. Significantly, this connection with the AGM paradigm is independent of any specific constructions (such as systems of spheres), and is directly established between the AGM postulates and the axioms of the proposed non-monotonic system.

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## Coral reef sediment dissolution in a changing ocean: insights from a temporal field study

Laura Stoltenberg

Abstract of a thesis for a Doctorate of Philosophy submitted to  
Southern Cross University, Coffs Harbour, NSW

Calcium carbonate sediments form an essential part of coral reefs yet have often been overlooked when studying the effects of future ocean acidification (OA). This original field-based research aims to assess the temporal variability of organic and inorganic sediment metabolism under ambient and elevated  $p\text{CO}_2$ . OA caused a shift from net precipitation to net dissolution, but the sensitivity to OA varied seasonally, depending on interactions with temperature and benthic productivity. A

slack-water approach of net ecosystem calcification revealed that sediments can play an important role in carbonate budgets, particularly at night, and become increasingly important as the oceans continue acidifying.

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## Diamonds — time capsules of volatiles and the key to dynamic Earth evolution

Suzette Timmerman

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The Earth consists of a core, mantle, crust, and atmosphere. Noble gas analyses of basaltic rocks indicate that the present-day structure of the Earth comprises a slightly degassed lower mantle and highly degassed upper mantle. The extent and timing of mantle in- and out-gassing and sources of volatiles are, however, not well-constrained and require quantification for development

of a high-resolution model of the structure of the Earth's mantle and its evolution to a differentiated state. Noble gas data for the Earth's mantle are still almost exclusively limited to two temporal end-members: i) the present-day mantle, with compositions from modern basalt glasses, and ii) the undifferentiated primordial Earth at 4.6 Ga, with data from extra-terrestrial samples



and nuclear synthesis models. Further, the noble gas compositions of important reservoirs — the deep mantle, (subducted) oceanic crust and sub-continental lithospheric mantle (SCLM) — are not well established.

The objective of this thesis is to address the noble gas composition (with a focus on helium) of these reservoirs through a study of diamonds from the Southern Hemisphere (Brazil, DRC Congo, Southern Africa, Australia). Diamonds form at depths of ~120–800 km and cover most of the history of Earth with ages of 3.5 to 0.05 Ga. Diamonds, being chemically inert, can preserve information on the fluid and mantle composition at the time of diamond formation. Specific objectives are to explore the potential of U-Th/He systematics for dating fibrous diamonds, the influence of volatile subduction on the heterogeneity in the SCLM, and how helium isotopic compositions have evolved over time in the SCLM.

Fibrous diamonds are generally assumed to have formed shortly before the kimberlite (volcanic) eruption but there is currently no way to date these diamonds. The U-Th-Sm/He systematics of fibrous Congo and Jwaneng diamonds showed that in most cases U-Th/He ratios are sufficiently high to produce significant radiogenic  $^4\text{He}$  to provide age constraints, and some fibrous diamonds are up to several 100 Myr older than the kimberlite eruption age.

High-density fluid (HDF) inclusions with different major element compositions found in South African fibrous diamonds have different noble gas compositions that show these fluids originated from subducted sediments and oceanic crust and had either limited interaction with the SCLM (silicic-low Mg carbonatitic fluids) or significant

interaction with the SCLM (saline fluids). A positive correlation between  $^3\text{He}/^4\text{He}$  and  $\delta^{13}\text{C}$  values in lithospheric (150–190 km depth) diamonds from Argyle (Australia), together with low  $^{40}\text{Ar}/^{36}\text{Ar}$  and He/Ne isotopic compositions, demonstrates a subduction influence caused by high U-Th/ $^3\text{He}$  ratios and thus low  $^3\text{He}/^4\text{He}$  ratios in subducted organic material. A noble gas depth profile of these diamonds shows fluid-rock interaction over scales of at least 15 kilometres above the accreted subducted material. Superdeep Brazilian diamonds from the transition zone (410–660 km depth), in contrast, show a negative correlation between  $^3\text{He}/^4\text{He}$  and  $\delta^{13}\text{C}$  values.  $^3\text{He}/^4\text{He}$  ratios are decoupled from trace elements and Pb-Sr isotope systematics that have characteristics of subducted material. This indicates that the deeply subducted sediments have been deprived of U-Th-He and a high  $^3\text{He}/^4\text{He}$  source, located in the deep mantle (>410 km depth), is dominating the helium budget.

Previously dated monocrystalline diamonds (with multiple ages ranging from 0.07 to ~3.4 Ga) were analysed for trace elements and He-Ar isotopic compositions and, after correcting for radiogenic ingrowth since diamond formation, a large variation remains in  $^3\text{He}/^4\text{He}$  values at ~1.0 Ga that can be explained by mixing between mantle and subducted components. Given the preservation of heterogeneities, it is difficult to develop a simple noble gas evolution curve for the SCLM. From examination of fibrous and monocrystalline diamonds from different formation depths, formation ages, and geographic locations this study showed the large influence of subduction at the base of the lithosphere and a more SCLM-like noble gas composition at shallower depths. The addition of U-Th by subducted sediments

could result in lower  $^3\text{He}/^4\text{He}$  ratios in the SCLM compared to the upper mantle.

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## Managerial quality, firm performance, technical efficiency and productivity in New Zealand

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The objective of this thesis is to investigate the effect of managerial quality and business environment on the ownership–performance, technical efficiency and productivity nexus of firms in New Zealand (NZ). Despite the growing number of theoretical and empirical studies examining the determinants of firm performance and productivity, managerial quality has traditionally been ignored. Since the global financial crisis, there has been renewed interest in investigating the factors influencing firm performance and productivity growth to enable managers to position their firms to be competitive in the growing and unpredictable global marketplace. Leibenstein's x-efficiency theory provides a sound theoretical basis for incorporating the role of managerial quality into modelling technical efficiency, productivity and firm performance. This thesis is the first attempt

to extend the traditional model of efficiency, productivity and firm performance by incorporating managerial quality using Leibenstein's x-efficiency framework to explain NZ's underperformance, despite its policies and institutional quality being close to or at best practice under Organisation for Economic Co-operation and Development (OECD) guidelines. To achieve the objectives and provide sound policy recommendations, three empirical studies were conducted to present new empirical evidence in the NZ context.

The first study used a meta-analytical framework to examine the effects of managerial quality on the ownership structure–firm performance nexus in OECD countries. A meta-analysis of data from 46 studies on OECD countries found that heterogeneity in the effects of ownership structure on firm performance may be explained by variations

in managerial quality in different ownership and country contexts. The results indicate that 91% of the 99% between-study variation in effect sizes of the ownership–performance relationship was attributable to differences in the quality of manager-related efforts. Methodological heterogeneity — related to differences in estimation techniques and measurements — explained only 1.29%, of which no more than 0.8% was caused by sampling error. This finding highlights the importance of accounting for the influence of managerial quality on firm performance in specific ownership and country contexts.

The second study investigated the effects of managerial quality on technical efficiency and firm productivity in NZ from the perspective of *x*-efficiency theory using stochastic frontier modelling and a longitudinal microdata set (2001–2012) from NZ. The results suggest that, on average, management is operating at a point well below the estimated *x*-efficient frontier in NZ. The rate of total factor productivity (TFP) growth for firms may have been double had managerial quality been more *x*-efficient and conformed to better practice frontier growth. Improvements in managerial quality may also enhance the rate of change in efficiency and technology, leading to greater TFP growth. These results stress the need to incorporate managerial quality as a determinant of TFP growth in productivity estimates to better explain NZ's productivity underperformance.

The third study utilised NZ longitudinal microdata to explore the moderating role of exogenous business environment determinants of technical efficiency on the managerial quality–TFP nexus in NZ. The empirical results indicate that improved external factors (industry competition, internation-

alisation and tariff trade liberalisation) did not enhance productivity growth as much as they should have because of managerial inefficiency. Closing this inefficiency gap by improving management quality may correct the underuse of resources by NZ firms by 40% and reduce NZ's 35 percentage point productivity gap relative to the simple average of the highest 17 OECD countries by up to 28 percentage points. Further, if managerial quality had been more *x*-efficient under conditions of improved external business factors, the rate of TFP growth could have been approximately 20% above the OECD average as predicted by the OECD framework.

This thesis makes three major contributions. First, the empirical findings provide new evidence to show that systematic variations in managerial quality under different ownership structures are key drivers of firm performance by affecting *x*-efficiency. This result helps to clarify the determinants of measured differences in firm performance across studies and countries. Second, using a frontier–counterfactual *x*-efficiency approach and comprehensive micro-level data from NZ, this thesis shows that managerial quality contributes to *x*-inefficiency, thus influencing technical efficiency change and productivity performance in NZ. Third, by accounting for the external business environment, this thesis provides insights into how managerial quality may explain NZ's *x*-inefficiency and productivity underperformance. The overall policy implication is the need for government intervention in the marketplace to create a vibrant business environment and establish frameworks for monitoring and developing managerial quality to enhance firms' technical efficiency, productivity and performance in NZ.

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## Obituary: Richard Limon Stanton AO FAA DistFRSN

16 February 1926–25 August 2020

Richard (Dick) Limon Stanton AO FAA DistFRSN (1926–2020), was Professor of Geology at UNE from 1975 to 1986. Born in Sydney on 16 February 1926, Professor Stanton died in Canberra at the age of 94 on 25 August 2020.<sup>1</sup>

He was appointed as one of 14 Fellows of the Royal Society of New South Wales when Fellowships were first created in 2010. Professor Stanton received this honour from the then Governor-General, Her Excellency Ms Quentin Bryce AC, at Admiralty House, Sydney, on 29 March 2010.

Ms Bryce outlined Professor Stanton's major discoveries about the formation and structure of metallic ore deposits. "He recognised the role of volcanism and sedimentation in the formation of new ore deposits, and the physics and chemistry involved in the concentration of copper, zinc and lead in volcanic lavas," she said. She added that this work was "documented in his numerous publications and books," which include *Ore Petrology* (1972) and *The Precursor Principle* (1989). His book *Ore Elements in Arc Lavas*, published in 1994, represents the culmination of 40 years of research on the ore deposits resulting from volcanic activity along island arcs such as the Indonesian archipelago. He also did some very important early work on so-called conformable lead (Pb) deposits, which set the stage for dating the age of the Earth. He predicted that Broken Hill-type ore deposits (of copper, zinc, and

lead) were likely forming in hydrothermal vents on the modern sea floor.

As an undergraduate, Dick Stanton studied geology and mathematics at Sydney University's New England University College in Armidale in the 1940s. During his undergraduate years he learnt to appreciate the elegance of science. In one class there was a mathematics problem that none of the students could solve. At the beginning of the next class Dick asked the lecturer whether he would work through the problem on the board — which he did, attacking it in a way that Dick had never thought of, so that the answer just dropped out. After completing this most elegant solution, the lecturer turned to the class and said, "Isn't that beautiful?" Dick remembered thinking to himself, "Yes, it is beautiful." In his future career Dick Stanton achieved some beautiful solutions to problems in ore genesis.

He worked as an exploration geologist for Broken Hill South Ltd, in mines in Broken Hill, far north Queensland and Burruga. This was the start of Dick's most important contribution to economic geology: the theory that massive sulphide deposits of zinc, lead and copper form on the seafloor associated with volcanism in regional volcanic island arc settings.

Dick quickly realised that on a larger scale than Burruga, the old mines and workings south of Bathurst occurred in a distinct pattern related to the geological features of the area: a particular association of volcanic rocks, shales and coralline reef limestones. Subsequently this became the topic of his PhD at the University of Sydney, started in

<sup>1</sup> I'm indebted to Don Hector FRSN and Professors Hugh O'Neill at ANU and Ross Large at Tasmania for information in this obituary. [Ed.]

1950 and completed in early 1954. In summary, the key finding from Dick's thesis was that, over a very large area, the massive sulphide deposits occurred in sedimentary rocks that had been laid down on the seaward side of little coral reefs that had developed round old volcanic islands. He published his research in 1955 in *Economic Geology*, resulting in diverse reactions from the economic geology community, either "brilliant" or "mad."

During his studies, he had been involved in the first systematic geological mapping of the Solomon Islands, for the British Geological Survey, as a Lecturer in Geology at the University of Sydney. He told of being dropped off on a beach of an island inhabited solely by locals by an inter-island steamer, and told to be back on the beach in six weeks to be picked up.

On completing his PhD, Dick took up a National Research Council of Canada two-year post-doctorate fellowship at Queen's University, Ontario, which gave him the opportunity to study some of the recently discovered massive copper and zinc sulphides in New Brunswick, in a district coincidentally with the name of the Bathurst camp. Dick was amazed by the similarities in the geology and style of mineralisation between the two Bathursts. This subsequently led to three publications in Canadian journals in 1960 and 1961, which had a major impact on massive sulphide mineral exploration in Canada. The last of these papers, laid out the model for massive sulphide mineralisation and the key parameters for their exploration. By this time Dick had gained an international reputation for his work, both in academia and the exploration industry.

He returned to Armidale in 1959, having been invited to take up a position as Senior

Lecturer in Economic Geology at the University — by then the autonomous University of New England — where he spent 29 years contributing very significant research in a number of aspects of ore deposit genesis. Probably his best recognised achievement in this period was his 1972 book *Ore Petrology*. This was the first publication to consider ore deposits as a natural part of geological evolution and to recognise that classes of deposits were controlled by their geological environment. The book was an immediate success: over 18,000 copies were sold world-wide. It became the basic text on ore deposits in most western universities for over 30 years.

During this time, Dick was constantly drawn back to Broken Hill, to study the ores, banded iron formations and host rock sillimanite schists. He supervised an excellent PhD thesis by Max Richards on the significance of the banded iron formations in the Broken Hill district, later published in *Economic Geology*. The most influential and helpful connection he established was with Haddon King, director of exploration and research with Zinc Corporation at Broken Hill and, ultimately, CRA. King was an international figure, very well-known and respected, and had an excellent research group which Dick worked with on understanding Broken Hill geology. King was the father of the syngenetic ore theory for Broken Hill, and thus together they had mutual interests and stimulating discussions. In the 1980s Dick became interested in the origin of the mineralogical banding in the banded iron formations and the sillimanite schists at Broken Hill, which led to him questioning the basis of regional metamorphism. The *precursor principal* that he published in 1989 demonstrated the impor-



tance of original composition and mineralogy on later metamorphic mineralogy and that iso-chemical metamorphism, involving little fluid, was a key process at Broken Hill.

After retiring from his personal chair at UNE in 1986, he maintained his connection with the University as Emeritus Professor. During his time at UNE he had taken sabbaticals to Harvard (1966–67) and Oxford (1978–80). Professor Stanton had been a Royal Society Bursar at Imperial College London and the University of Durham in 1964, Hoffman Research Fellow at Harvard in 1966–67, and British Council Visitor in the Department of Geology, Oxford, in 1978–80.

He was elected to the Australian Academy of Science in 1975 and was Vice-President of the Academy from 1989 to 1990. Professor Stanton's many awards include a Fulbright Award (1966), the Inaugural President's Award of the Australasian Institute of Mining and Metallurgy (1974), the Goldfields Gold Medal of the Institute of Mining and Metallurgy, London (1976), the William Smith Medal of the Geological Society, London (1987), the Browne Medal of the Geological Society of Australia (1990), the Penrose Medal of the Society of Economic Geologists (1993), the Haddon Forrester King Medal of the Australian Academy of Sciences (1998). He became an Honorary Fellow of the Institute of Mining and Metallurgy (London) in 1984 and was elected as an Honorary Fellow of the Geological Society of America in 1991. In 1993 he was one of UNE's Inaugural Distinguished Alumni.

As a teenager, he had been struck down by polio, which ended his swimming career. He married Alison Meyers (dec.), and they had three children (Ruth, Marion, and Richard Roger, dec.) and six grandchildren. He

was an avid gardener and tree planter at his house in Armidale: "I have farming in my blood." At 84 years of age Professor Stanton was still as active as ever in research. "In fact, I'm now involved in the most complex piece of work I've ever undertaken," he said in 2010. These projects included collaborative work with one of his former UNE research students — Ross Large, Professor of Geology at the University of Tasmania — and with Professor Hugh O'Neill at the ANU's Research School of Earth Sciences.

Professor Stanton joined the Royal Society of NSW on 27 July 1949 and was one of its longest standing members. During his career, he received several awards from the Royal Society, including the Archibald D. Ollé Prize in 1956,<sup>2</sup> the Society's Medal in 1973, and the Clarke Medal in 1998; he had presented the Clarke Memorial Lecture in 1985. He was made a Fellow of the Society in 2010 and was elevated to Distinguished Fellowship in 2012.<sup>3</sup> Moreover, he was instrumental in its successful operation and served as a long-standing chair, of the New England Branch of the Society. He was honoured for his achievements by becoming an Officer of the Order of Australia in 1996.<sup>4</sup>

— Robert E. Marks, Editor

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2 In 1955 Stanton published two papers in this journal: Stanton (1955a) and Stanton (1955b); it is not clear which was the prize-winning paper.

3 When the membership grade of Fellow was created in 2012, the existing 14 Fellows were elevated to Distinguished Fellowship.

4 In 2008 he was interviewed at length by Ken Campbell. See <https://www.science.org.au/learning/general-audience/history/interviews-australian-scientists/professor-richard-stanton>

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## Proceedings of the Royal Society of New South Wales The 2020 programme of events — Sydney

Date	Type and location	Presenter(s)	Topic
Wed 12 Feb	1280 <sup>th</sup> Ordinary General Meeting and Open Lecture  2019 RSNSW Scholarship Presentation  (Gallery Room, State Library of NSW, Shakespeare Place, Sydney)	Ms Emma Austin, University of Newcastle  Mr Shyam Balaji, University of Sydney  Mr Michael Papanicolao, University of Technology Sydney  Mr Thomas Pettit, University of Technology Sydney	Drought and wellbeing in Australian rural communities: implications for improving adaptive capacity and resilience to drought  Searches for Extended Higgs Sectors, Flavour Physics Anomalies and Dark Matter at the LHC  Charting the Extracellular Matrix Through Breast Tumour Progression  Botanical biofilters for the phytofiltration of urban air pollutants
Thu 20 Feb	Royal Society of NSW Liversidge Lecture  (The Galleries, John Niland Scientia Building, UNSW Sydney, Kensington)	Scientia Professor Martina Stenzel FAA, UNSW Sydney	The journey from simple polymers to nano-footballs: opportunities for better cancer treatment
Thu 27 Feb	SMSA/RSNSW joint presentation  (Sydney Mechanics' School of Arts, 280 Pitt Street, Sydney)	Dr David Hush and Anna Da Silva Chen (violinist)	Speaking the Music ... The Magic of the Solo Violin

JOURNAL & PROCEEDINGS OF THE ROYAL SOCIETY OF NEW SOUTH WALES  
 Proceedings, Awards, Gazetted Fellows — 2020

Date	Type and location	Presenter(s)	Topic
Wed 4 Mar	128 <sup>th</sup> OGM and Open Lecture  (Gallery Room, State Library of NSW, Shakespeare Place, Sydney)	Professor Robin J. Batterham, University of Melbourne	Soils: the least understood part of science, yet vital for all of us
Fri 6 Mar	Frontiers of Science Forum (presented by the Royal Society of NSW, the Teachers' Guild of NSW, the Australian Institute of Physics, and the Royal Australian Chemical Institute)  (Boston University (Sydney), 15–25 Regent Street, Chippendale)	Professor Ben Eggleton FRSN FAA FTSE, University of Sydney  Professor Mary Myerscough, University of Sydney  Ms Julianna Kadar, Macquarie University  Professor Richard Payne, University of Sydney	New frontiers in photonics — the science of light  The mathematics of healthy honeybee hives  Fitbits for sharks: combining biology and data science  Drug discovery inspired by natural products
Thu 12 Mar	Annual Meeting of the Four Societies (presented by the Australian Institute of Energy, the Australian Nuclear Association, the Sydney Division of Engineers Australia, and the Royal Society of NSW)  (Metcalf Auditorium, State Library of NSW, Macquarie Street, Sydney)	Professor Thomas Maschmeyer FRSN FAA FTSE FMAE, University of Sydney	Challenges for the Future: Energy Storage and Waste Plastic — Two Australian solutions going global
Wed 22 Apr	153 <sup>rd</sup> Annual General Meeting 1282 <sup>nd</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Emeritus Professor Ian Sloan AO FRSN FAA, President, Royal Society of NSW	Presidential Reflections — science stuff and the President's random path

JOURNAL & PROCEEDINGS OF THE ROYAL SOCIETY OF NEW SOUTH WALES  
 Proceedings, Awards, Gazetted Fellows — 2020

Date	Type and location	Presenter(s)	Topic
Thu 21 May	Ideas@theHouse: May 2020  (Zoom Webinar)	Emeritus Professor Robert Clancy AM FRSN, University of Newcastle and the Royal Society of NSW	Ten: The Mapping of Colonial Australia
Wed 3 Jun	1283 <sup>rd</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Distinguished Professor Elizabeth Elliott AM FRSN FAHMS, University of Sydney	Drinking for three: Mother, baby, and society
Wed 27 Jun	Virtual Annual Dinner, Distinguished Fellow's Lecture and 199 <sup>th</sup> Anniversary  (Zoom Webinar)	Distinguished Professor Brian Schmidt AC FRS DistFRSN FAA, Australian National University	Education and Evidence in a Post-Truth, Post-COVID World
Wed 8 Jul	1284 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Elizabeth Ann Macgregor OBE FRSN, Museum of Contemporary Art, Sydney	Why Art Matters in Times of Crisis
Wed 5 Aug	1285 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Professor Peter Radoll, University of Canberra	Growing Black Tall Poppies
Tue 18 Aug	Science Week Lectures  (Zoom Webinar)	Emeritus Professor Robert Clancy AM FRSN, Royal Society of NSW and University of Newcastle	The COVID Curve in Context: or Back to the Future — something old and some new
Wed 19 Aug	The Clancy Collection — an Exhibition of Maps  (Manly Art Gallery and Museum, Sydney)	Emeritus Professor Robert Clancy AM FRSN, Royal Society of NSW	Charting a Course: a 500-year story of discovery and development of Sydney
Thu 20 Aug	Science Week Lectures  (Zoom Webinar)	Emeritus Professor Brynn Hibbert, Royal Society of NSW and UNSW Sydney	The Periodic Table: a medley of haphazard facts falling into line and order

JOURNAL & PROCEEDINGS OF THE ROYAL SOCIETY OF NEW SOUTH WALES  
 Proceedings, Awards, Gazetted Fellows — 2020

Date	Type and location	Presenter(s)	Topic
Wed 2 Sep	1286 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Professor John Rasko AO, Centenary Institute	The Dawn of Molecular Medicine — Gene Therapy: Past, Present and Future
Wed 7 Oct	1287 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Professor Huw Price FAHA FBA, University of Cambridge	Where now for the study of time?
Wed 14 Oct	The Clancy Collection — an Exhibition of Maps (repeated)  (Manly Art Gallery and Museum, Sydney)	Emeritus Professor Robert Clancy AM FRSN, Royal Society of NSW	Charting a Course: a 500-year story of discovery and development of Sydney
Thu 5 Nov	RSNSW and Four Academies Forum  (Government House, Sydney, livestreaming, and subsequent availability on YouTube)	Hosted by Her Excellency The Honourable Margaret Beazley AC QC, Governor of NSW and Patron of the Royal Society of NSW	After COVID-19: Creating the Best of Times from the Worst of Times
Wed 11 Nov	1288 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Emeritus Professor Adrian Lee FRSN and Professor Thomas Borody FRSN, UNSW Sydney and Centre for Digestive Diseases	Where have all the ulcers gone, long time passing?
Wed 9 Dec	1289 <sup>th</sup> Ordinary General Meeting and Open Lecture  (Zoom Webinar)	Scientia Professor Matthew England FRSN FAA, UNSW Sydney	Dispelling climate change myths — how ocean physics can help explain surprises in the modern-day climate record



## The 2020 programme of events — Southern Highlands

Date	Presenter(s)	Topic and location
Thu 20 Feb	Professor John Thompson AO Melanoma Institute and University of Sydney	Controlling the Australian Melanoma Epidemic (Face-to-face in Mittagong, NSW)
Thu 19 Mar	Professor John Williams FTSE Australian National University and Charles Sturt University	The Murray-Darling Basin Scheme: a challenge in complexity in balancing social, economic and environmental perspectives (Via email circulation)
Thu 21 May	Associate Professor Andrew Holmes University of Sydney, Life and Environmental Sciences	The Microbiome and Gut-Brain Axis (Via email circulation)
Thu 18 Jun	Professor Geordie Williamson University of Sydney	Light, sound, and the magic of the Fourier Transform (Via email circulation)
Thu 20 Jul	Dr Brad Tucker Australian National University	Exploding Stars, Dark Energy, and the end of the Universe (Via email circulation)
Thu 20 Aug	Professor Toby Walsh UNSW Sydney and CSIRO Data61	2062 — The year that Artificial Intelligence (AI) made (Via email circulation)
Thu 17 Sep	Adjunct Professor Sandra Lynch University of Notre Dame Australia	Philosophical Ethics in Schools: Plan and Paradox (Zoom Webinar and YouTube)
Thu 15 Oct	Susannah Fullerton OAM FRSN Literary Lecturer and President, Jane Austen Society of Australia	Literary England: Susannah's Top Ten Places (Via email circulation and YouTube)
Thu 18 Nov	Ian Bryce MRSN	Relativity revealed: Einstein's discoveries, the origin and shape of the universe (Mittagong RSL, Carrington Room)

### The 2020 programme of events — Hunter Branch

Date	Presenter(s)	Topic and location
Fri 31 Jan	Professor Ryan Loxton, Curtin University	Mathematics in Industry: Optimisation in Action — Unlocking Value in the Mining, Energy, and Agriculture Industries (Newcastle City Hall (Hunter Room), 290 King Street, Newcastle)
Wed 27 May	Emeritus Professor Eugenie Lumbers AM DistFRSN FAA, University of Newcastle	COVID-19 and confusion: the story of a nasty but nice viral receptor (Zoom Webinar)
Wed 29 Jul	Professor Pia Ednie-Brown, University of Newcastle	Architecture and the Cultivation of Vitality (Zoom Webinar)
Tue 27 Oct	Professor Janet Nelson, Deputy Vice-Chancellor (Research), University of Newcastle	The Engaged University: Advancing Research and Innovation Through Powerful Partnerships (jointly with the University of Newcastle) (Zoom Webinar)
Wed 2 Dec	Professor Tony Capon, Monash University	Planetary Health: Safeguarding Health in the Anthropocene Epoch (Zoom Webinar)

## Awards 2020

### **James Cook Medal 2020 — Scientia Professor Richard Bryant AC FASSA FAA FAHMS**

The James Cook Medal is awarded from time to time for outstanding contributions to both science and human welfare, in and for the Southern Hemisphere.

**Professor Richard Bryant**, of the School of Psychology of UNSW (Sydney), has made many seminal advances in the diagnosis, treatment, and identification of neural, genetic, and cognitive markers of post-traumatic psychopathology. His work has challenged the pre-existing notions of acute psychological response to trauma leading to major policy and practice shifts internationally in relation to how trauma survivors are managed. Professor Bryant has translated his findings into improving the mental health of communities throughout the Southern Hemisphere (as well as many trauma-affected countries in the northern hemisphere).

### **Edgeworth David Medal 2020 — Associate Professor Brett Hallam**

The **Edgeworth David Medal** is awarded each year for distinguished research by a young scientist under the age of 35 years for work undertaken mainly in Australia or for contributing to the advancement of Australian science.

In less than six years from completion of his PhD, **Scientia Fellow Brett Hallam** of the School of Photovoltaic and Renewable Energy Engineering at UNSW (Sydney) has established himself as a national and international leader in the highly competitive field of crystalline silicon photovoltaics, particularly in the areas of light induced degradation, hydrogen passivation and defect engineering. Although he has made a major impact on photovoltaics globally, this is in addition to his profile and leadership in crystalline silicon photovoltaics in Australia. Professor Hallam's research addresses one of the key challenges in sustainability, that is, access to clean electricity. His work on hydrogen passivation to avoid light induced degradation of solar cells means that the cost of photovoltaics can be reduced greatly, increasing the competitiveness of this form of electricity compared with that generated by fossil fuels.

### **Clarke Medal for Botany 2020 — Distinguished Professor Michelle Leishman**

The **Clarke Medal** is awarded each year for distinguished research in the natural sciences conducted in Australia and its territories, in the fields of botany, zoology, and geology (considered in rotation). For 2020, the medal was awarded in botany.

**Distinguished Professor Michelle Leishman**, of the Department of Biological Sciences of Macquarie University, is internationally recognised for her work in plant ecology. In particular, her studies are directed towards understanding the success of invasive plant pathogens, vegetation responses and adaptation to climate change, plant conservation, and facilitating resilient urban green spaces. She has a number of active research programs which include development of a database for greening urban space, studying invasive plants and pathogens and climate vegetation response and adaptation to global climate change.

### **History and Philosophy of Science Medal 2020 — Professor Alison Bashford FRSN FAHA FBA FRHistS**

The **Society's History and Philosophy of Science Medal** is awarded annually to recognise outstanding achievement in the History and Philosophy of Science, especially the study of ideas, institutions, and individuals of significance to the practice of the natural sciences in Australia.

**Professor Alison Bashford**, ARC Laureate Fellow from the Faculty of Arts and Social Sciences at UNSW (Sydney), is one of Australia's most eminent historians, recognised internationally for her ground-breaking and transformative historical studies of the biomedical and environmental sciences. Her scholarly distinction is recognised by fellowships of both Australian and British academies. Professor Bashford has greatly enlarged and raised our understanding of past conceptions of race, population and place in Australia and the world. She has brought the history of the human and environmental sciences into the scope of world history. She has written five acclaimed books and numerous other published works in which she reveals connections of science and medicine with national projects and global ambitions. Further, her extensive and various studies have reoriented the history of science toward the southern hemisphere and the Pacific, showing us how natural knowledge has been assembled in Australia and the region.

### **Liversidge Lecture 2020 — Professor Richard Payne FRSN FRACI FRSC**

The **Liversidge Lecture** is awarded at intervals of two years for the purpose of encouragement of research in Chemistry. It was established under the terms of a bequest to the Society by Professor Archibald Liversidge MA LLD FRS, who was Professor of Chemistry in the University of Sydney from 1874 to 1907, and who was one of the Council members who sponsored the Society's Act of Incorporation in 1881.

The research of **Professor Richard Payne**, of the School of Chemistry of the University of Sydney, focusses on the development of technologies for the chemical synthesis of therapeutic peptides and proteins. These technologies have facilitated the preparation of numerous proteins bearing modifications that enhance activity and stability, critical features in the quest to develop efficacious protein therapeutics. His approaches have also been combined with recombinant methods to generate large therapeutic proteins and even antibodies — methods that have been widely adopted in the laboratories of international academics and pharmaceutical companies alike. He has developed synthetic proteins that are amongst the most potent antithrombotic agents ever reported, and which have an enormous therapeutic potential for thrombo-embolic disorders. Professor Payne has been awarded numerous prizes and medals including the 2014 RSNSW Edgeworth David Medal and the H G Smith and A J Birch Medals of the RACI.

### **Poggendorff Lectureship 2020 — Professor Angela Moles FRSN**

The **Poggendorff Lecture** is awarded periodically for research in plant biology and more broadly agriculture.

**Professor Angela Moles**, of the School of Biological, Earth and Environmental Sciences of UNSW (Sydney), is an international leader in the field of large-scale evolutionary ecology. In particular she studies the processes that shape global patterns and the way plants grow reproduce and interact with animals. She has a highly cited publication record and the innovation and quality of her work has been recognised by numerous awards.

### **Jak Kelly Award 2020 — Mr Matthew Donnelly**

The **Jak Kelly Award** was created in honour of Professor Jak Kelly (1928–2012), who was Head of Physics at University of NSW from 1985 to 1989, was made an Honorary Professor of University of Sydney in 2004, and was President of the Royal Society of NSW in 2005 and 2006. Its purpose is to encourage excellence in postgraduate research in physics. The award is supported by the Royal Society of NSW and the Australian Institute of Physics, NSW branch. The winner is selected from a short list of candidates who made presentations at the most recent Australian Institute of Physics, NSW branch postgraduate awards meeting.

**Mr Matthew Donnelly**, a PhD Candidate at UNSW (Sydney), is researching monolithic donor structures in silicon and their application in spin-based quantum computing. In particular, he is focussed on using 3D fabrication techniques to precisely control tunnel rates and other parameters critical to the operation of spin qubits.

### **Royal Society of New South Wales Scholarships 2020**

The **Royal Society Scholarships**, valued at \$500, together with a complimentary year of associate membership of the Society, are awarded annually in order to acknowledge outstanding achievements by young researchers in any field of science. Applicants must be enrolled as research students in a university in either NSW or the ACT on 1 January in their year of nomination.

For 2020, the RSNSW Scholarships have been awarded to:

- Mr Sajad Razavi Bazaz, University of Technology Sydney
- Mr Daniel Fox, Australian National University
- Ms Phillipa Specker, UNSW (Sydney)

In his PhD, **Mr Sajad Razavi Bazaz** studies the use of 3D printing for microfluidics. Microfluidics is a science which allows the manipulation of fluid samples, typically in the range of microlitres, within networks of channels ranging from tens to hundreds of micrometres. Microfluidic systems are becoming increasingly promising tools for the advancement of chemical and biological research with evident benefits. Today, 3D printing technologies have gained significant traction, being dubbed a third industrial revolution. Due to the expanding use of microfluidic systems in laboratories, 3D printing has emerged as an alternative method to traditional costly fabrication processes. Mr Razavi Bazaz has

developed a new method for the fabrication of microfluidic devices and has validated it. He and his colleagues have established a start-up company to develop 3D printed microfluidic devices for selective sperm selection for the IVF market.

**Mr Daniel Fox** is studying the clinically important, but much neglected, human and foodborne pathogen, *B Cereus*, and has discovered that enterotoxins produced by this bacterium can activate cytosolic innate immune inflammasome sensors which mediate host defence against pathogens. The sensing of pathogens by inflammasome sensor proteins results in the assembly of the inflammasome complex. Mr Fox has identified a toxin NHE as a novel activator of the NLRP3 inflammasome because it triggers formation of a lytic pore that promotes the efflux of potassium ions. He has also found it mediates the killing of cells from multiple lineages and hosts. It acts synergistically with another toxin secreted by the same organism, HBL.

**Ms Phillipa Specker** is investigating the role of emotional regulation in the management of post-traumatic stress disorder (PTSD) in refugees. Refugees represent one of the largest at-risk groups in the development of PTSD, with current treatments being much less efficacious compared to other trauma-exposed groups. Research suggests that emotion regulating strategies that refugees used to manage stress may be critically important in their recovery from PTSD. In the first part of her PhD program, she found that there were individual differences in the types of emotion regulation strategies that refugees used to manage stress and that those refugees who were better able to concurrently use cognitive reappraisal and emotional suppression had fewer PTSD symptoms. Currently, she is testing a novel experimental paradigm to investigate whether providing refugees with adaptive emotion regulation skills training will reduce PTSD symptomology and ultimately improve well-being.

## Awards for Service to the Society 2020

**Royal Society of NSW Medal — Emerita Professor Mary O’Kane AC FRSN FTSE Hon FIEAust**

The Society’s Medal is awarded from time to time to a member of the Society who has made meritorious contributions to the Society’s administration, organisation, and endeavours.

**Emerita Professor Mary O’Kane** was appointed as the first New South Wales Chief Scientist and Engineer in 2008 and remained in the position until 2018. Prior to that she was Vice-Chancellor and President of the University of Adelaide from 1996 to 2001. From 1994 to 1996 she was Deputy Vice-Chancellor (Research) and Professor of Electrical Engineering at the University of Adelaide. From 1989 to 1993 she was Dean of the Faculty of Information Sciences and Engineering at the University of Canberra.

Early on, as the New South Wales Chief Scientist and Engineer, she established a relationship between her office and the Royal Society of New South Wales which, in essence, provided the Society with access to the State Government. She was a strong supporter of the Society, providing funding for the publication of the Journal and Proceedings. Later she provided funding and hosted the Four Societies Lecture when it was the Royal Society’s turn to



organise this event. She also instigated an awards mechanism for the Society, by which the Science Deans of NSW and ACT universities came together under her chairmanship to make recommendations for the Society's prizes and scholarships. She advocated for the Society in government and also was a strong supporter of the Royal Society of New South Wales and Four Academies Forum held annually at Government House, Sydney.

**Royal Society of NSW Citation — Emeritus Professor Heinrich Hora FRSN FAIP FInstP**

The Royal Society of NSW Citations are awarded to a Member or Fellow of the Society who has made significant contributions to the Society, but who has not been recognised in any other way. A maximum of three Citations may be awarded in any one year.

**Emeritus Professor Heinrich Hora**, of UNSW Sydney, has served the Royal Society of New South Wales with distinction over many years. Professor Hora is a former Vice-President and Councillor of the Society and is a current member of the Fellows and Members Assessment Committee, to which he has made significant contributions over several years. In that role, he has helped ensure that the most talented and qualified individuals across many fields join the ranks of the Fellowship of the Society. In addition to his extensive service to the Society, Professor Hora is a noted theoretical physicist who has made and continues to make significant contributions to solid state physics, the optical properties of plasma, and non-linear dynamics with the application of lasers to the production of nuclear fusion energy.

## Note on Gazetting

The Government Gazette of the State of New South Wales is managed by the New South Wales Parliamentary Counsel's Office and has published Government notices, regulations, forms and orders since 1832. It went on line in 2001 and since 2014 is only to be found at <https://www.legislation.nsw.gov.au/#/gazettes>.



## *Government Gazette*

of the State of  
New South Wales  
Number 38  
Wednesday, 26 February 2020

On the initiative of RSNSW Fellow Robert Whittaker AM FRSN, the Society approached His Excellency the Governor to formally gazette fellows of the Society. All current fellows were included in the first gazetting in 2018, and subsequently at the beginning of each year fellows elected in the previous year will appear in the Gazette.

As the Gazette of Wednesday 26 February 2020 says:

“Her Excellency, The Honourable Margaret Beazley AC QC, Governor of New South Wales, as Patron of The Royal Society of New South Wales and in furtherance of the aims of the Society in encouraging and rewarding the study and practice of Science, Art, Literature and Philosophy, is pleased to advise and acknowledge the election of the following as Fellows and Distinguished Fellows of the Society in 2019.”

## Fellows

Proven leaders and experts in their field, entitled to use the post nominal FRSN. Please note Professorial titles — including adjuncts, conjoint, and professors of practice — have been used where applicable. Details as to their field of expertise, their resident university (or universities) or institution may be ascertained from the Royal Society of New South Wales.

ABBOTT, Mr Christopher Murray Abbott AM  
FRSN

ALEXANDER, Emeritus Professor Christine Anne  
Alexander FRSN

ASHTON, Professor Paul Ashton FRSN

BELL, Dr (DLit) John Anthony Bell AO OBE  
FRSN

BILEK, Professor Marcela Milena Bilek FRSN

BOTTEN, Emeritus Professor Lindsay Charles  
Botten FRSN

BOWDEN, Professor Brett Michael Bowden FRSN

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# Archibald Liversidge: Imperial Science under the Southern Cross

Roy MacLeod

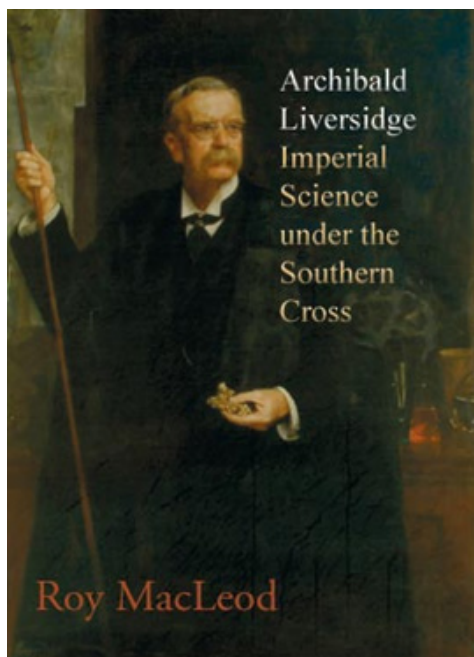
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When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology and Mineralogy and 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.



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