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# The remarkable contributions of ten outstanding women to Australian coral reef science

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\*Correspondence to: Pat Hutchings Australian Museum Research Institute, Australian Museum, Sydney, NSW 2010, Australia Email: pat.hutchings@austmus.gov.au ABSTRACT

This article summarises the careers of ten women who have made an amazing contribution to our knowledge of Australian coral reefs and their management, and how this contribution has been used by the Great Barrier Reef Committee (subsequently the Australian Coral Reef Society) to conserve and manage our reefs—an ongoing process in the face of climate change.

**Keywords:** biology, conservation, environmental science, history of Science, management, museum, taxonomy.

### Introduction

In 2022, the Great Barrier Reef Committee/Australian Coral Reef Society celebrates a 100-year record of impressive science and advocacy to secure the long-term future of Australian coral reefs. Women have played an important part of this history, both as reef researchers and through formal governance roles on the council of the society.

The Great Barrier Reef Committee, which later became the Australian Coral Reef Society, was established in 1922. In the opening pages of Dorothy Hill's historical account, we learn that Sir Matthew Nathan was elected chairman and that the first meeting was held in Brisbane on 12 September 1922. Miss H. F. Todd was appointed to the position of assistant secretary, in which she was allowed to take notes, subject to receiving permission from G. H. Knibbs, Director of the Queensland Office of the Institute of Science and Industry.<sup>1</sup> The permission was duly received and, in the decades that followed, notes were characteristically penned by women, with most of the rest of the committee being men who largely made the decisions.

The exclusion of women from the history of coral reef science perpetuates gendered expectations of what it means to be a coral reef scientist, creating further social and institutional barriers to female participation in this field.<sup>2</sup> Here, we help to address this problem by outlining the important roles that women have played in Australian coral reef science under the employment of museums, universities, often also working in a voluntary capacity as members and councillors of the Australian Coral Reef Society.

## Published: 21 September 2022

### Cite this:

Hutchings, P. and others (2023) Historical Records of Australian Science, 34(1), 19–35. doi:10.1071/HR22009

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### Australian coral reefs and coral reef science

Australia is surrounded by well-developed tropical- and sub-tropical reefs, including several World Heritage listed reefs. The coastline also exhibits a wide variety of reefs, from fringing to offshore atolls. With a relatively small human population and little subsistence fishing compared to places in the South Pacific and SE Asia, Australia has been able to establish marine parks and manage them effectively.

While Australia's coral reefs had been visited by Indigenous communities for thousands of years, coral reef science (the specialised scientific study of coral reefs) has only developed in Australia over the last two centuries. Many reefs in more isolated regions of Western Australia were not well documented until the foundation of the Museum of Western Australia in 1891, and the University of Western Australia in 1911. Even the famous Great Barrier Reef (GBR) on the east coast of Australia was not on the radar of researchers until the beginning of the twentieth century; prior to that it was best known for its hazard to shipping.

Reconnaissance investigations were made on the northern GBR in the early 1920s, with an attempt to drill a bore through Michaelmas Reef in 1926, but it was not until the 1928-9 expedition to Low Isles, led by the British marine zoologist, C. M. Yonge that a coordinated scientific program of research was applied to an Australian coral reef. We begin by profiling three women (Sidnie Manton, Sheina Marshall and Anne Stephenson) who took part in this expedition and whose work pre-dated the foundation of several of the aforementioned institutions. The innovative laboratory and field experiments that this expedition party of eighteen members, six of these being women (the three above and Gwyneth Russell, Elizabeth Fraser and Mattie Yonge), undertook during the twelve and a half months they spent at Low Isles on the northern Great Barrier Reef, heralded the emergence of modern coral reef science.<sup>3</sup>

In 1961, the University College of Townsville was established. On 20 April 1970 it was re-named James Cook University of North Queensland. Townsville became a major hub of coral reef research and management, with the establishment there of the Australian Institute of Marine Science (1972), the Great Barrier Reef Marine Park Authority (GBRMPA) (1975) and the Co-operative Research Centre (CRC) and later the Australian Research Centre (ARC) Centre of Excellence for Coral Reef Studies.

The Australian female scientists profiled in this article have made major contributions to Australian coral reef science in Australian institutions. They have not only undertaken research, but also worked with the GBRC/ACRS to understand and protect Australian coral reefs. These women include researchers who are deceased or have retired from active research, and of course there are many others currently undertaking ground- breaking coral reef research.

### Sidnie Manton (zoologist, reef work) 1902-79

Sidnie Manton was an extraordinarily talented scientist, a zoological legend in her own lifetime,<sup>4</sup> and Fellow of the Royal Society as a result of her work on comparative

arthropod anatomy and arthropod evolution. Following a stellar undergraduate career at the University of Cambridge, UK, culminating in her being placed first in the final year class list in zoology (but neither receiving a full degree nor a university prize as she was a female candidate; women only became eligible to be awarded a Cambridge degree in 1947), she moved in 1926 to Imperial College, London to work on crustacean embryology.<sup>5</sup> In 1927, she was offered a post as a university demonstrator, specialising in coelenterates, by Professor Stanley Gardiner, head of the Department of Zoology, University of Cambridge who had recognised her considerable ability. This was a significant move by Stanley Gardiner, not only because appointments up to that point had been exclusively male, but also because he had a major role in bringing about the Great Barrier Reef Expedition to Low Isles, 1928-9.

After graduating PhD in 1928, Manton, aged twenty-six, travelled to the mountains of Tasmania to study primitive *Anaspides* shrimps and from there joined the Low Isles expedition, before travelling, alone, to Sulawesi, Bali, Java (where she visited reefs in the Bay of Jakarta with the Dutch zoologist Jan Verwey) and Sumatra on her way home. She then returned to the Department of Zoology at Cambridge and taught at Girton College. She was the first woman to be awarded the university's highest research degree, Doctor of Science (ScD), in 1934 and in 1948 she was one of the first women to become a Fellow of the Royal Society (FRS). In 1949, she moved to King's College London to become a reader in zoology, with major publications on arthropod functional morphology and their evolution continuing almost up to her death, in 1979.

Manton joined the Great Barrier Reef Expedition in March 1929, some eight months after its commencement, and remained until its conclusion in July 1929. Her epiphany as to the magnificence of the shallow-water coral ecosystem she encountered there-and her forthright character and tenacity (both physical and mental)-are brilliantly captured in the recent publication of her letters home and diary from the expedition.<sup>6</sup> She quickly moved on from the 'donkey jobs' of cleaning aquaria, specimen preservation and general logistics to accompanying the leader of the shore party, T. Alan Stephenson, in the 'fearful game' of coral identification. Thus trained, and using a  $1.8 \times 0.8 \text{ m}$  quadrat (see Fig. 1), she played a major role in the survey of three 100-400 m reef platform traverses, identifying coral species, counting the number of colonies and measuring their size, and recording non-coral invertebrates and algae.<sup>7</sup> Furthermore, the traverses were extended to a depth of  $\sim -5$  m at their seaward margins, with Manton undertaking difficult quantitative reef

<sup>&</sup>lt;sup>3</sup>Spencer and others (2021).

<sup>&</sup>lt;sup>4</sup>Blower (1979).

<sup>&</sup>lt;sup>5</sup>See Akam (2015).

<sup>&</sup>lt;sup>6</sup>Clifford and Clifford (2020). For perceptive reviews of this work see: Brown and Fielding (2021); Hamylton (2021).

<sup>&</sup>lt;sup>7</sup>Manton and Stephenson (1935).



**Fig. 1.** Sidnie Manton (standing) setting out in the 'flattie' for ecological survey with the expedition's wooden quadrat frame, Low Isles, northern Great Barrier Reef, 1929, photographer unknown, and reproduced with kind permission from the Manton family's archives. Original image enhanced through AI colourisation by the Digital Content Unit, University Library, Cambridge.

front surveys, aided by a primitive dive helmet supplied by air pumped from the surface, establishing changes in coral cover by species with depth.<sup>8</sup> When plotted up alongside the tidal levels meticulously established by the expedition's surveyor, Michael Spender, these transects provided a precise baseline that scientists returned to 90 years later, establishing a rare record of long-term change in coral reef communities.<sup>9</sup> In addition, Manton sampled coral reproductive material and measured growth in pocilloporid corals,<sup>10</sup> quite apart from days photographing the reefal flora and fauna and nights drawing up maps and processing film (her photographic albums contain over 100 images from the Great Barrier Reef).

For the expedition leader, C. M. Yonge,<sup>11</sup> 'Sidnie did as much in those few months as the rest of us did in four times that period', adding 'this was no reflection on our activities, just an indication of the exceptional intensity of her own' and 'her exceptional capacities for observation and for illustration were given fullest range in this wonderfully rich ecosystem'.

### Sheina Marshall (phytoplankton worker) 1896–1977

Sheina Marshall was already an established expert on marine plankton when she joined the Great Barrier Reef

<sup>9</sup>Fine and others (2019). <sup>10</sup>Manton (1932).

<sup>11</sup>Fryer (1980) p. 329. <sup>12</sup>Russell (1978). Expedition 1928–9 at the age of thirty-two. Her love of natural history was fostered at an early age through the interests of her father, a medical doctor. In 1919, she grad-uated from the University of Glasgow specialising in zoology, botany and physiology. She then held a Carnegie Fellowship, 1920–2, at the university before starting work on the feeding of copepods at Millport Marine Station on the west coast of Scotland in 1922.<sup>12</sup>

Marshall's inclusion on the Great Barrier Reef Expedition, and that of her close colleague at Millport, Dr A. P. Orr, was brought about by Sir Graham Kerr who was her zoology professor at Glasgow. Marshall and Orr spent the full twelve and a half month duration of the expedition on the Great Barrier Reef. While Marshall was described as a 'phytoplankton worker' on the list of personnel in the reports of the Great Barrier Reef Committee (1931), she covered a much wider remit of research while on the expedition (Fig. 2). The breadth of the projects that she undertook was a testament to her skills as a highly accomplished zoologist and her 'indefatigable' character, as described by the deputy leader of the first part of the expedition, Frederick Russell.<sup>13</sup> Australian newspaper articles of the time also report that she was not only skilled in microscopy, but also in the use of hammer, plane and saw during the construction of furniture required for the expedition's laboratory.

<sup>&</sup>lt;sup>8</sup>Spender (1930).

<sup>&</sup>lt;sup>13</sup>Russell (1977).



**Fig. 2.** Sheina Marshall (left) demonstrating the apparatus for measuring coral growth on Low Isles to Mattie Yonge (right). Reproduced by kind permission of Scottish Association of Marine Science from Sheina Marshall's photograph album of the Great Barrier Reef Expedition.

Her most significant scientific findings at Low Isles were to document the lack of seasonality in the quantity of microplankton throughout the year, which was in stark contrast to that observed in temperate waters;<sup>14</sup> the ability of corals to live successfully in turbid (sediment-rich) environments and their strategies to rid themselves of sediment by ciliary action and behavioural mechanisms;<sup>15</sup> the lunar periodicity of planulation in the coral *Pocillopora damicornis*,<sup>16</sup> and oxygen production in coral planulae.<sup>17</sup> Her work on coral reproduction and sediment shedding are still extensively cited some 94 years after this remarkable expedition.

The contribution of Marshall, and that of her close colleague A. P. Orr, to the scientific study of the Great Barrier Reef is best summed up by the expedition leader C. M. Yonge: 'Looking back I cannot conceive of the Great Barrier Reef Expedition, a major event in the lives of all participants, without the scientific and personal contributions made by Sheina Marshall and A. P. Orr'.<sup>18</sup>

### Anne Stephenson (honorary zoologist) 1899–1977

Anne Stephenson joined the Great Barrier Reef Expedition to accompany her husband Dr T. A. Stephenson who directed the shore party and was deputy leader of the second half of the expedition. Anne married T. A. Stephenson, a lecturer in zoology at University College, London, in 1922. The leader of the Expedition C. M. Yonge had previously worked with T. A. Stephenson at Plymouth and he became an obvious choice for inclusion in the expedition, together with his wife. C. M. Yonge observed that 'as years passed [Anne] was to become an ever closer collaborator in his [T. A. Stephenson's] scientific work, [and] brought him enduring happiness'.<sup>19</sup>

By October 1928, it was clear that Anne Stephenson was contributing significantly to the scientific studies at Low Isles and C. M. Yonge wrote to Professor Stanley Gardiner requesting that Anne Stephenson be nominated as an 'honorary zoologist' in the team, a request that was subsequently supported. In the early stages of the expedition, she assisted her husband on shore excursions, helped in the building of aquaria and also in the marking off of reef areas for extensive study, as well as sampling reproductive material of selected reef organisms that were listed in the Natural History Museum Archives.<sup>20</sup>

In January 1929, Anne Stephenson assisted Michael Spender in his detailed levelling and surveying of traverses across the Low Isles reefs, a task that she repeated subsequently at Lizard Island (Fig. 3). Not only did she act as a 'staff man' but also contributed by identifying, through earlier reconnaissance with her husband, biological communities encountered along the traverse.<sup>21</sup> These surveys and the quantification of organisms along them, carried out by

<sup>&</sup>lt;sup>14</sup>Marshall (1933).

<sup>&</sup>lt;sup>15</sup>Marshall and Orr (1931).

<sup>&</sup>lt;sup>16</sup>Marshall and Stephenson (1933).

<sup>&</sup>lt;sup>17</sup>Marshall (1932).

<sup>&</sup>lt;sup>18</sup>Russell (1978).

<sup>&</sup>lt;sup>19</sup>Yonge (1962) p. 139.

<sup>&</sup>lt;sup>20</sup>Letter, 2 October 1928, Professor Stanley Gardiner to Chairman of British Great Barrier Reef Committee, DF214/6, Natural History Museum, London Archives.

<sup>&</sup>lt;sup>21</sup>Spencer and others (2021).



Fig. 3. Drawing up field mapping, excursion to Lizard Island, 31 May-13 June 1929. From left to right: M. Spender, T. A Stephenson, Anne Stephenson. Photo credit: S. Manton. Reproduced with kind permission from the family's archives. Original image enhanced through AI colourisation by the Digital Content Unit, University Library, Cambridge.

Manton and Stephenson,<sup>22</sup> were completed in such detail that they have become an important baseline for subsequent studies, providing one of the longest (91 years) coral reef surveys published to date.<sup>23</sup>

Anne Stephenson also made a significant contribution to the published outputs of the expedition, co-authoring with her husband and others articles on the structure and ecology of Low Isles and other reefs,<sup>24</sup> jointly publishing with her husband a chapter on the growth and asexual reproduction in corals,<sup>25</sup> and a chapter for which she was sole author on the breeding of reef animals other than corals.<sup>26</sup> In addition, Anne Stephenson produced over thirty-eight hand-drawn figures for the third volume of Scientific Reports, six of which were jointly produced with her husband, the remainder being her own work. Her husband was an exceptionally talented artist,<sup>27</sup> and there is no doubt that in him she had a remarkable, gifted teacher; after his death she was also a scientific illustration authority in her own right.<sup>28</sup>

Following the Great Barrier Reef Expedition, the couple subsequently travelled world-wide studying rocky shore zonation patterns which were summarised eleven years after her husband's death in Life between Tidemarks on Rocky Shores.<sup>29</sup> Using her husband's notes, the text was

<sup>25</sup>Stephenson and Stephenson (1933).

<sup>31</sup>Hill (1935).

compiled and written by Anne Stephenson with the help of Carl Pantin and C. M. Yonge, and included a chapter on the shores of Australia and New Zealand.

### Dorothy Hill (GBR Committee secretary, 1946-55) 1907-97

Dorothy Hill was an authority on Palaeozoic corals and Australia's most acclaimed woman scientist of her era. Hill began studying geology as an undergraduate student at the University of Queensland in 1924, under the guidance of Professor Henry Caselli Richards. Her inspiration to specialise in coral palaeontology came from a holiday encounter with a small Lower Carboniferous fossil reef in the Wide Bay district of Queensland.<sup>30</sup>

In 1930, Hill won a scholarship to the University of Cambridge, and she remained in England working on the Carboniferous corals of Scotland and Queensland for seven years (Fig. 4). During this time she established a systematic terminology for describing rugose corals based on their structure and morphology.<sup>31</sup> Hill's return from England in 1937 coincided with the second bore on the Great Barrier

<sup>&</sup>lt;sup>22</sup>Manton and Stephenson (1935).

<sup>&</sup>lt;sup>23</sup>Fine and others (2019).

<sup>&</sup>lt;sup>24</sup>Stephenson and others (1931).

<sup>&</sup>lt;sup>26</sup>Stephenson (1934).

<sup>&</sup>lt;sup>27</sup>Williams and Moore (2011).

<sup>&</sup>lt;sup>28</sup>Stephenson (1962).

<sup>&</sup>lt;sup>29</sup>Stephenson and Stephenson (1972). <sup>30</sup>Jell (1997).



**Fig. 4.** Dorothy Hill working in the field, Queensland 1930. Source: Fryer Library Miscellaneous Photograph Collection, University of Queensland, Brisbane.

Reef drilled at Heron Island, and Hill worked with Richards to describe the physical and chemical properties of coralline material recovered from this bore, as well as material recovered from the Michaelmas Cay bore in 1926.<sup>32</sup> At this time she also began dating, mapping and outlining stratigraphic sequences for many of the limestone coral faunas of Australia, working in all Australian states except South Australia. Hill's greatest scientific legacies stem from her perceptive understanding of coral morphology, particularly their tissue patterns and skeletal deposition, which were supported by early observations in England and later advanced through crystallography work with Dr W. H. Bryan.<sup>33</sup> The criteria Hill established in her coral descriptions remain the world-wide standard for stratigraphic interpretation today.

In 1946, Hill became secretary of the GBRC. During her nine year period of service, Hill lent her practical and administrative support to supervising the construction and equipping of Australia's first field research station at Heron Island in 1952. This station continues to be a major international centre for reef research and teaching of undergraduates and school groups. Hill was also a member of the committee, chaired by Dr M. H. C. Day, that established the Australian Institute of Marine Sciences in Townsville in 1972.<sup>34</sup> During her time on the Great Barrier Reef Committee, Hill proved to be a meticulous record keeper and wrote two extensive histories of the society based on a thorough examination of their archives.<sup>35</sup>

In addition to being an exceptional geologist, Hill's energetic activities extended across both her personal and professional life. She was an enthusiastic sportswoman,

<sup>35</sup>Hill (1984). Hill (1985).

excelling in hockey, athletics and rowing. While at Cambridge, she learned to fly planes, gaining a pilot's licence and was very active with the Women's Royal Auxiliary Naval Service in Brisbane during the Second World War.

# Isobel Bennett (zoologist, GBRC council member, and photographer) 1909–2008

Isobel Bennett, was a pioneer in Australian coral reef biology, devoting her life to marine biology, education and conservation.

Bennett's career was remarkable especially considering that she had no formal training—being trained 'on the job'. Bennett was very disappointed when her parents decided she had to leave school at the age of sixteen to enrol in a business college to get a job. Her career underwent a major change following a chance meeting with Dr William Dakin, Professor of Zoology, University of Sydney in 1933. Bennett's forty-year association with the university began when Professor Dakin hired her as a research assistant.

Bennett and Elizabeth Pope were critical in preparing the final copy of Australian Seashores which was published in 1952, two years after Dakin's death in 1950.<sup>36</sup> Although only the name Dakin appears in the title, with Bennett and Pope just being acknowledged as assisting in the production, they did all the compiling of the book after his death-an example of historical exclusionary practices. This extraordinarily popular book went on to become a classic study and essential reading for Australian marine biologists at all career stages. Over the next forty years, it was reprinted eleven times and Bennett was responsible for coordinating the publication of several subsequent editions. Bennett also published The Great Barrier Reef in 1971,<sup>37</sup> a book that portrayed the first general overview of the GBR and was well illustrated with wonderful photographs, again this was revised and reprinted several times. These two books made a major contribution because of their accessibility to a broad readership, which meant that they became key sources of information and inspiration to the Australian public, particularly an aspiring generation of young marine scientists. In part, the accessibility of these books was due to their many excellent illustrations, which included many of Bennett's photos taken in the field, a contribution that was recognised in 1988 when Bennett won the Whitley Award for best photography, awarded by the Royal Zoological Society of NSW. When asked how she obtained such wonderful underwater shots for the Great Barrier Reef book, she smiled and responded 'the secret is not to get your camera wet!'

<sup>&</sup>lt;sup>32</sup>Richards and Hill (1942).

<sup>&</sup>lt;sup>33</sup>Bryan and Hill (1941).

<sup>&</sup>lt;sup>34</sup>Campbell and Jell (1998).

<sup>&</sup>lt;sup>36</sup>Dakin (1952).

<sup>&</sup>lt;sup>37</sup>Bennett (1971).



**Fig. 5.** Isobel Bennett in the summer of 1963, on board *Te Vega* during the Indian Ocean expedition. Photo: Michael Hadfield, University of Hawaii.

As a female marine scientist in the 1950–60s, Bennett was often in the minority as a researcher aboard international oceanographic scientific expeditions. In 1952, she was the only woman with 118 males on board the Danish research ship *Galathea*, which took her from Sydney to Adelaide and back to Melbourne collecting samples and taking photographs.

Bennett became familiar with the Great Barrier Reef with her first visits to the Whitsundays in 1946 and Heron Island in 1950, collecting and taking photographs. Some of her material from Heron Island was donated to the Australian Museum and then sent to world experts for identification. One of these was the polychaete *Reteterebella queenslandia* which was identified by Olga Hartman in Los Angeles in 1963, and which is common on the reef flat at Heron, although you only see the long white feeding tentacles spread out over the reef because the body is well concealed underneath the boulders.

As a member of the GBRC, Bennett participated in the University of Queensland Expedition to Low Isles in 1954, which surveyed the variety of reef flat habitats around Low Isles. This data was compared with the findings from the Low Isles expedition, 1928–9, to evaluate how the fauna had changed following the 1950 cyclone. The 1954 expedition provided detailed species lists and abundances of fauna and flora in each of the major habitats visited, which established baseline data making it easier for future surveys to assess changes.<sup>38</sup>

In 1963, Bennett was appointed as a visiting associate professor by Stanford University, USA; a position that allowed her to take part in the International Indian Ocean Expedition, spending time on *Te Vega*, a yacht converted into a research and marine-biology training ship (Fig. 5). Bennett was a talented teacher and during the voyage she lectured on coral reef biology to postgraduate students in the mid-ship room and trained them on the collection and identification of tropical animals.

Bennett was the co-editor of *A Coral Reef Handbook* (1978) written with Patricia Mather and subsequent editions in 1984, 1993 and 1994. This text was supported by the GBRC and later by ACRS and has been used by many generations of students studying tropical marine biology. Bennett certainly used various editions during the twenty-three student field trips to Heron Island that she ran for the Biological Society of the University of Sydney.

Bennett was a councillor on the GBRC, 1973–9, a period in which the activities of the committee were dominated by explosions of crown-of-thorns starfish on the reef and lively and often heated debates within the GBRC over the cause of these plagues.

In October 2008, GBRMPA named a reef Isobel Bennett (Reef 21–505), which is located in the Swains, off Heron Island.

# Patricia Mather (née Kott) (ascidian systematist) 1925–2012

Patricia Kott graduated BSc (Hons) from the University of Western Australia in 1948, with a thesis on the taxonomy of two families of worms Nereididae and Euncidae. She won a fellowship with the Commonwealth Scientific and Industrial

<sup>&</sup>lt;sup>38</sup>Stephenson and others (1958).



Fig. 6. Patricia Mather in her office at the Queensland Museum. February 1981. Copyright Queensland Museum, Brisbane.

Research Organisation (CSIRO) in late 1949, to spend time at University of London, the Natural History Museum and the Marine Biological Association laboratory at Plymouth. Here she started working on ascidians, the taxonomy of which became her lifetime passion.

Kott returned to Australia in 1951 to continue working at CSIRO, but in 1955 she married Wharton B. Mather who was a lecturer at Queensland University, and moved to Brisbane. Subsequently she used her married name except when publishing her systematic work on ascidians. During the next ten years she juggled having children and doing research funded by small research grants, and 1961–2 she was awarded a Commonwealth Graduate Award leading to her being awarded a PhD (on ascidians) at the University of Queensland in 1962 (Fig. 6).

Over the next few years she established herself as an authority on ascidians and became a research fellow at the University of Queensland, and was awarded a DSc from the University of Western Australia in 1970. In 1973, she was appointed to the Queensland Museum as a curator, initially of molluscs and then of higher invertebrates, allowing her to resume working on the ascidians of Australia and Indo-west Pacific.<sup>39</sup> She was a strong advocate for the importance of taxonomy doing much of the work that paved the way for *Discovery Biodiversity, a Decadal Plan for Taxonomy* funded by the Australian Academy of Science 2018,<sup>40</sup> which provides a road map for documenting Australia's biodiversity

and outlines the importance of this and the economic impacts of failing to correctly identify biota.

Mather was passionate about protecting marine natural resources. As secretary and president of the GBRC, she played a significant role in the 'Save the Barrier Reef' campaign, a period of concerted conservation advocacy that eventuated in a recommendation that oil drilling be banned on the GBR by the Royal Commission into Exploratory and Production Drilling for Petroleum in the GBR in 1970. Mather advised the Australian Conservation Foundation (ACF) president, Sir Garfield Barwick, that GBRC policy did not support a moratorium on oil drilling as this would not only hold up national development in many ways but also ignored the equal dangers already existing from tankers. Dangers to the reef from pollution of all kinds could be avoided by expedient action initiated by an independent, authoritative and preferably a statutory body. The Royal Commission also recommended that an authority to manage the GBR be established. Mather was subsequently heavily involved in drafting the initial Bill for an Act for the Great Barrier Reef that would lead to the establishment of GBRMPA in 1975.

Mather played a major role in organising, and overseeing the publication of the proceedings, of the 2nd International Coral Reef Symposium under the auspices of the GBRC, which was held on board M.V. Marco Polo in 1973, which cruised the waters of the Great Barrier Reef between Brisbane and Lizard Island with days of talks interspersed by diving and snorkelling activities. The symposium attracted 264 researchers from seventeen countries with 120 papers presented, which was a major expansion on the 1st International Coral Reef Symposium, held in India in 1969 with twentyfive papers. The Australian Federal Minister for Science and Minister for External Territories the Honourable W. L. Morrison sent a message to the symposium indicating the establishment of the Australian Institute of Marine Science. Mather attended many of the subsequent international coral reef symposia.

As well as carrying out research in ascidians and building up extensive collections in the Queensland Museum, Mather spent a great deal of time at Heron Island, where she worked closely with Bennett to produce *A Coral Reef Handbook*, a guide to the fauna and flora of the Capricorn Bunker Group, the area of the GBR initially known in most detail. A more expansive version was produced in 1993 and reprinted in 1994, which had a much broader coverage of the GBR, and involved a range of specialists with Mather and Bennett acting as editors. The royalties from the sale of these books were given to the ACRS to support student research grants. These handbooks were widely used by the many school and student groups visiting Heron Island Research Station. They laid the foundation for the subsequent publication by Hutchings and others (2008, revised in 2019),

<sup>&</sup>lt;sup>39</sup>Davie (2012).

<sup>&</sup>lt;sup>40</sup>Anonymous (2018).

for which Mather wrote the ascidian chapter for the first edition.  $^{41}$ 

Mather was a determined lady and could be a little intimidating to younger colleagues and even well-established workers, but behind that façade she was a generous person, an excellent cook and entertainer, and passionate not only about the GBR, but ascidians. She was also supportive of other female researchers at the Queensland Museum and strongly supported Carden Wallace at a time when there were few female researchers at the museum. She worked relentlessly up until her death even though during her last few years she was in poor health.

### Vicki Harriott (coral reef ecologist) 1955–2005

Vicki Harriott was an active researcher of both Australian tropical and subtropical coral reefs, including Lizard Island, the Solitary Islands and Lord Howe Island. She was one of first researchers to recognise the significance of coral bleaching and to document spatial and temporal patterns in coral recruitment, and how these are impacted by climate change. As well as being an active researcher, Harriott was heavily committed to undergraduate and graduate teaching.

Harriott obtained her BSc (1976) in zoology and MSc (1980) from the University of Queensland. Her MSc thesis was on the reproduction and ecology of holothurians at Heron Island. She then undertook a PhD at James Cook University (JCU) (1984) on the reproduction of corals and community structure at Lizard Island (Fig. 7). She published one of the first papers on coral bleaching, which documented the mortality of shallow-water corals at Lizard Island during a 1982 mass bleaching event, postulating that bleaching may be related to high levels of UV radiation at times of elevated water temperature.<sup>42</sup> She continued working on coral reefs as part of a post doctorate at JCU from 1984 to 1987 and established the foundation for a number of new directions, including coral reef restoration techniques, spatial and temporal patterns in coral reef recruitment, and the impacts of crown-of-thorns starfish on the GBR. Her work on accelerated regeneration of hard corals was published as a manual for coral reef users and managers by the GBRMPA until recently but this has recently been updated and is available online.

After her post doctorate, Harriott worked as assistant curator at the Great Barrier Reef Aquarium (ReefHQ) in Townsville, where she set up the main exhibit—then the largest coral reef tank in the world. Awarded a Churchill Fellowship in 1988, she visited the USA and SE Asia to research ways of improving conditions in the aquarium. Harriott then joined Southern Cross University (SCU) in



Fig. 7. Vicki Harriott preparing for a dive. Photographer Lyle Vail taken at Lizard Island during her PhD studies in the early 1980s.

Lismore, NSW as a lecturer in 1990 and was later promoted to associate professor. Shifting her research focus to subtropical reefs in the Solitaries and Lord Howe, Harriott initiated collaborative research programs on latitudinal patterns of coral recruitment and growth, and also investigated the impact of divers on coral communities.

Harriott was at the forefront of investigating how such subtropical reefs would fare with climate change. In a seminal study, she proposed a biophysical model to show how latitudinal patterns affected the composition of coral communities at eleven sites spanning a latitudinal range of over 2500 km, from the northern Great Barrier Reef (11°S) to South West Rocks (31.5°S).<sup>43</sup> For the first time, Harriott outlined differences in community structure, composition of major taxa and species and cover of hard corals, linking these community characteristics to interacting factors such as water temperature, aragonite saturation, light availability, currents and larval dispersal, competition between

<sup>&</sup>lt;sup>41</sup>Hutchings and others (2008). Hutchings and others (2019).

<sup>&</sup>lt;sup>42</sup>Harriott (1985).

<sup>&</sup>lt;sup>43</sup>Harriott and Banks (2002).

corals and other biota including macroalgae. She also documented the presence of crown-of-thorns starfish on Lord Howe Island and on the ability of such a remote location being able to recover from a severe infestation.<sup>44</sup> Whilst at SCU, she supervised numerous students and developed new courses in biology, marine ecosystems, ecology and aquaculture.

After a successful career at SCU, she returned to Townsville in 2000 as the program leader for Education and Communication in the CRC Reef Research Centre. She wrote a major report on the Queensland Coral Fishery, which operated from the tip of Cape York to the southern extent of the Great Barrier Reef Marine Park. This industry collected small, predominantly fast growing corals (Acroporidae and Pocilloporidae), which were then shipped alive around the world as part of the aquarium trade. The report outlined knowledge gaps that would need to be filled to ensure that ongoing live coral harvesting did not significantly threaten the Great Barrier Reef and was published by the CRC Reef Research Centre. She was invited as a plenary speaker to a workshop held in Indonesia in 2001 and developed internationally adopted guidelines of operation for the live coral trade.<sup>45</sup> Harriott's report was incorporated into the Expert Advice for the Assessment of Australian Coral Fisheries—Queensland Coral Fishery 2006-7 to 2019-20 prepared for Australia's Scientific Authority for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), prepared by Morgan Pratchett.<sup>46</sup> As of July 2022, species-specific harvest limits will be implemented by GBRMPA for several heavily collected and potentially vulnerable coral species. Ongoing coral harvesting on the Great Barrier Reef continues to attract considerable political and public scrutiny, especially given extensive coral loss caused by coral bleaching and destruction by crown-of-thorns starfish. Public awareness, continued operation and viability of this industry is largely due to insights and recommendations made by Harriott in 2001.

Harriot made an important contribution to coral reef science even though her career was cut short by cancer, leaving a substantial volume of published papers, and technical and consultancy reports focussed on developing threats to coral reefs. Much of her research was focussed on providing useful information for managers and constitutes a major legacy. Her contributions to science and advocacy for Australian coral reefs are honoured with a student prize for the best oral presentation at the annual ACRS conference.

Vicki Harriott was an excellent communicator engaging students of all ages, and while being a really hard worker she also enjoyed life and certainly participated in some of the memorable parties held at Lizard Island over the years.

### Loisette Marsh (echinoderm taxonomist) 1928–2021

Loisette Marsh was a world expert on echinoderms, a group of invertebrates that are abundant on coral reefs, and which includes seastars, brittle stars, bêche-de-mer and sea urchins.

Marsh was one of the first women to obtain a degree in marine biology from the University of Western Australia (1950), and a master's degree on the ecology of Western Australian Limestone Reefs (1956). From the early 1950s, she dived extensively along the vast West Australian coast using home-made SCUBA equipment. In 1976, Marsh was the first woman to participate on a CSIRO cruise off the west coast of Australia, and while there was much opposition to this, she made valuable collections of benthic organisms collected during benthic trawls. This set a pathway for regular participation of women in CSIRO cruises ever since, although women had been allowed on non-Australian research vessels for many years before as highlighted above in the text on Bennett. Marsh also participated in cruises in RV Soela (1979, 1982) along the West Australian coast and RV Franklin (1986, 1988) across the North West shelf and North Queensland slope respectively. She undertook extensive field work in the Indo-Pacific and lived in Fiji for several years, where she continued to collect marine fauna using SCUBA to obtain specimens from deeper underwater environments, and snorkelling in shallower zones and intertidal collecting, accumulating a wealth of knowledge on the distribution and abundances of echinoderms.

While undertaking her master's degree, she worked parttime in the Department of Zoology, University of Western Australia, and then moved to Suva, Fiji where she taught high school biology. On her return to Australia in 1968, she resumed working at the University of Western Australia before joining the Western Australian Museum in 1970, initially as a part-time graduate assistant, then as a curator in Marine Invertebrates from 1974 until she retired in 1993. She built up extensive collections of echinoderms, especially seastars (*Asteroidea*) and scleractinian corals. These collections were used for research as well as for public displays at the Western Australian Museum.

Marsh presented a paper at the 2nd International Coral Reef Symposium on the distribution of crown of thorns starfish at Kendrew Island, Dampier Archipelago in Western Australia. This was the first such study to draw attention to the presence of this species on the west coast

An extensive obituary was published in the *Australian Marine Sciences Bulletin* in 2005 by Peter Harrison.<sup>47</sup>

<sup>&</sup>lt;sup>44</sup>Harriott (1995).

<sup>&</sup>lt;sup>45</sup>Harriott (2001). Harriott (2003).

<sup>&</sup>lt;sup>46</sup>Pratchett (2021).

<sup>&</sup>lt;sup>47</sup>Harrison (2005).



Fig. 8. Loisette Marsh, onboard RV *Piscean* in 1984, writing up notes after a day in the field at Scott reef, WA. Photo Clay Bryce, copyright West Australian Museum.

of Australia. She suggested that the populations move across the reef over time in response to prevailing wind directions, water temperatures and tidal fluctuations.<sup>48</sup> This research was funded by the Advisory Committee on Research into the Crown of Thorns Starfish, Canberra, which was established after the lobbying by the GBRC spearheaded by Dr Robert Endean.

Marsh was involved in many of the surveys undertaken by the Western Australian Museum on remote reefs off Western Australia such as Rowley Shoals, Scott Reef, Ashmore Reef Cartier Reef, Cocos (Keeling) Islands and Christmas Island, Abrolhos Islands and Montebello Islands, and the Dampier Archipelago (Fig. 8). These surveys went beyond simply documenting the biota of these areas, they were critical in developing the rationale for nominating these places as marine parks, thereby protecting many of these areas from threats such as offshore oil and gas exploration.<sup>49</sup> These expeditions to offshore reefs in NW Western Australia represented the first comprehensive marine biology surveys of these reefs and inter-reef areas, during which Marsh made extensive collections of corals and echinoderms.

Marsh continued to publish after her retirement, producing the 543-page *Field Guide to Shallow Water Seastars of Australia* (2020) with Jane Fromont from the Western Australian Museum, who edited and compiled Marsh's hand-written field notes as Marsh never used a computer. This field guide was awarded a Royal Zoological Society of NSW Whitley award in 2021. Marsh had previously won a similar award in 2010, for the *Field Guide to Sea Stingers and Other Venomous and Poisonous Marine Invertebrates of Western Australia* with Shirley-Slack-Smith also from the Western Australian Museum.

### Carden Wallace (coral systematist) 1946-

Carden Wallace's research contributions have focussed on the taxonomy of the *Acropora* genus of coral, commonly known as Staghorn corals, which are one of the major groups of reef building corals, especially in the Indo-Pacific. This genus is well represented on both modern and fossil reefs, including many fast growing species that are badly affected by coral bleaching, but can rapidly recover. Through a series of extensive, detailed taxonomic studies, Wallace has developed theories on the dispersal, genetics and evolution of staghorn corals over the last 20 million years.

Her vast knowledge of coral taxonomy which was based not just on specimens of dried coral colonies, but also seeing those species alive in the field. One cannot study coral reefs without being able to identify the components of the reef and many students and established coral reef researchers have benefitted from Wallace's willingness to assist others in understanding coral taxonomy.

Wallace graduated from the University of Queensland (UQ) in biology, becoming one of only two women to enter tertiary education from her senior high school year. In 1970, she became Curator of Lower Invertebrates at the Queensland Museum, Brisbane (QM), three years before Patricia Mather was appointed, and undertook many field trips along the Queensland coast and on offshore islands to build up the coral collections. Such field trips often involved taking a nanny to look after her children, something not allowed today. She was awarded her PhD in 1979 from UQ on the Staghorn corals of the GBR, with Drs John Jell and Tom Hailstone as her supervisors, and Dorothy Hill as her mentor.

Wallace resigned from the QM and moved to AIMS as a research scientist, and then moved to JCU as a research fellow. She was a member of the team that solved the mystery of mass coral spawning on the GBR by unlocking the environmental factors allowing the precise timing to be predicted,<sup>50</sup> and for this they were awarded the Pol Eureka Prize for Environmental Research 1992, hosted by the Australian Museum. This discovery of mass coral spawning on the GBR had immense implications for the connectivity of reefs which were then incorporated into the rezoning of the GBR for management. It also meant that researchers were now able to predict the timing of spawning and thus, collect gametes and larvae which have been critical for subsequent studies such as on the hybridisation of corals, impact of changes in temperature and acidification on development, distance dispersed and update of zooxanthellae.<sup>51</sup>

Wallace moved to Canberra in 1985 and worked as a scientific editor for the Australian Biological Resources Study (ABRS), working on the mollusc volume of the

<sup>&</sup>lt;sup>48</sup>Wilson and Marsh (1974).

<sup>&</sup>lt;sup>49</sup>Marsh (1986*a*). Marsh (1986*b*). Marsh (1994). Marsh and others (1993).

<sup>&</sup>lt;sup>50</sup>Harrison and others (1984).

<sup>&</sup>lt;sup>51</sup>Harrison and Wallace (1990).



**Fig. 9.** Carden Wallace examining *Acropora* samples from the Kimberleys at the Western Australian Museum. Photo: Zoe Richards.

*Fauna of Australia*, while still working on a major work on the staghorn corals, which took many years to complete.<sup>52</sup>

In 1987, Wallace was appointed as the first manager and subsequently director of the Museum of Tropical Queensland (MTQ) in Townsville (Fig. 9). Here, she continued her coral taxonomic research and built up one of the most extensive coral collections in the Indo-Pacific, which was combined with the AIMS's coral collections to yield a comprehensive record of Australian corals from around the tropical and subtropical coastlines, as well as the Indo-Pacific region.<sup>53</sup> Wallace supervised and mentored many students, who have gone on to become world-renowned coral reef researchers, often benefitting from Wallace's encouragement to use the museum collections. During the early years of the MTQ, she was instrumental in developing exhibits, outreach programs (especially for school children), and collaborating with researchers at AIMS and JCU. She also continued her own research including producing a monograph of the Staghorn Corals of the World in 1999, which became a bible for anybody working on this group, as well as many other papers. She participated in numerous field trips throughout the Indo-Pacific.

Wallace served on the council of ACRS, 1991–2, as well as hosting council meetings in the Museum of Tropical Queensland and being involved in judging student prizes. She was a contributor to all the handbooks edited by Mather and Bennett, and wrote chapters on corals and sea anemones for *The Great Barrier Reef, Biology, Environment and Management* (1st and 2nd editions).<sup>54</sup>

In summary, Wallace's contribution to coral reef science has facilitated much of the research on the reef, not only in Australia but in the Indo-Pacific, and allowed members of ACRS to do their own research. Certainly, any researcher working on Australian corals would have visited the Museum of Tropical Queensland to talk to Wallace and examine their extensive coral collections. Many ended up staying with her and becoming life-long friends.

### Bette Willis (coral reef ecologist) 1951-

Bette Willis commenced a PhD at James Cook University (JCU) in 1982, which combined translocation studies with histocompatibility and genetic studies to explore factors governing morphological variation in corals. Willis' research demonstrated conclusively that the underlying causes of morphological variation differ among coral species and can be governed by environmental or genetic factors.<sup>55</sup> As a graduate student, Willis was a key member of the JCU team that discovered many GBR coral species spawn over three-four predictable nights in late spring.<sup>56</sup> After initial work at Magnetic Island, the team expanded their studies from the central to northern GBR. Working at Lizard Island, Willis discovered that many species spawned synchronously with conspecifics separated by over 5° latitude.<sup>57</sup> In 1992, the team was awarded the Pol Eureka Prize for Environmental Science for the ground breaking discovery of the mass spawning of corals on the GBR.

Building on knowledge of the predictability of coral spawning as a Marine Science Technology Grant Scheme (MSTGS) funded research fellow, Willis investigated the capacity of coral larvae to disperse between reefs. In a large collaborative study involving oceanographers from AIMS and overseas, Willis co-ordinated underwater diving teams, plankton sampling teams, and aerial surveys to simultaneously document inter-reef dispersal of coral larvae in coral spawn slicks and retention of coral larvae on a natal reef.<sup>58</sup> Knowledge of the inter-connectivity of reefs was

<sup>&</sup>lt;sup>52</sup>Wallace (1999).

<sup>&</sup>lt;sup>53</sup>Wallace and others (2012).

<sup>&</sup>lt;sup>54</sup>Hutchings and others (2008). Hutchings and others (2019).

<sup>&</sup>lt;sup>55</sup>Willis and others (1985).

<sup>&</sup>lt;sup>56</sup>Harrison and others (1984).

<sup>&</sup>lt;sup>57</sup>Willis and others (1985). Babcock and others (1986).

<sup>&</sup>lt;sup>58</sup>Willis and Oliver (1988). Willis and Oliver (1990).



Fig. 10. Bette Willis. Photo courtesy of Centre of Excellence, James Cook University, Annual Report 2016.

taken into consideration when the entire GBR was rezoned in 2004. Intrigued by observations of closely-related species spawning on the same nights, Willis also developed controlled laboratory crosses to demonstrate successful inter-specific fertilisation among many coral species.<sup>59</sup> Such challenges to the biological species concept led to her seminal paper on the role of hybridisation in the evolution of reef corals.<sup>60</sup>

Willis was appointed a senior lecturer at JCU in 1993, introducing new undergraduate and postgraduate subjects in coral life histories and coral reef ecology, as well as coordinating and growing postgraduate coursework programs. Willis became the first female professor in marine biology at JCU in 2006 and supervised over 100 postgraduate students, many of whom are now prominent coral reef scientists (Fig. 10). She also believed in the utility of island research stations to support cost-effective research and access to the field, and played an active role in developing Orpheus Island Research Station, gaining a federally-funded research infra-structure grant to build environmentally controlled experimental facilities.

Willis collaborated with many national and international experts to elucidate the potential of dinoflagellate algae from the family Symbiodinaceae to govern the physiology and thermal tolerance of their coral host.<sup>61</sup> Further pivotal studies identified the importance of coral-bacterial associations to coral health.

Willis joined the Global Environmental Facility (GEF)/ World Bank Working Group on Coral Disease as the Australian coral expert in 2002 to assist the working group with exploring the significance of emerging coral diseases on reefs worldwide. Willis and her team documented the widespread presence of diseases like 'white syndromes' and 'black band disease' on the GBR and identified 'brown band disease' for the first time.<sup>62</sup> As part of the working group, Willis surveyed the prevalence of coral diseases on reefs in the Caribbean and throughout the Indo-Pacific. Willis and her colleagues showed that MPAs can ameliorate coral disease,<sup>63</sup> a major concern to GBRMPA. Willis's work highlights that climate change and declining water quality have critical, long-term consequences for the continued viability of coral reefs.

Willis was a chief investigator in the ARC Centre of Excellence for Coral Reef Studies from its inception in 2005 until she retired, becoming emeritus professor in 2017. For research, primarily on Australian coral reefs, she received an International Society Reef Studies (ISRS) Eminence in Research Award. Willis served on the council of the ACRS, 1990–4, during which time she actively participated in developing the society's submission for the initial zoning of the GBRMP, and then again, 2000–4.

### **Concluding remarks**

The remarkable body of work by the ten female coral reef scientists highlighted here has substantial implications for how we understand the structure and function of Australia's coral reefs, across a range of temporal and spatial scales. In no small part, Australia is now well-recognised as a major world player in coral reef science due to the contribution of the ten women profiled here. This rise in coral reef science in Australia began with the Great Barrier Reef expedition to Low Isles, 1928–9, in which three of the profiled women contributed.

The other women were able to make contributions as research stations developed on the GBR, and through the establishment of AIMS (initially in Townsville but later with laboratories in Darwin and Perth) and the COE in Townsville.

<sup>&</sup>lt;sup>59</sup>Willis and others (1997).

<sup>&</sup>lt;sup>60</sup>Willis and others (2006).

<sup>&</sup>lt;sup>61</sup>Little and others (2004).

<sup>&</sup>lt;sup>62</sup>Willis and others (2004).

<sup>&</sup>lt;sup>63</sup>Lamb and others (2016).

The women also contributed to the establishment of coral reef marine parks, facilitated long-term management of the reefs, and supported management orientated research.

Three of the women highlighted were employed in museums (Mather, Marsh and Wallace) and actively collected and documented the biodiversity of Australia's coral reefs and nearby Indo-Pacific reefs. In the 1960s, Australian coral reef research was helped by the advent of scuba diving, which meant that collections previously restricted to the intertidal zone, or carried out using ship operated dredges, could focus on underwater fauna. Indeed, Manton's use of primitive dive gear to descend down the reef slope at Low Isles likely yielded Australia's earliest close-up scientific observations of changing coral character with water depth.

The broader reef-scale work of Manton and Stephenson at Low Isles represented one of the first ecological surveys of a complete coral reef platform, giving rise to better understanding of the ecological zonation while provided a foundation for later studies, including detailed re-surveys of to establish reef community changes over some of the longest global coral community records (for example, 90 years of ecological survey).

The documentation, identification and description of the wealth of new species of marine fauna encountered across Australia's vast reefs was critical in developing field identification guides, which ecologists would later use to study the ecological processes operating on those reefs. Collections from some of Australia's remotest reefs are now accessible through the Atlas of Living Australia, such that researchers anywhere in the world can see what is available for loan, or visit Australian institutions to examine the material.

Although not formally trained in marine science, both Stephenson and Bennett acquired considerable skills in handdrawing and photography respectively to illustrate reef biotas. Bennett went on to combine this talent with her editorial skills to prepare numerous books. These exposed the general public and academics to what was present on Australian seashores, and the wonders of the GBR, leading many student field trips to the reef from Sydney University. Manton also drew beautiful coral maps and was a master photographer.

Through the discoveries made by Harriott, Wallace and Willis, we now understand the metabolism of free swimming coral larvae, the timing and scale of coral spawning, and how corals are able to survive in turbid environments. The capacity of Hill and Wallace to organise, interpret and classify large collections of specimens has given us the terminology to describe living corals across broad geographic areas, as well as fossil corals through stratigraphic sequences drilled deep into reefs as expressed through fossil limestones, helping us to understand both Australian and global coral faunas through space and time. In turn, this has helped us to elucidate latitudinal gradients in coral community composition and coral recruitment, how coral reefs are connected through larval dispersal.

In making some of Australia's earliest observations of coral bleaching at Lizard Island in 1982, Harriott postulated causal links to UV radiation and ocean warming that would later be confirmed. Indeed, as reef scientists have increasingly focused on understanding threats to coral reefs, links that these women uncovered between ocean warming and coral disease, and the variable symbioses of corals with dinoflagellate algae from the family Symbiodiniaceae, have led to a greater understanding of the vulnerability of coral reefs.

The Australian women highlighted in this paper were involved in teaching, running field-trips, writing instructional material such as field guides, developing museum displays, communicating coral reef science to the general public and supervising the next generation of scientists and Hill was an important mentor to Wallace. More recently Harriott, Wallace and Willis all worked together and interacted with many other members of ACRS as well as being close friends.

All the women profiled in this paper were leaders in their field, and many combined motherhood with their careers, and all were/are strong women who basically broke through barriers to undertake their research.<sup>64</sup> They were often the first women to be appointed to positions, and became role models for the next generation of female researchers.<sup>65</sup> As well as undertaking their own research, these women mentored students into an era where there are almost equal numbers of men and women undertaking undergraduate and postgraduate degrees in geology and marine biology. As the women enter the academia, however, parity declines.<sup>66</sup>

We suggest that as coral reef science is a relatively young discipline, which really took off after the advent of SCUBA, and an era in which there was increasing acceptance of women in the work force, that women are better represented in this field than in others.<sup>67</sup> All these Australian women were committed to the conservation and responsible management of coral reefs, as reflected in their heavy involvement in GBRC/ACRS, alongside other conservation groups. At times, their advocacy resulted in meaningful, practical outcomes for Australian coral reefs, notably in relation to preventing limestone mining on the GBR, providing foundation for the establishment of marine reserves and ensuring the sustainable operation of the Queensland Coral Fishery. Their achievements in advancing our understanding of Australia's coral reefs were recognised by numerous scientific awards, esteemed scientific fellowships and, four of them were made Officers of the Order of the British Empire (Marshall) and Australia (Bennett, Marsh, Wallace) respectively. Hill was also

<sup>&</sup>lt;sup>64</sup>Hooker (2014).

<sup>&</sup>lt;sup>65</sup>Gillanders and Heupel (2019).

<sup>&</sup>lt;sup>66</sup>Gillanders and Heupel (2019).

<sup>&</sup>lt;sup>67</sup>Gillanders and Heupel (2019).

president of the Australian Academy of Sciences in 1970, a society which has also supported Australian coral reef science.

Bennett and Harriott have both had reefs on the GBR named after them, one close to Heron Island and the other in the Cairns/Cooktown management Area, respectively, a fit-ting tribute to both.

Many of the women highlighted in this paper, were not only leaders in their field of research but were involved in promoting Australian coral reef research,<sup>68</sup> and increasingly in the conservation and management of reefs through the ACRS. Making their achievements visible enables them to act as role models for the next generation of female students.

We argue that in their own unique ways, each of these women is outstanding by virtue of having overcome some of the exclusionary obstacles that face women scientists. In the field of marine sciences, these include exclusion from, or marginalisation while working on, boats,<sup>69</sup> which was a form of discrimination experienced by Marsh, Wallace and Bennett. There has also been a lack of acknowledgement of their contributions. Bennett's contribution to the landmark *Australian Seashores* was under-acknowledged on its publication in 1952. She went on to revise eleven editions, including an update with her own colour photographs.

Most of these women also juggled bringing up children with field work. In a published oral account, Wallace recalled a significant moment of scientific discovery in which mass coral spawning was first witnessed on a beach at Magnetic Island with her kids and one other researcher in the middle of the night: 'he (the other scientist) stands up and is making all these noises through his snorkel, screaming out. And they were all spawning. And everything was spawning—just going off. I had to wait until he came back up to say "don't you leave my kids!" before I got my chance to go in the water.'<sup>70</sup> It is a moment that illustrates the tensions experienced by women scientists who have caring responsibilities. All of these women broke barriers in women's participation in the work place.

Making the remarkable scientific achievements of these women visible while also emphasising the outstanding steps they took to overcome obstacles to their professional advancement as scientists, and the work they did to translate science into coral reef protection and management subverts their absence from much of the recorded history of coral reef science and enables them to act as role models for the next generation of female scientists.

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<sup>&</sup>lt;sup>68</sup>Gillanders and Heupel (2019).

<sup>&</sup>lt;sup>69</sup>Vila-Concejo and others (2018).

<sup>&</sup>lt;sup>70</sup>Foxwell-Norton and others (2021).

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Data availability. Data sharing is not applicable as no new data were generated or analysed during this study.

Conflicts of interest. The authors declare no conflicts of interest.

#### Declaration of funding. None.

Acknowledgements. We thank the following for providing images, Fryer Library, University of Queensland, Jeanie Clifford, Western Australian Museum, Zoe Richards, Mike Hadfield, Lyle Vail and ARC Centre of Excellence. Several people were very helpful in providing information including Mike Kingsford, Andrew Hosie and Fred Wells. Pat Hutchings is polychaete systematist and ecologist who has worked extensively on coral reefs, especially with regard to bioerosion. She was on the GBRC as the museum representative and has been President of the ACRS and was a Member of the Resource Assessment Committee–Biodiversity and World Heritage–Great Barrier Reef Marine Park Authority for ten years. Barbara Brown is a coral ecophysiologist who has worked in the Caribbean and south east Asia. She has combined research on coral bleaching responses with an interest in the history of science, specifically the scientific legacy of Professor Stanley Gardiner and his involvement with the GBRC, and the scientific achievements of the 1928–9 Great Barrier Reef Expedition to Low Isles. Maria Byrne is a coral reef biologist and ecologist with field experience in the Caribbean Sea and South Pacific Ocean. Her research has focussed on tropical echinoderms with recent publications on the crown of thorns sea star focussing on the early life history stages and how they contribute to outbreaks as well as on bêche-de-mer sea cucumbers with respect to the fishery on the Great Barrier Reef Acces for 20 years. Her interests in the history of coral reef science have led her to publish on Darwin's theory of coral reef formation, historic island mapping expeditions on the Great Barrier Reef. Tom Spencer is a coral reef geomorphologist, sedimentologist and ecologist with field experience in the Caribbean Sea, South Pacific Ocean and Western Indian Ocean. He has interests in the history of reef science, publishing recently on the origins of the GBRC and the achievements of the I928–9 Great Barrier Reef.

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