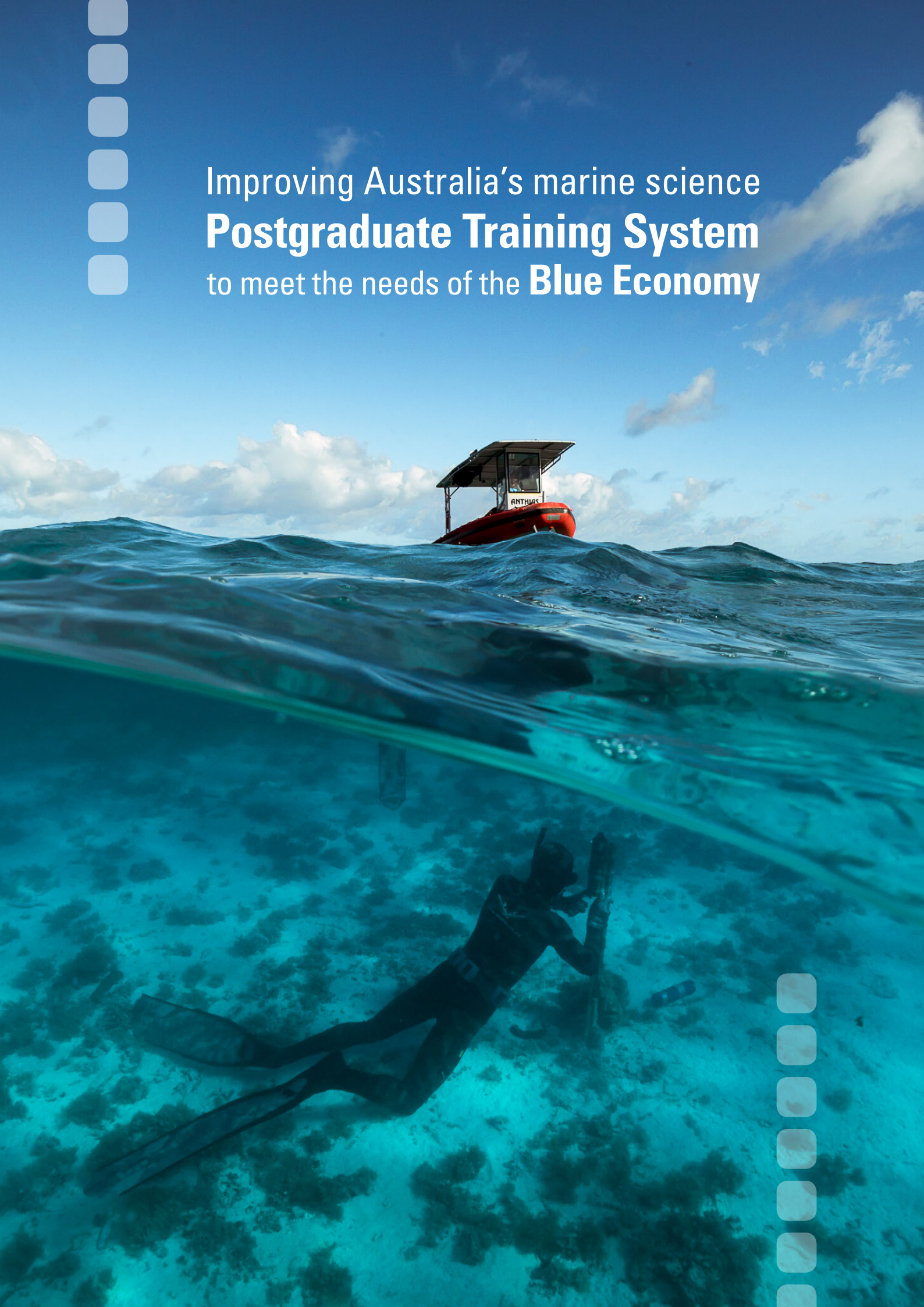
Improving Australia's marine science

Postgraduate Training System

to meet the needs of the **Blue Economy**



NATIONAL MARINE SCIENCE – COMMITTEE –

Improving Australia's marine science Postgraduate Training System to meet the needs of the 'Blue Economy'

Prepared by a Working Group of the **National Marine Science Committee**

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Front cover Image: Fabrice Jaine
(Sydney Institute of Marine Science)

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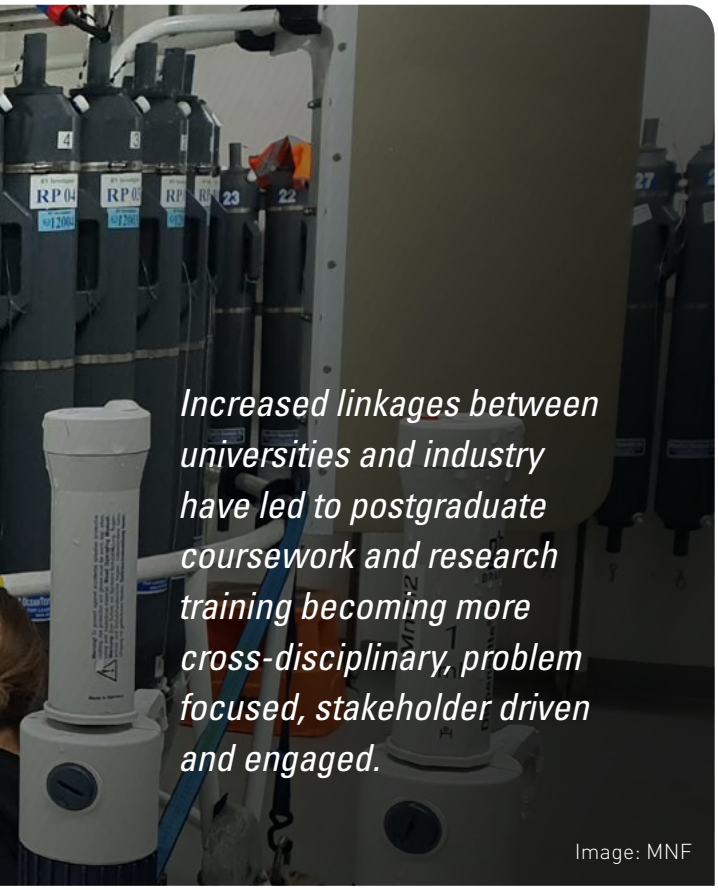
Executive **summary** |

- In 2015, the National Marine Science Plan concluded that developing the 'Blue Economy' would require a strong and skilled work force of marine scientists trained in emerging science fields, with strong quantitative skills, working at world-class level in cross-disciplinary team environments. The Plan recommended refocusing marine science research training to make it more quantitative, cross-disciplinary and congruent with the needs of the industry and government.
- This report was developed and overseen by the Working Group established by the National Marine Science Committee to lead the implementation of this recommendation.
- Although there have been no major changes in the course requirements for postgraduate degrees in Australia, government funding and reporting drivers changed in 2017 to provide universities with additional incentives to improve their research collaboration with industry. In addition, the 2016 ACOLA Review of Research Training stressed the need for universities to take transferable skills training more seriously which resulted in the Commonwealth making significant investment in industry internships for PhD students.
- Increased linkages between universities and industry have led to postgraduate coursework and research training becoming more cross-disciplinary, problem focused, stakeholder driven and engaged. Also, various recent initiatives, both external and internal to universities, have increased opportunities for postgraduate students to undertake work-integrated learning (WIL), internships and industry-embedded, co-supervised and funded PhDs.
- We investigated the current situation using a number of approaches including: (1) surveying 57 senior representatives of 47 employers from various marine sub-sectors, 65 recent graduates from 15 universities, and 362 Masters and PhD students from 31 universities; and, (2) conducting in-depth interviews with 47 employers, and (3) analysing submissions from 23 of the 39 comprehensive universities across Australia.
- In their priority order, the top disciplinary knowledge areas currently sought by marine sector employers are: (1) environmental science and management; (2) marine biology; (3) mathematics, statistics, and modelling; (4) marine and microbial ecology; (5) cross-disciplinary studies;

(6) marine engineering; (7) oceanography; (8) fisheries; (9) computer science; and (10) social science. Both the environmental consulting sector and publically funded research agencies (PFRAS) put mathematics, statistics, and modelling at the top of their list.

- Employers reported difficulties in finding graduates with expertise in social science, quantitative fisheries science, water quality, agronomy, engineering (coastal, structural, maritime, metocean[1]), and mathematics. They were also concerned about their quantitative, teamwork, and/or project management skills, empathy, emotional intelligence, and/or personality fit.
- A third of employers anticipated that the disciplinary knowledge and skills needs of their organisation would change over the next decade, with more emphasis on specialist skills (information technology, computing, analytics, statistics/modelling, artificial intelligence, machine learning) and a greater focus on social science, genetics, law, and engineering. Employers also want marine science professionals who are more adaptable, flexible, and have the ability to work across disciplines on large complex projects.



Increased linkages between universities and industry have led to postgraduate coursework and research training becoming more cross-disciplinary, problem focused, stakeholder driven and engaged.

Image: MNF

- Australian universities have world-class expertise in these areas. There are many postgraduate offerings in the disciplines relevant to the current and future needs of the 'Blue Economy'.
- Few universities have explicitly attempted to address the 'legacy mismatch' between the disciplinary focus of postgraduate training and industry demand.
- All universities surveyed specifically mentioned formal, informal and/or ad-hoc training offerings (workshops, seminars, coursework, informal support, etc.) that help students develop the transferable skills sought by employers and/or required to complete their postgraduate degrees.
- Some universities have made considerable efforts to increase the quantitative skills of marine scientists, largely through short courses and advanced coursework. This approach seems to be aimed at increasing the skills of non-mathematicians, rather than attracting people with advanced quantitative skills to apply them in a marine science context.
- Most of these improvements are generic rather than targeted to the 'Blue Economy'. The next stage in addressing 'Blue Economy' training needs should be establishing bespoke initiatives based on the many good ideas provided by the employers, graduates, students and universities who contributed to this study.
- The available information on the number of research higher degree candidates studying marine science is inaccurate. There is no Field of Research code for marine science and the marine science is listed as a 6–digit code (010907) under the biological sciences' "broad" Field of Education, which means that is unlikely to be used as a reporting code for students in other "broad" disciplinary areas e.g., engineering. Including a specific code for marine science in the Fields of Education and Fields of Research typologies would enable more accurate data to be collected.

[1] Metocean data are an important and highly useful category of oceanographic and marine data that comprises observed measurements of current, wave, sea level and meteorological data.

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BELOW: **Meghan Duffy – undergraduate student studying geology and biology** – Image: CSIRO

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Acronyms used in this report |

AIMS – Australian Institute of Marine Science
ANU – Australian National University
ATN – Australian Technology Network
CDU – Charles Darwin University
CQU – Central Queensland University
CSIRO – Commonwealth Scientific and Industrial Research Organisation
ECU – Edith Cowan University
HDR – Higher Degree by Research
JCU – James Cook University
NMSP – National Marine Science Plan
NMSC – National Marine Science Committee
PFRA – Publicly Funded Research Agency
QUT – Queensland University of Technology
RMIT – Royal Melbourne Institute of Technology
SCU – Southern Cross University
UNSW – University of New South Wales
UQ – University of Queensland
UTAS – University of Tasmania
UWA – University of Western Australia
UOW – University of Wollongong
WSU – Western Sydney University

Acknowledgements |

We gratefully acknowledge the National Marine Science Committee, especially Tim Moltmann, for catalysing and funding this work. We thank the other members of the Working Group Dr. April Abbott (Macquarie University), Professor Lynnath Beckley (Murdoch University), Dr. Penny Berents (President of the Australian Marine Sciences Association), Associate Professor Will Figueira (University of Sydney), and Professor Iain Gordon (James Cook University). Professor Erika Teshera (University of Western Australia) chaired the Working Group in 2017. The National Marine Science Committee provided important contacts and valuable insights. Margaret Carlin (Australian Institute of Marine Science) provided research assistance, especially during the early stages of the project. Associate Professor Inger Mewburn (Australian National University) generously provided access to unpublished work. Finally, we gratefully acknowledge the employers, graduates and students who took the time to contribute to this research and whose responses have informed our work.

Image: April Abbott

1. Introduction |

Australia is a maritime nation with the world's third largest Exclusive Economic Zone. Our marine, aquatic, and maritime (hereafter, 'marine') sector is dedicated to working with governments, industries and communities to ensure that Australia gets the most from its marine estate while protecting the things we all care about.

The size of the workforce associated with the 'Blue Economy'[2] is large. The Australian Institute of Marine Science Index of Marine Industry (2018) reported that there were 393,000 marine related industry workers in 2015-2016. The Intergovernmental Oceanographic Commission estimated that Australia had 2000 ocean science personnel and researchers, with approximately 50% being researchers (IOC 2017). The development of this 'Blue Economy' is guided by the National Marine Science Plan (NMSP), launched in August 2015.

The NMSP outlines the science needed to "*help Australia realise the triple-bottom-line benefits of our marine estate while protecting the values and natural assets we all hold so dearly*" (NMSC 2015). One of the Plan's conclusions was that central to the development of the 'Blue Economy' is a strong and skilled work force of marine scientists trained in emerging science fields, with strong quantitative skills, working at world-class level, and in cross-disciplinary team environments. Indeed, one of the Plan's eight recommendations was to "*develop marine science research training that is more quantitative, cross-disciplinary and congruent with the needs of the industry and government*".

Addressing this recommendation requires first understanding the situation in Australia. To provide leadership on the implementation of this recommendation, the National Marine Science Committee (NMSC) established our Working Group in 2017 and commissioned research to assess whether Australia's university postgraduate training offerings can meet the needs of the future Blue Economy.

The specific aim of our research was to investigate the congruence between Australia's postgraduate training and the professional staff needs of non-university employers in Australia's marine sector.

We tackled our research aim using three objectives. Our first objective was to understand the professional staff needs of relevant non-university employers and capture their perspectives on the training and recruitment of graduates (Bachelors, Masters, PhD). Our second objective was to understand the perspectives of students and recent graduates (Masters and PhD) seeking employment in Australia's marine sector. Specifically, we assessed their awareness of employer needs and captured their perspectives regarding their postgraduate training. Our third and final objective was to assess current university offerings in the context of employer needs and to evaluate efforts of universities to address issues highlighted by employers, graduates and students. Our results reflect the situation in 2019.

The specific aim of our research was to investigate the congruence between Australia's postgraduate training and the professional staff needs of non-university employers in Australia's marine sector.

[2] According to the World Bank, the **blue economy** is the "sustainable use of **ocean** resources for economic growth, improved livelihoods, and jobs while preserving the health of **ocean** ecosystem." European Commission defines it as "All economic activities related to oceans, seas and coasts."

2. Methods |

2.1. Definitions

For the purpose of our study, we use the term 'marine sector' to collectively describe all organisations for which some or all activities are associated with the marine environment. We use the term 'industry' to refer to businesses, governments, and non-government organisations (excluding universities) that are end users of marine research and/or employers of marine professionals. Finally, our definition of 'marine science' incorporates all disciplines relevant for working in the marine sector, including engineering, mathematics, law, business, statistics, technology, biological, ecological, chemical, physical and social sciences. Our definition also includes cross-disciplinary studies that may be associated with project and research work for a higher degree.

We referred to the Australian Institute of Marine Science (AIMS) Index of Marine Industry (AIMS 2018) to develop five broad groupings (hereafter 'sub-sectors') of marine industry: (1) fishing (marine-based aquaculture, commercial and recreational fishing); (2) offshore oil and gas exploration and extraction; (3) boat/ship building, repair and maintenance services and infrastructure; (4) marine tourism and recreation; and, (5) ports and shipping. We also identified an additional nine sub-sectors of marine industry that employ marine professionals: (1) not-for-profit organisations; (2) publicly funded research agencies (PFRAs); (3) environmental consulting; (4) emerging marine industries (deep sea mining, renewable ocean energy, bioprospecting); (5) marine insurance; (6) marine safety; (7) federal/state government departments; (8) local governments and councils; and, (9) marine construction.

2.2. Employer online surveys and interviews

We implemented online surveys and telephone interviews with a cross-section of non-university employers from Australia's marine sector. Eligible participants were senior representatives of employers from one of the 15 identified sub-sectors of marine industry, who seek to hire marine science graduates – specifically, Masters (both Masters by coursework and Masters by research[3]) and PhD graduates. Potential employer interviewees were identified through the established networks of the Working Group and invited via e-mail to participate in the study. Further participants were identified through snowball sampling and online searches. Given that our aim was to interview as many people as possible within the budgeted time period, we used purposive sampling (Etikan et al. 2016) to obtain the best possible spread across sub-sectors.

Online survey questionnaires included closed and open-ended questions designed to capture employers' perceptions regarding graduate recruitment (Appendix 1). Employers were asked to provide information regarding: (1) the disciplinary backgrounds of their professional staff; (2) the transferable skills, personal attributes and disciplinary knowledge areas prioritised in considering a graduate for employment, and how each might change over the next decade; and, (3) the level of importance placed on five 'categories' of skills, experience and knowledge when recruiting graduates, namely, technical knowledge, transferable skills, life experience, technical skills, and professional experience (each rated on a 5-point scale). We also collected relevant human resources-related information for each employer, including the size of the organisation (number of employees, annual total financial turnover), hiring rates for marine graduates of different qualification levels (Bachelors, Honours, Masters, PhD), and the percentage of permanent versus temporary staff (Appendix 1).

We conducted telephone interviews with a subset of online survey participants to obtain additional qualitative and quantitative information to complement online surveys (Appendix 1). During the interview, we asked employers closed and open-ended questions to capture their perceptions regarding postgraduate training and graduate recruitment, including: (1) the importance of disciplinary background and research experience as selection criteria; (2) the importance of both coursework and research in defining a candidate's disciplinary background (each rated using a 5-point scale); (3) the desired qualification level of new hires; (4) the potential advantages and disadvantages of one qualification over another; (5) the added value of recruiting staff with a PhD; and, (6) challenges in recruiting and keeping job-ready graduates.

[3] In Australia, a Masters degree by research (typically called an MPhil) must contains >66.7% research. A Masters degree with a lower percentage of research is called a Masters by coursework (typically a named Masters degree e.g. MSc). Many coursework Masters require a small project as part of the assessment.

We also asked interviewees to provide information regarding any existing graduate entry training programs and internship programs, including the role of internships in the selection of new employees.

2.3. Graduate and student online surveys

Online survey questionnaires containing closed and open-ended questions were used to record the range of perceptions, experiences and opinions of marine science graduates and students regarding their postgraduate training (Appendix 2, 3). Eligible participants for the surveys were individuals who aspired to a career in Australia's marine sector and, at the time of the research, were enrolled in, or recently graduated from (within 5 years), a relevant Masters or PhD program at an Australian university. Given the diversity of Australia's marine industry, relevant programs included studies in engineering, mathematics, statistics, technology, biological, social and physical sciences, law, and business. Consent to participate in the survey was incorporated as the first survey question. To ensure the reliability of our results, an initial screening question was used to exclude ineligible graduates and students from continuing through the survey.

Students and graduates were asked to provide information about their postgraduate training (qualification, institution, discipline of study, phase of degree) and to reflect on their training and career aspirations, including: (1) employment experience relevant to their degree; (2) links to, collaboration and/or experiences with relevant non-university supervisors and workplaces; (3) participation in internships, cadetships or professional placements; (4) their preferred sub-sector of employment after obtaining their degree; (5) which transferable skills, personal attributes and disciplinary knowledge they thought were most important to employers in their preferred sub-sector; and, (6) how well the transferable skills they selected were developed through their postgraduate training (graduates were asked to provide a rating on a 5-point scale). We also collected demographic information (age, gender, country of birth). Graduates were asked additional questions regarding: (1) their current employment (status, contract type, role, employer); (2) the strengths and weaknesses of their postgraduate training; (3) how their training could have been modified to better meet their employment needs; and, (4) what advice they would give to current postgraduate students aspiring to a career in the marine sector (Appendix 3).

2.4. Invitations for University submissions

Following preliminary analysis of employer, graduate and student responses in January 2019, we used the issues identified by these groups as the basis of an invitation for Australian universities to make submissions to the project. We asked for information regarding their postgraduate programs relevant for training Australia's future marine professionals, and their ongoing and/or proposed action to address issues identified in our study. All 39 of Australia's comprehensive universities were invited to make a narrative submission.

Our invitation included four sections (Appendix 4). The first section was designed to obtain overview information on the university's engagement in postgraduate coursework and research training in marine science (e.g. programs offered, nature of the student body). The second section included questions aimed at understanding what the university is currently doing (or could be doing) to help produce graduates with the key transferable skills, disciplinary expertise and personal attributes sought by employers. The third section included questions designed to gather information regarding: (1) the existence of internship, work placement and/or cadetship programs and availability across different disciplines; and, (2) any links with industry and government employers who hire university-trained marine professionals. Finally, the fourth section included questions designed to capture the university's perspective on Australia's postgraduate training in marine science, including: (1) what features should be retained to ensure graduates are internationally competitive; (2) the suggested structure of the training system within universities; (3) opportunities for cross-institutional collaboration; and, (4) how universities can help overcome barriers to participation experienced by under-represented groups.

2.5. Sampling

We collected responses from employers (n = 57), graduates (n = 65), and students (n = 362) from November 2018 through March 2019. University submissions (n = 23) were obtained during March and April 2019.

Online surveys for employers, graduates, and students were distributed via university mailing lists, alumni newsletters, peak industry body and association mailing lists and social media. Potential participants received an e-mail containing a link to the relevant online survey, as well as information about the study, its purpose, and how the data would be used. To maximise the response rate for graduate and student surveys, we provided financial incentives in the form of two enter-to-win prizes valued at $500 (Australian Dollars), one for each group. Given that we could not determine the total number of eligible participants that received the online surveys, we were unable to record response rates.

Potential employer interviewees were invited via e-mail to participate in the study. Employers who agreed to participate were asked to complete the online survey prior to the scheduled telephone interview. Before beginning the interview, we reminded participants about the purpose of the study and how the data would be used. For each interview, we obtained the participants verbal consent for the conversation to be audio recorded.

The invitation for university submissions was distributed via an e-mail invitation to the Vice Chancellor and Deputy Vice Chancellor (Research) at each of Australia's 39 comprehensive universities (response rate was 59%). The e-mail included information about the study, our definition of marine science, and an invitation for the university to make a submission informed by university staff from relevant disciplines. Universities were given five weeks to prepare and upload a submission online.

The sampling protocols for employers, graduates, students and universities were reviewed and approved by James Cook University's Human Research Ethics Committee (Approval #H7559).

2.6. Data analysis

We used hierarchical ordinal regression models to explore the level of importance employers place on five 'categories' of skills, experience, and knowledge (technical knowledge, technical skills, transferable skills, life experience, and professional experience). The first model considered employers from all sub-sectors collectively, while subsequent models considered sub-sectors individually where the sample sizes were large enough to permit analysis (i.e., where $n \geq 5$). Category was modeled as a categorical independent variable, with rating modeled as an ordinal dependent variable.

To account for the clustered structure of the data (i.e., multiple responses from the same respondent), we set respondent as a random effect *a priori*.

The proportional odds assumption was verified by testing for nominal and scale effects. Where the effect of category had a probability below 0.05, post hoc pairwise contrasts (Tukey-adjusted for multiple comparisons) were performed to test for differences in perceived importance across categories. Hierarchical ordinal regression models and pairwise comparisons were implemented using the *clmm* and *lsmeans* functions of the *ordinal* package in R (version 3.5.3, R Core Development Team 2019).

To examine the disciplinary knowledge areas prioritised by employers and qualitatively assess their congruence with the perceptions of students and graduates, we used relative frequencies – the number of times a discipline was mentioned by a specific group (employer, graduate, or student) divided by the total number of responses for that group. The same procedure was applied to examine the transferable skills and personal attributes most sought by employers, and qualitatively compare their responses to those of students and graduates. To determine whether overall trends were consistent across different sub-sectors of marine industry, we also examined individual sub-sectors where samples sizes were large enough to permit qualitative comparison (employers, $n \geq 5$; graduates ≥ 5; students ≥ 20).

We used two categorical clustering approaches to explore whether: (1) individual employer respondents ($n = 57$) and, separately, (2) sub-sectors ($n = 12$) could be grouped based on their similarities with respect to the disciplinary knowledge, transferable skills and personal attributes they prioritised when recruiting graduates for employment. In both analyses, clusters were identified from an agglomerative clustering approach using the *kmodes* function of the *klaR* package in R (version 3.5.3, R Core Development Team 2019). This approach failed to reveal any clear or logical groupings due to considerable variation between responses within sub-sectors and the results are not included in this report.

We used an iterative grounded theory approach (Glaser and Strauss 1967; Corbin and Strauss 1990) to identify themes as we uncovered them in the interview responses and university submissions. Notes taken during the interviews were used as a thematic framework to guide the subsequent qualitative analysis.

3. Results |

3.1. Sample descriptions

3.1.1. Employer sample

We received responses from 57 senior representatives of 47 employers from various marine sectors across Australia including environmental consulting (*n* = 10), marine tourism and recreation (*n* = 9), federal and state government (*n* = 5), offshore oil and gas (*n* = 1), non-profit (*n* = 7), ports and shipping (*n* = 1), emerging marine industry (*n* = 2), PFRAs (*n* = 12), local government (*n* = 4), and fishing and aquaculture (*n* = 3) (Figures 1 and 2).

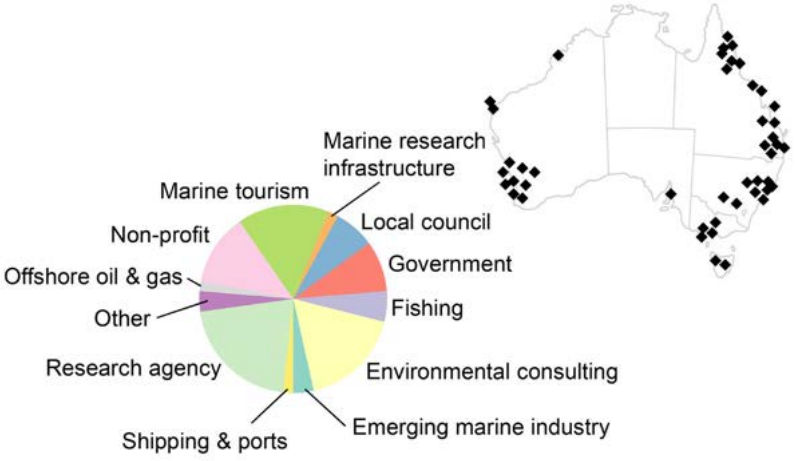

Figure 1. Geographic and sub-sectoral distribution of employer online survey respondents (*n* = 57).

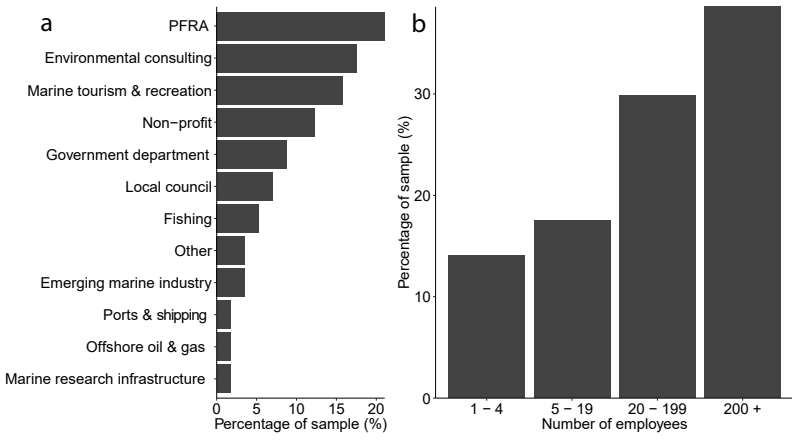

Figure 2. Distribution of employer online survey respondents (*n* = 57) across: (a) sub-sectors of Australia's marine industry and (b) organisation sizes, based on the total number of employees. The information on organisation size is designed to illustrate the type of firm interviewed rather than the number of 'Blue Economy' workers *per se*.

Employers supervised professional staff with a variety of disciplinary backgrounds, with the three most common overall being marine biology, environmental science and management, and marine ecology (Figure 3a). A subsample of 39 employer respondents provided rich additional information via telephone interviews.

3.1.2. Graduate sample

We received responses from 65 graduates from 15 universities (Figure 4) who, at the time of the study, had recently (within 5 years) graduated from a Coursework Masters (23%, *n* = 15), Research Masters (9%, *n* = 6), or PhD (65%, *n* = 42) program at an Australian university (Table A1, Figure A1, Appendix 5). Graduate respondents varied in nationality (20 countries with Australia, USA, France, Switzerland and Canada being the top five) and age (means being 31.6 years for Masters by coursework, 32.3 years for Masters by research and 32.4 years for PhD; Appendix Table A1, Appendix Figure A2, Appendix 5), and had been trained in various disciplines (Appendix Figure A1, Appendix 5). Overall, the three most common disciplines of study were marine biology (45%, *n* = 29), marine ecology (19%, *n* = 12), and environmental science and management (6%, *n* = 4) (Appendix Figure A1, Appendix 5). Just over one third (35%, *n* = 23) were currently living in an Australian state different to that in which they completed their postgraduate degree.
Among employed graduates (88%, *n* = 57), 56% were working full-time, 21% held a permanent or ongoing position, and 74% were using skills and/or knowledge gained from their degree in their current work. Among unemployed graduates (12%, *n* = 8), 75% (*n* = 6) were looking for work.

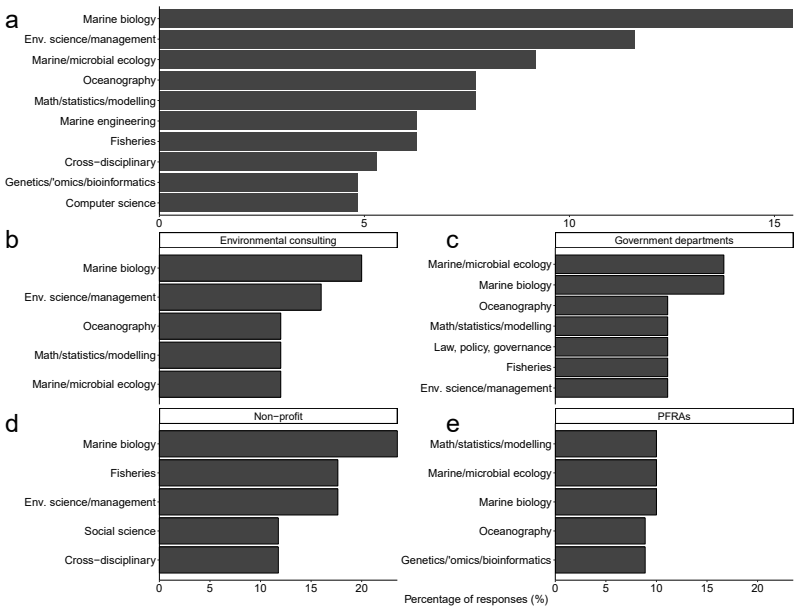

Figure 3. Most common disciplinary backgrounds of staff as reported by employers from: (a) all sub-sectors (n = 57), and within (b) environmental consulting (n = 10), (c) government departments (n = 5), (d) non-profit organisations (n ¬= 7), and (e) publicly funded research agencies (PFRAs, n = 12).

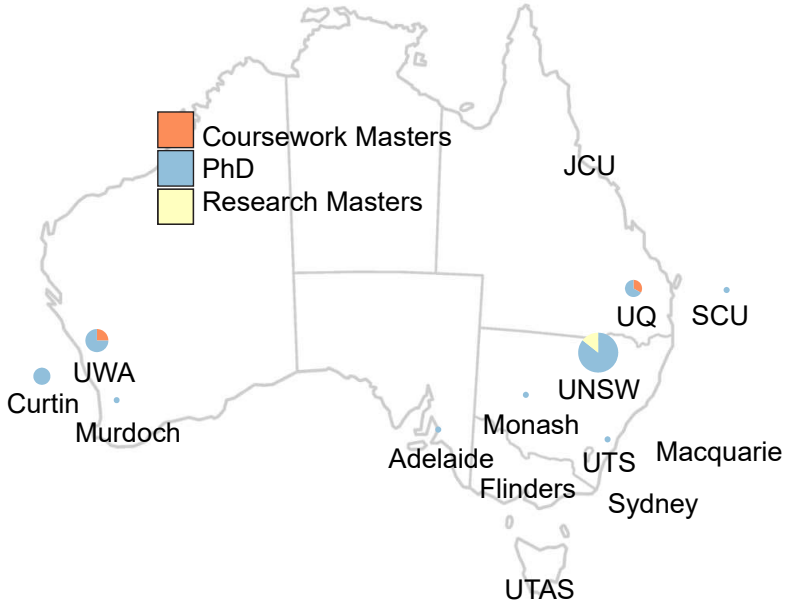

Figure 4. Graduating university and highest postgraduate qualification of graduate respondents (n = 65). JCU, James Cook University; SCU, Southern Cross University; UNSW, University of New South Wales; UQ, University of Queensland; UTAS, University of Tasmania; UTS, University of Technology Sydney; UWA, University of Western Australia.

Most graduates (72%, n = 47) said they would prefer to work for a non-university employer in the marine sector (Figure A3, Appendix 5), and 60% felt moderately or very confident that they would be able to successfully pursue a career in their preferred sub-sector.

3.1.3. Student sample

We received responses from 362 students who, at the time of the study, were enrolled in a coursework Masters (17%, n = 63), research Masters (9%, n = 32) or PhD (74%, n = 267) program at an Australian university (Table A1, Figure A4, Appendix 5) (Figure 5). Students enrolled in a research degree (83%, n = 298) were in various stages of their candidature (planning: 19%, execution: 38%, finishing: 37%, examination: 6%). Student respondents varied in nationality (18 countries with Australia, India, USA, China, and Iran being the top five) and age (means being 28.4 years for Masters by coursework, 33.8 years for Masters by research and 32.4 years for PhD; Table A1, Figure A5, Appendix 5). Students were undertaking study in various disciplines (total = 13; Figure A4, Appendix 5), with the three most common being marine biology (24%, n = 87), marine ecology (11%, n = 38), and cross-disciplinary studies (7%, n = 25). Most students (74%, n = 267) said they would prefer to work for a non-university employer in the marine sector after obtaining their degree (Figure A6, Appendix 5), 52% preferred a research role after graduation, and 70% felt moderately or very confident that they would be able to successfully pursue a career in their preferred sub-sector (Table 1).

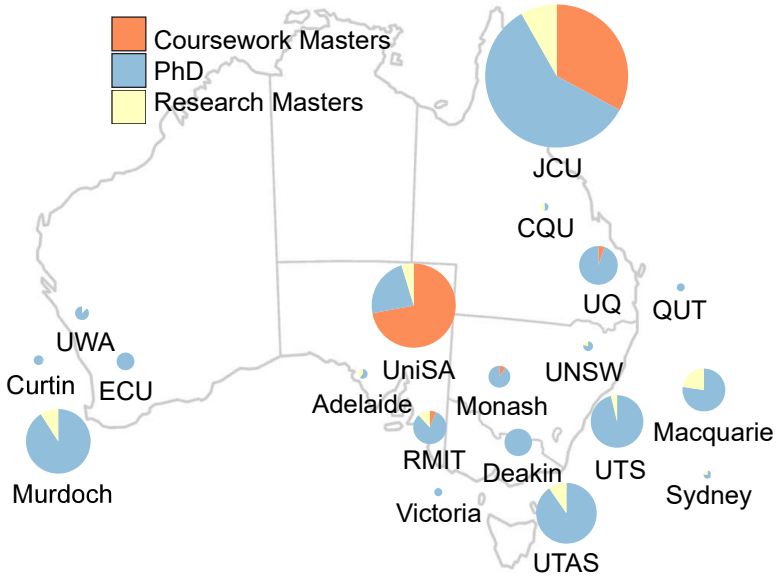

Figure 5. Institution and course of study of Masters and PhD student respondents (*n* = 362). CQU, Central Queensland University; ECU, Edith Cowan University; JCU, James Cook University; QUT, Queensland University of Technology; RMIT, Royal Melbourne Institute of Technology; UNSW, University of New South Wales; UQ, University of Queensland; UniSA, University of South Australia; UTAS, University of Tasmania; UTS, University of Technology Sydney; UWA, University of Western Australia.

Table 1. Responses of Masters and PhD students (*n* = 362) regarding their desire to pursue research after graduation, and confidence in their ability to successfully pursue a career in their preferred sector of employment. Values are percentages (%).

Survey question	Qualification			
Desired role after graduation	Coursework Masters	Research Masters	PhD	Total
I do not want a research role	30.2	15.6	9.4	13.5
I don't know / no preference	34.9	34.4	31.8	32.6
I want a research role	34.9	50.0	58.8	53.9
Confidence in future success				
Don't know	11.1	3.1	7.1	7.5
Not confident	14.3	21.9	24.3	22.4
Moderately confident	60.3	59.4	47.6	50.8
Very confident	14.3	15.6	21.0	19.3

3.1.4. University submissions

We received submissions from 23 of the 39 comprehensive universities across Australia, including seven of the Group of Eight Universities (Australian National University, Monash University and the Universities of Melbourne, New South Wales, Queensland, Sydney, and Western Australia); one of the five Australian Technology Network (ATN) universities (Curtin); five of the seven Innovative Research Universities (Charles Darwin, Flinders University, James Cook University (JCU), Murdoch University, and Western Sydney University (WSU); two of the six members of the Regional Universities Network – Central Queensland University (CQU) and Southern Cross University (SCU); and seven of the 13 non-aligned comprehensive universities – Deakin University, Edith Cowan University (ECU), Macquarie University, Swinburne University, and the Universities of Canberra, Tasmania and Wollongong.

Submissions were received from universities head-quartered in all states and territories (Figure 6). Thus although we did not receive submissions from all universities undertaking teaching and research in marine science, the submissions represented most of them and had a wide geographic spread. The provisions of our Human Ethics Approval prohibit us from making all the university submissions accessible on-line. In accordance with this restriction, the submissions have not been included in the references listed for this report.[4]

3.2. Employer perceptions

3.2.1. Importance placed on technical knowledge, technical skills, transferable skills, life experience, and professional experience

In considering Masters or PhD graduates for employment, employers collectively placed similar levels of importance on transferable skills, technical knowledge, life experience (median = 4 out of 5, interquartile range = 2 out of possible 4), technical

[4] We asked universities who made submissions if their submission could be shared with the other universities that made submissions in a common internet folder. Among the 23 submitting institutions, 18 agreed to this arrangement.

Figure 6. Geographic distribution of universities that made submissions to this project (*n* = 23).

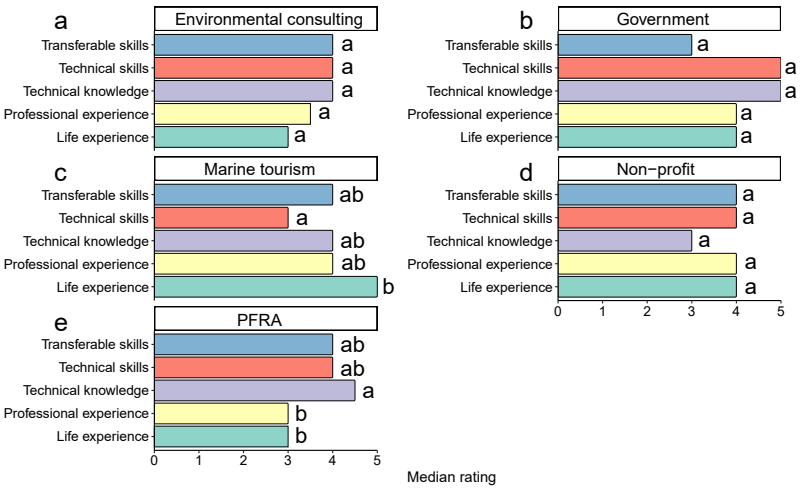

Figure 7. Median level of importance placed on each of five categories of skills, knowledge and experience by employers from: (a) environmental consulting (*n* = 10), (b) government (*n* = 5), (c) marine tourism (*n* = 9), (d) non-profit organisations (*n* = 7), and (e) publicly funded research agencies (PFRAs, *n* = 12) when considering a Masters or PhD graduate for employment. Within each sub-sector, medians with the same letter have a probability of > 0.05 of being similar (based on results of hierarchical ordinal regression followed by Tukey-adjusted *post hoc* pairwise contrasts).

skills and professional experience (median = 4, interquartile range = 1 our of possible 4) (χ^2 = 9.0948, p = 0.059). The only notable difference in ratings was observed for transferable skills and life experience, with transferable skills rating higher than life experience (p = 0.044, z-ratio = 2.771).

Patterns in relative importance differed across five sub-sectors for which sample sizes permitted analysis: environmental consulting (*n* = 10), government (*n* = 5), marine tourism (*n* = 9), non-profit (*n* = 7), and PFRAs (*n* = 12) (Figure 7). Employers from government differed from other sub-sectors in that they placed relatively low importance on transferable skills (Figure 7). Employers from marine tourism also differed somewhat from other sub-sectors in that they placed greater importance on life experience than technical skills (z ratio = -3.248, p = 0.010), which were considered important to employers in the other sub-sectors (Figure 7). Employers from PFRAs placed greater importance on technical knowledge than either life experience (z ratio = 3.02, p = 0.021) or professional experience (z ratio = 3.32, p = 0.008, Figure 7).

3.2.2. Advantages and disadvantages of different qualification levels

When asked to list the potential advantages and disadvantages of one qualification level over another when recruiting marine professionals, employers provided a variety of responses (Table 2). A recurring theme in responses regarding the advantages of a PhD were the disciplinary expertise (*n* = 5), research skills and experience (*n* = 5), and strong written communication skills (*n* = 5) of a PhD graduate.

Key disadvantages of a PhD over other qualifications were that the focus and/or skills of PhD graduates may be too narrow or specialised (n = 9), and that they may be overqualified for (and thus not satisfied by) some technician-type roles (n = 5).

Table 2. Advantages and disadvantages of recruiting one qualification over another, as reported by non-university employers (n = 39) in Australia's marine sector.

Degree	Category	Response
Bachelors	Advantages	Less expensive; generalist; may have more work experience; may be more adaptable, flexible and open to alternative approaches and career paths; broad knowledge base; ability to engage with people; better time management; well-rounded skill set
	Disadvantages	Lack of technical skills; lack of life, work and/or research experience; less depth of knowledge; smaller professional network; less maturity in softer skills; less well-developed skills in written communication, time management, research, project management, critical thinking
Honours	Advantages	Some understanding of project management
	Disadvantages	Less depth of knowledge and project management experience than Masters or PhD graduates
Masters	Advantages	Greater exposure to industry; stronger network; ability to work independently, ability to lead own project; stronger skills in project management, research, written communication, critical thinking, time management; greater depth and breadth of experience and knowledge; solid technical background; more well-rounded skillset; additional specialist knowledge
	Disadvantages	Lack of life skills; fewer skills than a PhD
PhD	Advantages	Well-developed problem solving, research, data analysis, written communication, project management and quantitative skills; specialised skills; added depth of knowledge, experience, perspective; stronger/wider professional networks; credibility; broader skill set; independent workers; field experience
	Disadvantages	Difficulties adjusting to commercial environment; more expensive; lack of life skills; difficult to manage (more ego); poor time management; less open to alternative approaches; overqualified for some roles; difficulty writing concisely; skill set and focus too narrow or not relevant to role

3.2.3. Added value of recruiting a PhD graduate

When asked to describe the potential added value of recruiting staff with a PhD, employers provided a variety of responses (Table 3). Recurring themes were that PhD graduates added credibility (n = 5 employers) and were valued for their stronger skills in critical thinking and communication. Other responses included the superior problem-solving ability, independence, and networks of a PhD graduate compared to other qualification levels.

3.2.4. Job-readiness

Sixty-two percent of employers said job-readiness was important in considering potential new hires. When we asked employers what job-readiness meant to them, some of the key themes in their definitions were that job readiness means being able to communicate effectively (in particular, write well), and having well developed skills in time management and teamwork (Figure 8).


Image: JCU

Table 3. Selected comments by employers (*n* = 39) from Australia's marine sector regarding the added value of recruiting staff with a PhD. EMI, Emerging marine industries; PFRA, Publicly funded research agency.

Quote	Respondent
"I think they are much more independent workers, we're huge but we're spread all around the world and we're often in many different cities and people sometimes in an office on their own so they really need to be able to work independently and have the skills and confidence to do that."	Employer #3 (Non-profit)
"I would think possibly... the credibility that comes with having staff with PhDs. Sometimes that matters to people and it can add credibility to the company."	Employer #33 (EMI)
"...with that increasing experience and knowledge you are also building your networks as an individual scientist. With time you meet more people, you do collaborative work, you build up your professional network."	Employer #30 (PFRA)
"You hope that they've got sufficient project management/writing/scientific skills. That's the area that we often need to discriminate the level of actual input and direction from the individual versus the system that they've been shot out of, which is getting harder."	Employer #28 (Government)

Figure 8. Word cloud showing responses from employers (*n* = 39) asked for their definition of job-readiness. The size of words represents the relative frequency of responses. Note the word "publish" and its derivatives do not appear.

3.2.5. Challenges faced by employers in recruiting and retaining graduates

When asked to describe challenges in recruiting job-ready graduates, employers reported difficulties finding graduates with certain disciplinary expertise, transferable skills, and personal attributes (Table 4). Other reported challenges to recruitment included uncertainties around job-readiness, funding limitations on recruitment, the lack of access to graduates, and poor links with universities (Table 4). With respect to retention, a recurring theme in the responses was the challenge of maintaining interest and motivation among young professionals who are "*often hungry for change... their first and second year are learning environments and then... they are ready to move on again... invariably they'll be frustrated in an organisation construct*" (Employer #21). Other reported challenges to recruitment and/or retention were the location and/or seasonal nature of the work.

3.2.6. Changing organisational needs

When asked to reflect broadly on how the needs of their organisation were expected to change over the next ten years, employers focused on a variety of themes (Table 5). Key themes that emerged were the growing need for specialist skills (information technology, computing, analytics, statistics/modelling, artificial intelligence, machine learning), and a

greater focus on social science, genetics, law, and engineering. Employers also emphasised the growing need for adaptability, flexibility, and the ability to work across disciplines on large complex projects.

Table 4. Challenges in recruiting job-ready graduates, as reported by non-university employers (*n* = 39) within Australia's marine sector.

Category	Responses
Disciplinary expertise	Lack of social science, quantitative fisheries science, water quality, engineering (coastal, structural, maritime, metocean), mathematics
Transferable skills	Lack of quantitative, teamwork, and/or project management skills
Personal attributes	Lack of empathy, emotional intelligence, and/or personality fit
Other	Fluctuating and/or patchy industry, access to graduates, poor link with universities, ineffective recruitment and/or selection process, finding graduates from developing countries

Table 5. Sample responses from employers (*n* = 39) who reflected broadly on how their organisational needs are expected to change over the next decade.

Quote	Employer type
"I think we're always going to need quantitative people. That will be a staple. Going forward though, use of new technologies and being in the cross-disciplinary space…they would be the areas I could see increasing in the future."	Employer #13 (Government)
"…I believe there will be a sort of communication revolution and those strategic alliances across different groups are going to become much more important… the social science side of things is going to become really critical for effective science, management, conservation and industry operations."	Employer #25 (Fishing)
"We're going to need that ability for graduates who have just been trained in one discipline to be able to empathize and discuss with much broader disciplines… we expect outputs to pass the national interest test. We find that many of the people we deal with just haven't got their heads around that need to communicate the broader benefit of the research….[new graduates] will have to have some sort of grounding in that broader policy, governance…We don't see a lot of that flexibility in the current workforce to be able to shift that traditional merit-based science thinking."	Employer #15 (Other)
"The basic skills of understanding… dynamical oceanography (large scale ocean circulations) and (their) applications to military topics such as acoustics and dealing with large volumes of data – those sorts of skills will stay."	Employer #5 (Government)
The nature of the workplace is changing…. [people] need to be able to adapt and change and pick up new skills or use their skills differently. All comes down to agility and adaptability in the work place and different work styles."	Employer #30 (PFRA)
"I'd say it's going to become more and more based upon numerical ability and the use of large data sets… collection of information from remote sources rather than having people go off into the field… a lot of people get into marine science because they like being in the ocean and diving… that [as an activity] is likely to decline substantially over the next 5 – 10 years. People have to have an understanding of the expectations of what their actual work and requirements will be."	Employer #28 (Government)
"I think our graduates will be expected to be much more flexible in the future, so a broader skill base [will be required] … which is a conundrum… we want people with specialist experience and specialist knowledge, but we are offering a generalist role."	Employer #38 (Offshore oil & gas)

3.3. Disciplinary knowledge needs

3.3.1. Trends, differences, gaps

Overall, the top disciplinary knowledge areas prioritized by employers were environmental science and management, marine biology, marine ecology, mathematics/ statistics/modelling, and marine engineering (Figure 9). One third of employers (33%, *n* = 19) anticipated that the disciplinary knowledge needs of their organisation would change over the next decade, with the main focus of changes being around the greater need for cross-disciplinary knowledge (*n* = 4), as well as knowledge and/ or expertise in climate science (*n* = 2), computer science (*n* = 2), and social science (*n* = 2). Students and graduates also recognized the importance that employers place on disciplinary knowledge in environmental science and management, however they undervalued the importance of marine engineering (Figure 9).

Between group differences in emphasis on disciplinary knowledge areas varied by sector (Figure 10). Students and graduates aspiring to work in the non-profit sector undervalued the importance that non-profit employers place on oceanography (Figure 10a). Students aspiring to work in the environmental consulting sector overvalued the importance of disciplinary knowledge in law, policy and governance, while undervaluing the importance of oceanography and marine engineering (Figure 10b). Students and graduates aspiring to work in government overvalued the importance that employers place on cross-disciplinary

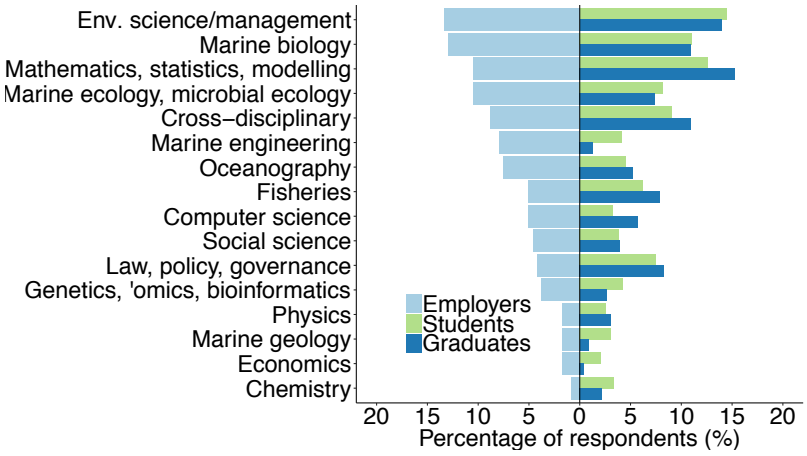

Figure 9. Disciplinary knowledge areas prioritised by non-university employers (*n* = 57) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students (*n* = 267) and recent graduates (< 5 years; *n* = 47) from Australian universities.

knowledge and law, policy and governance, while undervaluing the importance placed on social science, oceanography, and environmental science and management (Figure 10c). Students and graduates aspiring to work with a PFRA overvalued the importance that employers place on environmental science and management, while undervaluing the importance placed on marine engineering and genetics, genomics and other 'omics, and bioinformatics (Figure 10d).

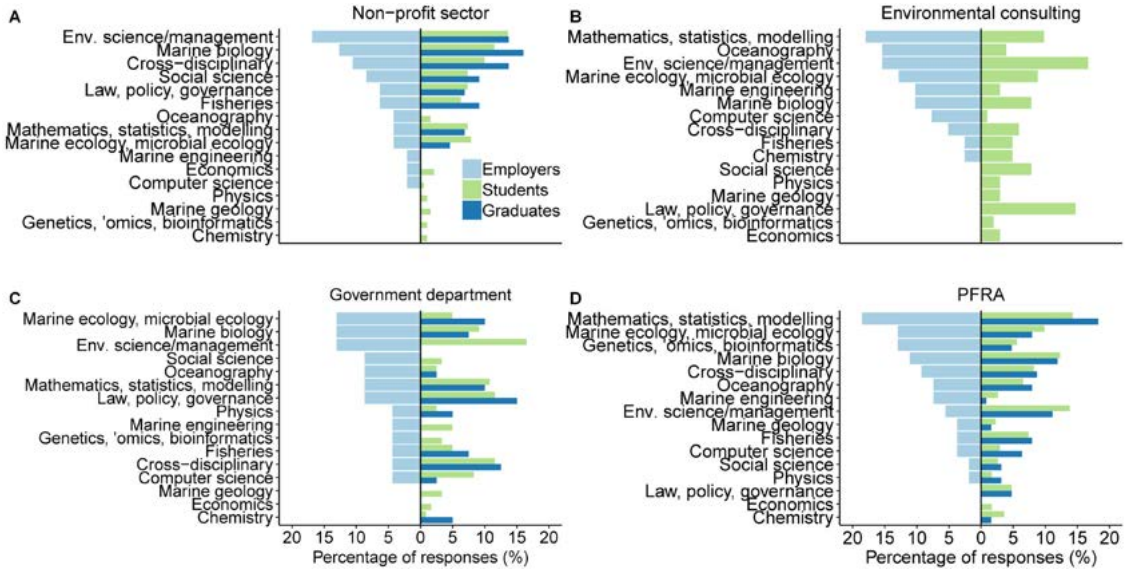

Figure 10. Disciplinary knowledge prioritised by: (a) non-profit organisations (*n* = 7), (b) environmental consultancies (*n* = 10), (c) government departments (*n* = 5), and (d) publicly funded research agencies (PFRAs; *n* = 12) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students and recent graduates (< 5 years) from Australian universities. Comparisons were made using the relevant subset of graduate and student respondents based on their preferred sub-sector of employment: non-profit (graduates: *n* = 7; students: *n* = 31), environmental consulting (students: *n* = 20), government (graduates: *n* = 9; students: *n* = 26), or PFRA (graduates: *n* = 25; students: *n* = 127). Graduates preferring employment in environmental consulting were excluded due to the small sample size.

Table 6. Outline of Masters by coursework offered by all Australian universities in disciplines sought by employers as obtained through internet searches in July 2019. Note this is unlikely to be a complete list and does not include marine disciplines that were not prioritised by the employers we surveyed e.g. aquaculture. The information is included here to demonstrate the wide range of coursework offerings in relevant disciplines.

Degree name	No. of universities
Quantitative Science: Master of Science in Quantitative Biology and Bioinformatics, Master of Quantitative Biology, Master of Applied Data Analytics, Master of Data Science, Master of Analytics/Applied Analytics, Master of Computational Biology	17
Mathematics and Statistics: Master of Mathematical Sciences, Master of Science (Mathematics), Master of Mathematics, Master of Science (Mathematics and Statistics), Master of Statistics, Master of Applied Statistics, Master of Statistics and Operations Research, Master of Biostatistics, Master of Geostatistics, Master of Science Innovation in Statistics	8
Climate change & environment: Master of Climate Change, Master of Environment (Climate Change Adaptation)	2
Marine/maritime engineering: Master of Science (Global Subsea Engineering), Master of Subsea Engineering, Master of Maritime Engineering (Specialisation/Technology Management/Naval Engineering)	2
Artificial Intelligence/Machine Learning: Master of Applied Artificial Intelligence, Master of Machine Learning and Computer Vision	2
Computing, Information and Communication Systems/Technology: Master of Science (Computer Science), Master of Computing, Master of Computer Science, Master of Information Technology, Master of Information Technology in Cyber Security, Master of Information Technology (Professional), Master of Science Innovation in Information Technology, Master of Networks and Security, Master of Information and Communications Technology, Master of Information Science, Master of Information Systems, Master of Information Systems and IT Management, Master of Information Systems Management, Master of Information Technology and Systems, Master of Engineering Science (Software)	21
Policy: Master of Public Policy, Master of Science (Science Policy and Communication), Master of Environment (Economics and Policy), Master of Environmental Policy and Management, Master of Public Policy and Management, Master of Public Policy and Governance, Master of Maritime Policy	9
Biotechnology and Bioinformatics: Master of Biotechnology and Bioinformatics, Master of Bioinformatics, Master of Science (Bioinformatics)	5
Marine and Coastal Science: Master of Biological Sciences (Marine Biology Specialisation), Master of Marine Science and Management, Master of Science (Marine and Coastal Management Specialisation), Master of Science (Marine Biology)	9*
Social Science: Master of Social Science	1
Multi-disciplinary (marine biology, ocean engineering, marine management, law, policy and governance): Master of Ocean Leadership	1

*Including the four universities that jointly offer the Master of Marine Science and Management through the Sydney Institute of Marine Science

Image: JCU

3.3.2. How do current university offerings meet the disciplinary knowledge needs of employers?

Nature of offerings

Online searches of Masters by coursework offerings in Australia (all 39 comprehensive universities) revealed a wide range of programs available in disciplines sought by marine sector employers now, and into the future (Table 6).

We could not reliably identify all the research higher degrees in marine science offered in Australia as there is inconsistency in the way that universities code these degrees using the Fields of Education (FoE) typology[5]. We have been informally advised that most universities do not keep these records either. In addition, marine science is listed as a 6–digit code (010907) under the "broad" FoE of Biological Sciences, which means that it may not be used as the 6-digit FoE code for students in "broad" disciplinary areas such as engineering. This problem also means that the data in the National Marine Science Plan is unlikely to be accurate. The number of research higher degree completions in marine science in Australia 2009-2013 is likely to be an underestimate and the proportion of these in the biological and ecological sciences is likely to be over-estimated.

Research higher degree candidates, particularly those who move universities to undertake a PhD, tend to inform their choice

5 https://www.arc.gov.au/grants/grant-application/classification-codes-rfcd-seo-and-anzsic-codes
The FoR codes are currently under review including how cross-disciplinary areas (such as marine science) should be coded.

based on the research reputation of the university and especially their chosen primary supervisor. We used the results of the 2018 Excellence in Research for Australia (ERA)[6] as evidence of the research capacity of Australia's universities in the disciplinary knowledge areas sought by marine sector employers (Table 7). Australia's national research evaluation framework (ERA) defines disciplines using the two-digit and four-digit Fields of Research (FoRs) codes identified in the Australian and New Zealand Standard Research Classification[7]. From 2019, universities are required to report up to two four-digit F0R codes for each research higher degree student. However, this will not solve the problem of identifying marine science students as there is no FoR code for marine science *per se*. Thus the research capacity of Australia's universities in the marine component of most of the disciplines sought by employers cannot be identified from the data in Table 7.

Table 7. Excellence in Research scores for 2018 for Australian universities and professional workforce for some of the disciplines prioritised by employers in the marine sector as indicated by 4-digit Fields of Research (FoRs). In most cases, the marine component of the FoR activity cannot be identified from these data.

Disciplinary knowledge areas prioritised by non-university employers	Relevant ERA categories	Number of universities ranked			
		total	as world class (ERA score ≥3)	Given maximum ranking (ERA score 5)	Publishing workforce FTEs
Environmental science and management	0502 Environmental science and management	32	32	28	495.4
Mathematics Statistics Modelling	0102 Applied mathematics	25	25	13	261.5
	0104 Statistics	17	16	8	235.5
Marine ecology /Microbial ecology	0602 Ecology	25	25	21	369.7
	0501 Ecological applications	16	16	13	145.3
	0605 Microbiology	18	18	10	314.2
Marine engineering	0911 Maritime engineering	47.1	2	2	2
Oceanography	0405 Oceanography	6	6	4	94
Fisheries	0704 Fisheries science	10	10	7	111.3
Computer science	0801 Artificial intelligence and image processing	30	29	7	562.6
Social science	1601 Anthropology	11	11	1	173.1
	1604 Human geography	17	16	2	187.9
Law, policy, governance	1605 Policy and administration	18	18	2	288.7
Genetics, 'omics, bioinformatics	0604 Genetics	17	17	11	350.8
Physics	0299 Other physical sciences	4	4	4	78.8
Marine geology	0403 Geology	16	16	12	226.9
Economics	1402 Applied economics	30	20	3	620.3

Nonetheless, some marine science disciplines do appear in the four digit codes (e.g. fisheries science, maritime engineering, oceanography). Although there are comparatively few universities that are strong in fisheries science, maritime engineering or oceanography, there are clearly numerous universities with world-class expertise in the more generic disciplines that employers seek.

Many universities develop graduate level coursework in the context of their coursework Masters degrees and other coursework postgraduate qualifications. One challenge for universities using this coursework at PhD level is that coursework postgraduate programs are typically fee-paying while most domestic research higher degree candidates receive tuition-fee scholarships. Some universities provide their research higher degree students with the option of enrolling in a number of coursework postgraduate subjects to broaden their skill base, with no fees, in some cases via enrolment in an appropriate graduate certificate.

Rising to the challenge of cross-disciplinarity

As university research training has become more industry-linked, postgraduate training has become more cross-disciplinary and focussed on applied, real-world issues, a point made by several universities in their submissions. For example, Murdoch University estimated that approximately 20% of their research student projects were cross-disciplinary.

Some marine science research centres and institutes actively foster a cross-disciplinary approach. For example, the University of Western Australia's Oceans Institute is *"highly multidisciplinary, its members spanning all UWA Faculties. Past Directors have included marine biologists, a maritime lawyer, and a marine archaeologist"*.

6 https://www.arc.gov.au/excellence-research-australia/era-reports

7 https://www.arc.gov.au/grants/grant-application/classification-codes-rfcd-seo-and-anzsic-codes

Many UWA marine science research students are located in the Indian Ocean Marine Science Centre building, where they are co-located with AIMS and CSIRO staff and exposed to a wide range of disciplines and actively encouraged to attend numerous seminars, symposiums, and keynote addresses from across the four faculties of the UWA.

The ARC Centre of Excellence in Coral Reef Studies supports some 150 PhD students across four Australian partner universities (Australian National University, James Cook University, Universities of Queensland and Western Australia). Some co-supervisors come from other Australian and international universities, the Great Barrier Reef Marine Park Authority and research agencies such as CSIRO, AIMS, and the Museum of Tropical Queensland. The Centre actively fosters a cross-disciplinary intellectual environment. Student projects are not only in biological sciences but include socio-ecology, oceanography, climate science, conservation planning and policy. Students are provided with opportunities to develop their quantitative and modelling skills through cross-university bespoke workshops delivered in block mode and are extensively mentored. A student committee is responsible for allocating funds to support student training, mentoring and leadership.

Many coursework Masters programs are also cross-disciplinary and problem-focussed (e.g. climate change, environment and sustainability, and food security). Some universities also offer training modules designed to foster cross-disciplinary skills. For example, the interactive 'Transdisciplinarity in Research' module offered by the Queensland University of Technology (QUT) teaches students to communicate and demonstrate mental agility and flexibility with students from other disciplines. Flinders University offers short-term research project opportunities for small teams of research students to work with an industry mentor, for example through hackathons, in which a large number of people meet to engage in collaborative computer programming.

Group field projects are also used to enable cross-disciplinary teams to work on specific projects. For example, the Collaborative Australian Postgraduate Sea Training Alliance Network (CAPSTAN) program brings together scientists and students from a range of disciplines from many institutions on a research vessel (RV *Investigator*) to enhance the cross-disciplinary nature of marine research training (see Box 1).

Box 1

CAPSTAN – A COLLABORATIVE ALLIANCE

https://mnf.csiro.au/en/Education/CAPSTAN

A network of Australian industry and university partners delivers CAPSTAN (Collaborative Australian Postgraduate Sea Training Alliance Network), a program equipping marine students with industry-relevant training on board the Marine National Facility's RV *Investigator*.

CAPSTAN, led by a team of educators and marine science experts, is helping to develop the next generation of world-leading, innovative marine experts.

To date, CAPSTAN has provided training to over 40 postgraduate students and 16 trainers and Chief Scientists/co-Chief Scientists from 17 Australian universities representing every state and territory.

CAPSTAN is administered by Macquarie University, and supported by a network of leading industry and university partners, as well as through grants of sea time on RV *Investigator*.

Strategies to broaden the disciplinary base

Engineering and law are both important to the future of marine science but students from these areas need to be convinced and excited by the relevance of their discipline to marine science. Macquarie University suggested that they could provide engineering and law students with opportunities for relevant experience through the CAPSTAN program. However, it can be difficult to convince students from non-standard marine science disciplines to participate. Block mode training at field stations could provide similar opportunities.

Few students undertake marine or ocean law related research. One university suggested that the numbers of students studying in these

areas could be increased through dedicated 'marine science' scholarships co-funded by universities, government bodies and industry

Flinders University's doctoral programme is targeting areas of emerging intellectual, economic and social importance involving online profiles – including video – of significant scholars. The 'Blue Economy' is a targeted area of growth for Flinders in 2019 through this online branding and profiling of supervisors from the spectrum of relevant disciplines.

Other cross-university collaborations in coursework delivery

The Sydney Institute of Marine Science (SIMS) is a partnership between Macquarie University, UNSW, the University of Sydney and UTS. The partnership collaborates with several state and federal government departments, the Australian Museum, as well as the University of Wollongong. SIMS is a focal point for collaborative marine research and innovation, the provision of marine research for policy makers and managers, and research training and teaching in the marine sciences. SIMS offers a coursework Master of Marine Science and Management run by the four partner universities. The arrangement allows students to receive *"advanced specialist information from experts in the field"* (Macquarie). The program is *"working well from the student perspective, however it is difficult to maintain linkages between the University systems…the operational challenges make it difficult… the models are in place…but are, it seems at times… dragging the universities along due to issues surrounding enrolment shares"* (SIMS partner university). The Victorian Marine Science Consortium also attempted to provide marine science education but closed in 2017, a situation which exemplifies the challenges associated with a multi-institutional approach.

Several universities supported cross-institutional development and delivery of coursework units or full coursework postgraduate qualifications in their submissions, provided that the administrative issues in areas such as enrolment, credit recognition and cost could be addressed. For example, Monash University identified the potential for specialised short courses developed and delivered by several institutions to take advantage of the economies of scale and overcome the barriers of the geographical spread of both subject experts and students. The University of Melbourne discussed the potential of this approach at the course level, using the example of ocean engineering. They identified three institutions with the required expertise (Universities of Melbourne, Monash and Western Australia). Although there is industry demand for specialist skills in this area, the demand is likely too small for any one of these institutions to justify a specialist Masters, whereas a cross-institutional offering using online education or block mode courses might be viable.


Image: MNF_Ben Arthur

Many Australian universities offer joint (i.e. co-tutelle) PhD degrees with overseas universities. It is possible for two Australian universities to offer a joint PhD, and the Group of Eight universities have a memorandum of understanding to provide joint PhD training. However, this approach is rare because of the administrative burden and the importance of the number of PhD completions to each university's share of research block funding. Cross-institutional supervision is much more common.

3.4. Transferable skills

3.4.1. Trends, differences, gaps

Overall, the transferable skills prioritised by employers were problem solving, time management, written communication, teamwork, and oral communication (Figure 11). Over one third of employers (37%, *n* = 21) anticipated that the skills needs of their organisation would change over the next 10 years, with the main focus of changes being around the greater need for skills in working across disciplines (*n* = 4), working with big data, (*n* = 4), artificial intelligence (*n* = 4), and machine learning (*n* = 3). While students and graduates also emphasised problem solving, they overvalued the importance that employers place on research and project management skills while undervaluing the importance of time management (Figure 11).

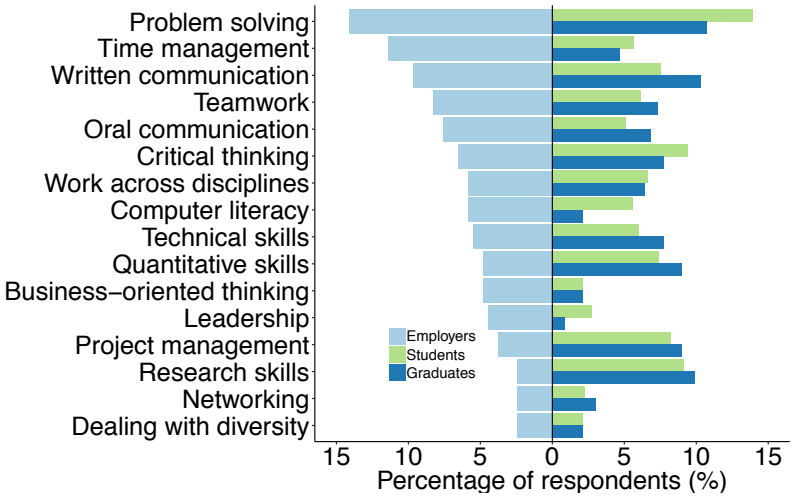

Figure 11. Transferable skills prioritised by non-university employers (*n* = 57) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students (*n* = 267) and recent graduates (< 5 years; *n* = 47) from Australian universities.

Between-group differences in the emphasis on transferable skills varied by sub-sector (Figure 12). Students and graduates aspiring to work in the non-profit sector overvalued the importance that employers place on teamwork and dealing with diversity and project management, while undervaluing the importance that employers place on written communication and time management (Figure 12A). Students and graduates aspiring to work in government overvalued the importance that employers place on critical thinking and the ability to work across disciplines, while undervaluing the importance placed on teamwork (Figure 12C). Students and graduates aspiring to work with a PFRA overvalued the importance that employers place on research skills and project management while undervaluing the importance placed on computer literacy and time management (Figure 12D).

3.4.2. How well does postgraduate training enable development of key transferable skills?

When graduates were asked to rate (on a 5-point scale) how well their postgraduate training had enabled them to develop the skills that they perceived to be important to employers in their preferred sub-sector, some skills rated higher than others (Figure 13). Overall, graduates considered their skills in research, oral communication,

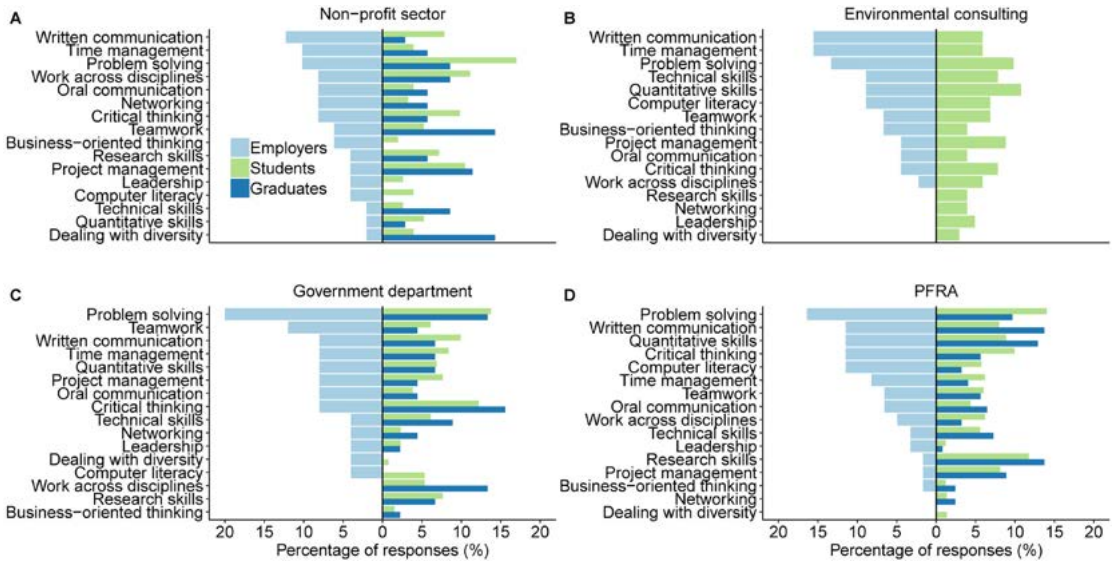

Figure 12. Transferable skills prioritised by: (A) non-profit organisations (n = 7), (B) environmental consultancies (n = 10), (C) government departments (n = 5), and (D) publicly funded research agencies (PFRA, n = 12) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students and recent graduates (< 5 years) from Australian universities. Comparisons were made using the relevant subset of graduate and student respondents based on their preferred sub-sector of employment: non-profit (graduates: n = 7; students: n = 31), environmental consulting (students: n = 20), government (graduates: n = 9; students: n = 26), or PFRA (graduates: n = 25; students: n = 127). Graduates preferring employment in environmental consulting were excluded due to the small sample size.

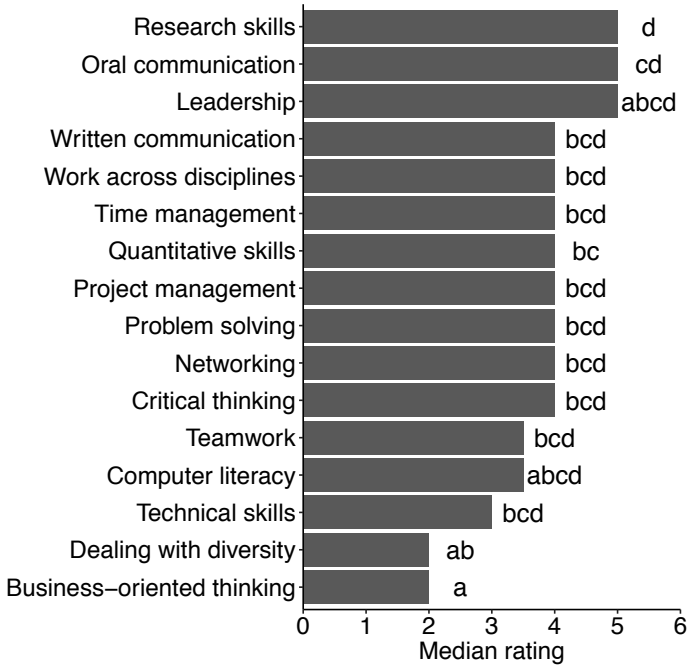

Figure 13. Median ratings (out of 5) provided by Masters and PhD graduates (n = 65) to reflect how well their postgraduate training enabled the development of transferable skills they consider to be important to employers in their preferred marine sub-sector. Medians with the same letter are not significantly different from each other (based on results of hierarchical ordinal regression followed by Tukey-adjusted post hoc pairwise contrasts).

and leadership to have been relatively well-developed through their training, while skills in dealing with diversity and business acumen were relatively poorly developed (Figure 13). The skills with the most variability in ranking were problem solving, project management, technical skills and time management (interquartile range = 2 out of 4 for all). The skill that showed the least variability in ranking was dealing with diversity (interquartile range = 0.75 out of 4).

3.4.3. How do current university offerings meet the transferable skill needs of employers?

Opportunities for skills training

While most universities did not mention formalised transferable skills programs in their submissions, all 23 made specific mention

of formal, informal and/or ad-hoc training offerings (workshops, seminars, coursework, informal support, etc.) that help students develop the transferable skills sought by employers and required to complete their postgraduate degrees. These include training and support on statistical analysis, research ethics, quantitative and qualitative research methods and skills (including software training), project management, leading teams, networking, marine molecular techniques, and career planning and advice.

Many universities mentioned that they offer free seminars and/or workshops that deliver training in academic writing, science communication (including media training), professional development, information technology, and computer skills.

Most submitting universities made specific mention of training offerings that contribute to the development of communication skills (n = 17 universities) and quantitative skills/statistical analysis (n = 15). In contrast, fewer than half of submitting universities specifically mentioned offerings that help students develop skills in networking (n = 11), teamwork (n = 8), project management (n = 7), business-oriented thinking (n = 7), and leadership (n = 6). An emerging theme from universities was that *"many of the skills that graduates will need for future employment are intrinsic in their research degree... [including] critical thinking, project management, the ability to conduct analysis..."* (University of Queensland). Indeed, three universities considered project management to be inherent to research degrees, with one stating that "*in general, all research degrees require students to develop a broad range of project management skills from project inception, design, planning, managing budgets and timelines, reporting and results dissemination*".

Some universities offer careers workshops for postgraduate students to enable them to understand the future of work, how to plan for their career, know the job market, and market themselves

Quantitative skills

Opportunities to develop quantitative skills varied across universities. Several universities reported offering (or being in the process of introducing) coursework on advanced statistics. For example, at the University of Tasmania *"the majority of... [marine] postgraduate degrees place strong emphasis on quantitative skills, data analysis, critical interpretation and span a broad range of research themes"*. Starting in 2020, the University of Queensland will introduce a new and flexibly structured Masters by coursework program in Quantitative Biology: *"The program will have a strong emphasis on acquiring core quantitative skills in a variety of topics ranging from data management to machine learning techniques, advanced statistical analyses, and mathematical modelling. Students will then apply those skills through opportunities to consult with academic, industry, and government teams, providing solutions to real world in-demand problems"*.

In association with CSIRO, the University of Tasmania offers PhD programs focussing on highly-quantitative projects (Quantitative Marine Science, Quantitative Antarctic Science). Students in this Quantitative Marine Science program must undertake seven units of coursework in the first two years. Coursework units are run either in summer school (February) or winter school (June-July). The quantitative coursework units include: data analysis, methods in physical oceanography, marine biogeochemistry, fisheries science, structure and function of marine ecosystems, techniques in marine remote sensing, management strategy evaluation and risk assessment. Now in its 15th year, the QMS program has funded more than 80 PhD students to undertake projects that apply mathematics and statistics to marine science problems of local, national, regional and global significance (see https://www.imas.utas.edu.au/qms).

James Cook University has a strategic partnership with AIMS (AIMS@JCU) that seeks to support the professional development of quantitative marine science skills through PhD scholarships. This investment is a strategic contribution to building critical mass in tropical quantitative marine science in Australia. AIMS@JCU supports professional development in quantitative methods appropriate to

a student and their project. Recipients of the AIMS@JCU scholarship receive agreed additional funding support to meet the costs of this professional development. Further, to accommodate the time required to develop and consolidate skills, their scholarship is awarded for four years (instead of the usual 3.5 years). AIMS@JCU scholarship recipients are required to develop a professional development plan that includes quantitative skills appropriate to the candidate and their project, which may include formal coursework (at JCU or another tertiary institution), informal coursework, online coursework, training provided by software companies, or internships with experts.

Skills training arrangements

Universities have addressed the needs of individual students to undertake transferable skills training in various ways. For example, several universities undertake "a skills needs analysis" at the beginning of the students' program, using tools to track and record progress on skill development. Some universities use SkillsForge, an interactive tool *"designed for Higher Degree by Research (HDR) students (and their supervisors/advisors) to enable them to obtain the skills and guidance they need to succeed in completing their candidature on time."* (Finders University) (https://staff.flinders.edu.au/colleges-and-services/ids/drs/inspire-project).

Researcher training frameworks have been implemented in some universities and are in development for others. While the specific frameworks differ across universities, most appear to be based on the UK Vitae Researcher Development Framework, and all focus on developing various research, transferable and professional skills. Some universities include compulsory coursework on topics such as "Communicating Research", "Advanced Information Research Skills" and "Professional Development".

While most universities do not offer formal, compulsory training on the full range of transferable skills important to employers, opportunities to develop different skills were highlighted in the submissions. In general, universities considered some transferable skills – namely business-oriented thinking, networking, leadership, teamwork, and project management – to be best developed through work placements, internships, or through research on industry-applied projects with *"extensive interaction and involvement of industry partners, both within supervisory teams, as industry mentors and through project steering committees"* (University of Tasmania). Three universities – the UWA, Flinders, and Macquarie – mentioned working closely with the 'Industry Mentoring Network in STEM' to provide students with mentoring and skill-development opportunities.

Some universities also mentioned formal training opportunities for students to develop entrepreneurial skills and business-oriented thinking. For example, the UWA provides scholarships for students to participate in a course offered by the Centre for Entrepreneurial Research and Innovation, which develops *"skills in entrepreneurship, start-up formation and innovation"*. Another university was *"looking to expand training in entrepreneurship and innovation for [postgraduate research students] through a local "Innovation Network"*. Deakin University commented that their marine science PhD students *"do not receive formal training in leadership, project management and business-oriented thinking, but... we believe there are clear opportunities to embed these skills more systematically..."* (Deakin University).

Several universities considered field experience and group projects (in postgraduate coursework) to be valuable in developing and fostering leadership, teamwork, and dependability. Queensland University of Technology (QUT) research students and staff and coursework students have participated in two research tours aboard the RV *Investigator* (https://www.abc.net.au/news/2017-08-20/csiros-world-class-research-ship-floatingclassroom/8821318).

Diving and boating qualifications are increasingly required for marine science fieldwork. Both the University of Tasmania and Central Queensland University take advantage of their vocational training arms to offer such training to postgraduate students.

Networking and communication skills were generally considered to be developed through participation in workshops, social events, research communication competitions (Three Minute Thesis Competition (3MT®), Visualise Your Thesis), seminars (mandatory components of the candidature management process at most likely all Australian universities) and conferences.

Career development

Several universities offer programs that are explicitly designed to foster the career development of postgraduate students, typically in the context of broader transferable skills programs. For example,

the University of Queensland's Career Development Framework provides a range of development opportunities for research higher degree candidates during their studies. The framework pivots around the following three key areas:

- Research skills including integrity and ethics, quantitative and qualitative research and analysis skills, scientific writing and publishing skills;
- Transferable skills including communication skills, team working skills, project management skills and presentation skills; and
- Professional skills including entrepreneurial skills, and how to have influence and impact.

Some universities offer career workshops for postgraduate students to enable them to understand the future of work, how to plan for their career, know the job market, and market themselves.

Some universities are training students to incorporate information about their skills training into job applications. For example, James Cook University requires research higher degree candidates to write an account of their professional development training in the format that they can use for their CV as part of compulsory requirements for the mandatory professional development subject. (Exemplars are provided to students.) Similarly, Flinders is developing a series of exemplar competency statements to enable PhD students to describe their skills, expertise, abilities and knowledge to help them develop and demonstrate these competencies to future employers.

Recording skills development

Several institutions have implemented e-portfolios and/or other audit tools that allow for the identification, development and recognition of skills and competencies: (1) that research higher degree students will need to demonstrate in their research degree; and (2) that will support broader professional and career development. Both Deakin and James Cook Universities record the skills each research higher degree graduate has developed during their candidature on their Australian Higher Education Graduation Statement.

Collectively, the personal attributes that employers prioritised most frequently were positive attitude, honesty, initiative, dependability, and adaptability.

BELOW: **Weather balloon launch** – Image: MNF

Several universities have introduced a requirement for research higher degree candidates to complete a Graduate Certificate. By providing units in transferable skills and discipline-specific electives, the Graduate Certificate *"is designed to imbue research higher degree graduates with the fundamental skills and attributes that future employers would expect…[and] assist candidates [to] systematically acquire the skills and training they need to complete their research"* (University of Tasmania).

Charles Darwin University is in the process of developing a series of micro-credentials to recognise the development of transferable skills. The Australian Qualifications Framework (AQF) is the national policy for regulated qualification-types. The current review of the Australian Qualifications Framework (AQF) is considering incorporating shorter form credentials to establish standards for, and increase recognition of this approach to up-skilling.

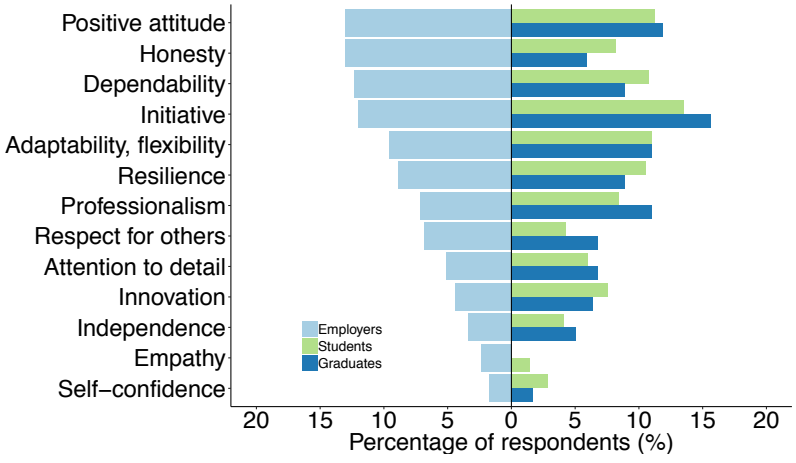

Figure 14. Personal attributes prioritised by non-university employers (*n* = 57) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students (*n* = 267) and recent graduates (< 5 years; *n* = 47) from Australian universities.

Cross-university collaboration

e-Grad school is a collaboration of the Australian Technology Network (ATN) of universities that offers online delivery of transferable skills development to HDR students *"so that they can enter the workplace more employer, innovation and industry ready"* (ATN website). Modules are assigned to one of three learning pathways (*Advance*: critical and creative thinking, global sustainability, digital competencies for researchers, research integrity, *Lead*: leadership and communication, project management, developing your career, *Engage*: research commercialisation, entrepreneurship, public policy). The program is managed by the Queensland University of Technology. Students from universities outside QUT and the ATN can access the modules on a fee-paying basis.

3.5. Personal attributes

3.5.1. Trends, differences, gaps

Collectively, the personal attributes that employers prioritised most frequently were a positive attitude, honesty, initiative, dependability, and adaptability (Figure 14). While students and graduates recognised the importance that employers place on a positive attitude, they undervalued the importance placed on honesty and respect for others (Figure 14). Only 16% of employers (*n* = 9) anticipated that the personal attributes sought by their organisation would change over the next ten years.

Between-group differences in emphasis on various personal attributes also varied by sub-sector (Figure 15). Students and graduates aspiring to work in the non-profit sub-sector overvalued the importance that employers place on dependability and adaptability, while undervaluing the importance that employers place on honesty and empathy (Figure 15A). Students aspiring to work in environmental consulting overvalued the importance of resilience and innovation,

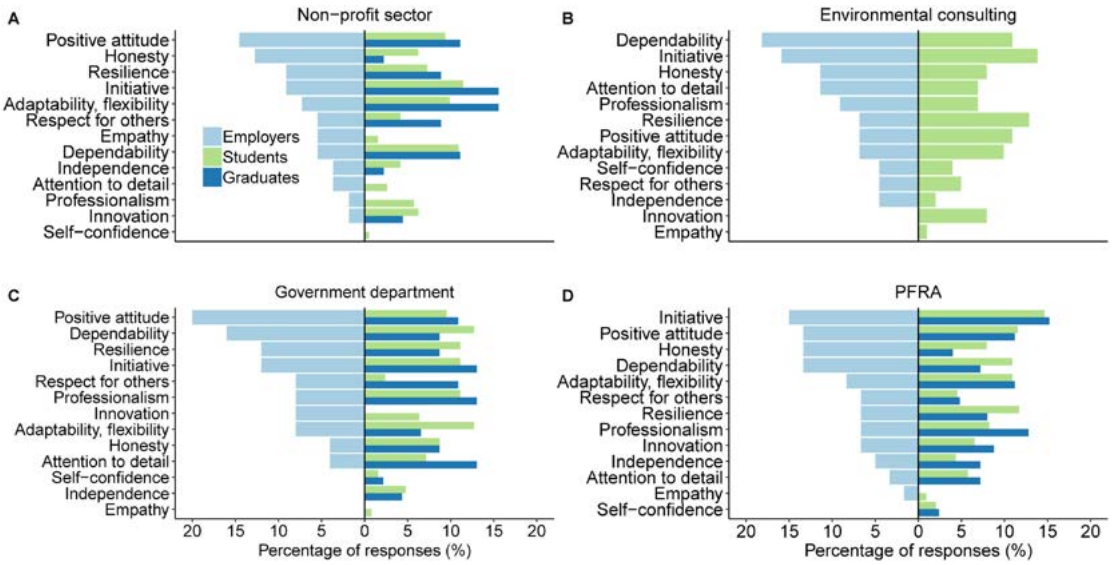

Figure 15. Personal attributes prioritised by: (A) non-profit organisations (n = 7), (B) environmental consultancies (n = 10), (C) government departments (n = 5), and (D) publicly funded research agencies (PFRA; n = 12) when considering a Masters or PhD graduate for employment, showing relative emphasis and comparison to the perceptions of Masters and PhD students and recent graduates (< 5 years) from Australian universities. Comparisons were made using the relevant subset of graduate and student respondents based on their preferred sub-sector of employment: non-profit (graduates: n = 7; students: n = 31), environmental consulting (students: n = 20), government (graduates: n = 9; students: n = 26), or PFRA (graduates: n = 25; students: n = 127). Graduates preferring employment in environmental consulting were excluded due to small sample size.

while undervaluing the importance of honesty and attention to detail (Figure 15B). Students and graduates aspiring to work in government overvalued the importance that government employers place on adaptability and attention to detail, while undervaluing the importance placed on respect for others and innovation (Figure 15C). Students and graduates aspiring to work in a PFRA overvalued the importance that employers place on resilience, while undervaluing the importance placed on honesty and respect for others (Figure 15D).

3.5.2. What are universities doing to foster the personal attributes sought by employers?

Among submitting universities (n = 23), 39% made specific mention of informal or formal training offerings that serve to highlight the importance of personal attributes sought by employers (positive attitude, honesty, initiative, dependability, adaptability, flexibility), and/or foster their development.

The activities mentioned were industry placements and internships (n = 5 universities), workshops on ethics and integrity (n = 4), cross-disciplinary collaborations (n = 4), and student mentorship programs (n = 2). Some universities mentioned that the attributes desired by employers are fostered through the university research and social culture (and reinforced in group meetings). The University of Melbourne mentioned that *"well-trained researchers need to be adaptable and flexible"*, stating that it is inherent in research activities.

Several universities considered that the importance of honesty and integrity are highlighted to research students during the compulsory training on research integrity required by the Australian Code for the Responsible Practices in Research, 2018 https://www.nhmrc.gov.au/about-us/publications/australian-code-responsible-conduct-research-2018 and/or covered though orientation events. Other universities mentioned that the importance of positive attitude, initiative and dependability are emphasised in postgraduate coursework through project-based activities, which are student-led, team-based, and research focused. One university mentioned that its postgraduate coursework and research students must complete an academic honesty module. Another offers a regular workshop which presents the latest advances on the determinants of positive attitudes, honesty and integrity.

Macquarie University's Master of Research has built training in these personal attributes into all aspects of the program. For example, in their project students learn the importance of adaptability, and flexibility and teamwork through specific units which are student-led or research focussed. Here, students drive research direction and work in teams, thus developing strong interpersonal skills and relevant attributes. The Master of Research also includes specific workshops to develop soft skills.

Some universities considers these attributes are best promoted through industrial placements and mentoring schemes.

3.6. Student and graduate experiences

Graduates listed many strengths and weaknesses of their postgraduate training (Figure 11). Graduates perceived the development of key transferable skills (research, written communication, project management) and personal attributes (e.g. independence) to be strengths of their training. The development of some transferable skills (e.g. networking, quantitative skills, oral communication) were considered strengths by some graduates, and weaknesses by others (Figure 16).

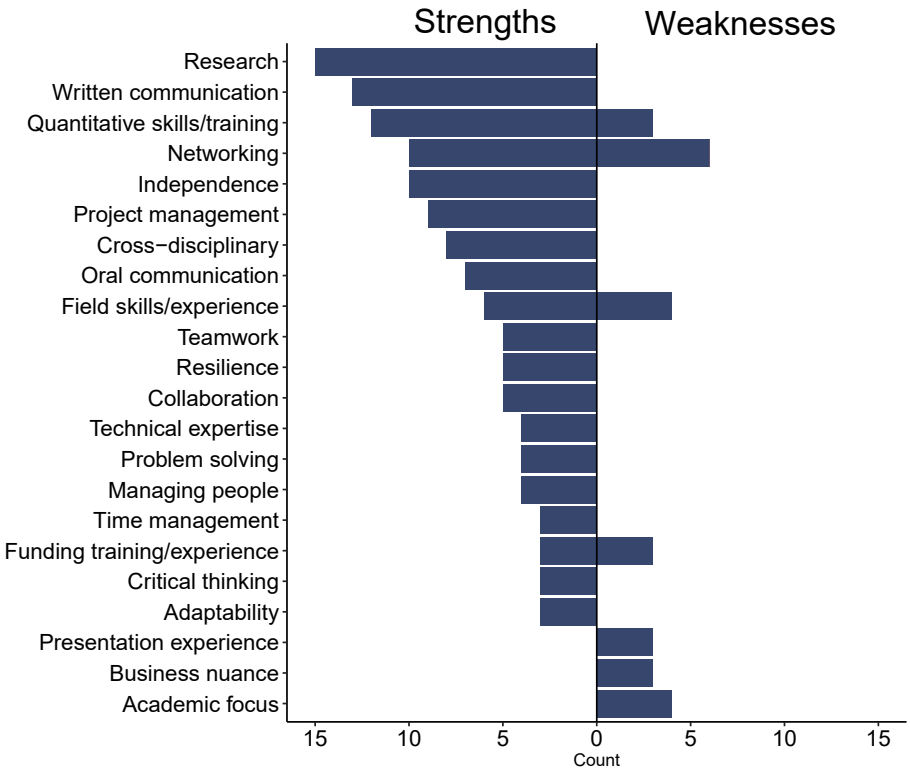

Figure 16. Strengths (n = 65 respondents, 162 responses) and weaknesses (n = 65 respondents, 82 responses) of postgraduate training reported by Masters and PhD graduates from Australian universities.

When we asked graduates what advice they would give to current students who aspire to a career in Australia's marine sector, their key messages (Figure 17) were:

1. To get industry experience through internships or volunteer opportunities;
2. To network and collaborate across disciplines; and
3. To make time to help others so that you can develop teamwork and interpersonal skills, because *"PhDs are largely conducted in solitude, but this is rarely the case for employment post-PhD"*. (Graduate #38)

Figure 17. Word cloud showing responses from graduates (*n* = 65) regarding what advice they would give to current students who aspire to a career in the marine sector in Australia. The size of words represents the relative frequency of responses. Note the word "publish" or its derivatives do not appear.

Most students (61%) and graduates (74%) had employment experience related to their degree. In addition, many students and graduates reported that one or more components of their postgraduate training involved a non-university supervisor (students: 30%, graduates: 39%); took place in a non-university setting (students: 36%, graduates: 46%); and/or involved research relevant to or defined by industry (research students: 70%, graduates: 54%). The Australian government has required each university to report on industry involvement in research training using prescribed metrics since 2018.

Nonetheless, our respondents reported low participation in internships, cadetships, and/or work placements (students: 13%, graduates: 5%), and 43% of students who had not completed an internship did not plan to. Internship participants were students or graduates from 16 universities, with over half of student internships participants (56%, *n* = 27) coming from James Cook University or University of South Australia.

3.7. University strategies to forge links between postgraduate students and industry

Universities are using a range of strategies to forge links between postgraduate students and industry. These strategies include industry internships and work placements, industry engagement scholarships and industry-embedded PhDs. We discuss each of these strategies below.

3.7.1. Industry internships and work placements

Universities are increasingly providing opportunities for PhD students to undertake industry internships and work placements. For example, 30 of Australia's comprehensive universities are members of APR.Intern, a program that provides *"hands-on research project opportunities for HDR students to gain skills, particularly project management, business-oriented thinking, networking and teamwork"* (Flinders University). The program is Australia's only comprehensive national PhD internship program and offers short-term, 3–5 month university research collaborations. The inclusive nature of APR. Intern means it is open to all PhD students, with an emphasis on gender equity and placing domestic, regional, Indigenous and disadvantaged PhD students into STEM internships. The Australian

Government rebate is restricted to domestic students. As of July 2019, only seven students from five universities (Macquarie (2), Monash, Royal Melbourne Institute of Technology, University of Newcastle (2) and Victoria University) had taken up internships in the marine sector. These internships have been in mathematical sciences, engineering (2), environmental science (2), and information and computing sciences (APR.Intern *pers comm.*).

Some universities collaborate directly with industry to provide industry placements of varying duration independent of APR.Intern. For example, the Industry and PhD Research Engagement Program (iPREP WA) offers short-term industry placements for domestic and international PhD students based at one of the five universities in Western Australia. The program *"involves interdisciplinary teams, working on a six-week project (with stipend scholarship) for an industry partner during their thesis examination period. Industry partners range from start-ups and Small and Medium Enterprises through to large corporations and government departments and their projects focus on solving authentic workplace problems. [The program] is helping PhD graduates to recognise that skills they developed in the PhD, such as problem-solving and critical thinking skills, are applicable across a range of disciplines, providing them with the confidence and experience to apply for jobs outside academia"* (iPrep website: https://www.iprep.edu.au/). Participants of the iPrep WA program are trained in *"developing a business mindset, teamwork, communication, personal branding, delivering business and personal 'pitches', networking with industry and understanding the job market"* (Edith Cowan University).

Industry internships are now part of the accredited course design for both the research Masters and PhD degrees at the Queensland University of Technology (QUT). QUT employs an "HDR Partnership Officer" responsible for the development and implementation of industry engagement opportunities for HDR students. Apart from internships, this role includes industry mentoring programs which tend to be STEM focussed, development of industry networking events, development of workshops and events that will develop skills that are valuable to industry; and promotion of HDR student programs to industry and government partners for the development of mentoring, placement, funding and workshop opportunities.

Universities are increasingly providing opportunities for PhD students to undertake industry internships and work placements.

The Nicolas Baudin "Internships in France" initiative offers students from participating Australian universities the opportunity to undertake a research internship at a French host university in collaboration with an industry partner. In 2018 and 2019, Flinders University has placed a total of seven students in internships related to maritime robotics. The Baudin internships are an excellent way of building up student skills and capabilities to work with international partners.

Image: JCU

Many universities offer work placements as a way for students to gain experience in the workplace. For example, a number of universities offer work placements through Work Integrated Learning (WIL) programs, whereby students are given *"the opportunity to directly apply theoretical learning in a practical and real-world environment"* (University of Tasmania). WIL tends to be done well in aquaculture programs which are often developed in close consultation with aquaculture industries so that graduate can be exposed to an industry-relevant environment during their candidature. Further, some universities that offer WIL at the undergraduate level are exploring its introduction at the Masters level. However, in some cases *"space in existing coursework programs is a limitation to incorporating WIL"* (University of Western Australia).

3.7.2. Industry engagement scholarships

Some universities have industry engagement scholarships schemes to align scholarship stipends to projects and topics developed in collaboration with industry. For example, the University of Western Australia partners with Woodside and Chevron in many engineering-based initiatives and research centres. The strategic partnership between James Cook University and AIMS (AIMS@JCU) offers competitive scholarships that require projects to be developed across both institutions and cross-institutional supervisory panels. Since the program's establishment in 2004, 108 PhDs have been awarded to students in the AIMS@JCU program.

3.7.3. Industry PhDs

Several universities offer industry-embedded PhDs aimed at students who undertake a PhD in the workplace itself or include placements with the industry partner. Industry-embedded PhDs can be facilitated by co-location e.g. at the Indian Ocean Marine Science Centre building at University of Western Australia. CSIRO is developing an Industry PhD program in association with several Australian universities. The program actively promotes collaboration between academia, industry and the research sectors to shape the future of industrial research training and requires balanced investment: co-investment between industry partner, CSIRO and university partner. As of July 2019, there have been only three students in the program with projects directly or indirectly relevant to the 'Blue Economy': two at the University of New South Wales and one at Curtin University (D. Byrne, *pers. comm.*, June 2019).

BELOW: **Geocoastal Research Group**
Image: The University of Sydney

4. Discussion |

The NMSP recognised that an appropriately skilled professional workforce was essential to Australia delivering the potential of its 'Blue Economy and called for "*the development of marine science research training that is more quantitative, cross-disciplinary and congruent with the needs of industry and government*" (NMSC 2015).

In considering the current workforce, the NSMP was concerned about:

1. The disciplinary mismatch between the training of graduates and the future needs of non-university employers;
2. The quantitative skills of graduates, especially their skills in mathematics, engineering, technology;
3. Cross disciplinary training, especially in the mix of natural and social sciences critical for environmental scientists;
4. The ability of graduates to engage with stakeholders;
5. The focus on the candidate's thesis rather than the skills needed for employment;
6. The job-readiness of graduates;
7. Need for more formal connections between industry and universities;
8. The current duration and basic structure of PhD programs, which are built around three-year PhD scholarships; and
9. Graduate awareness of the very different drivers of research and development in the commercial world compared with academia.

As explained in our introduction, government drivers of university research have changed significantly in response to the Watt (Watt 2015) and ACOLA Reviews (McGagh et al. 2016). There is much greater emphasis on skills training and industry engagement. Consequently, the postgraduate training climate in Australia is very different from that operating at the time that the NMSP was launched and more postgraduate students are planning non-academic careers. Almost three quarters of our sample of students and graduates wanted to work in industry, both as a result of these changes and because they appreciate that the opportunities for academic careers are limited.

Nonetheless, the basic structure of higher education in Australia has not changed. Qualification requirements are dictated by the Australian Higher Education Framework (AQF see https://www.aqf.edu.au/). As the University of Melbourne pointed out in their submission, "*by international standards, Australia has a very compressed tertiary education system*", essentially a 3 year Bachelor+2 yr Master +3 yr PhD system or a 3 year Bachelor+1 yr Honours+3 yr PhD, compared with for example, the United States (4+2+4) or China (4+3+4). Consequently, time constraints are an issue in the Australian system, particularly at PhD level where the demands to produce multiple peer-reviewed publications and to produce researchers capable of international-standard research in three years is a significant challenge. Requirements for additional coursework, skills training and internships are hard to fit into this crowded curriculum.

The Australian PhD is designed to produce internationally competitive research professionals. Research higher degrees are awarded on the basis of an externally–examined thesis and there is increasing expectation that doctoral students will publish their findings during their candidature or soon after. This approach is important for the international standing of the degree and the university and vital for candidates who seek academic careers. PhD stipend scholarships can be for up to four years (four-year industry–funded scholarships are increasingly common) but there is emphasis on timely completions as an internationally-recognised index of degree quality. In addition, the number of research higher degree completions, weighted by degree type and discipline, is a significant driver of a university's share of research block grant funding. Thus the current duration and basic structure of PhD programs (the basis for concerns number 5 and 8 above) has not changed and is unlikely to change in the foreseeable future.

We discuss the findings of this project with regard to the other concerns articulated in the NMSP in the context of the present structure of the tertiary education system.

4.1. The disciplinary mismatch between the training of graduates and the future needs of non-university employers

The top two disciplinary knowledge areas currently prioritised by marine sector employers are environmental science and management and marine biology, while marine and microbial ecology ranks fourth. Nonetheless, some large marine industries in Australia (e.g. oil and gas) are less biologically focussed. Mathematics, statistics and modelling rank third, and marine engineering and oceanography sixth and seventh. Cross-disciplinary studies rank fifth and is discussed separately below.

Employers reported difficulties in finding graduates with expertise in social science, quantitative fisheries science, water quality, engineering (coastal, structural, maritime, metocean), and mathematics. A third of employers anticipated that the disciplinary knowledge needs of their organisation would change over the next decade with more emphasis on specialist skills (information technology, computing, analytics, statistics/modelling, artificial intelligence, machine learning) and a greater focus on social science, genetics, law, and engineering. So as one employer put it, *"there is a bit of a legacy mismatch between training and industry demand"*.

As the NMSP points out, some of this mismatch could be addressed through advanced coursework. Most of this coursework is offered at Masters level for the reasons outlined above. Australian universities offer a wide range of coursework Masters degrees relevant to the disciplines sought by marine sector employers and have considerable world-class research expertise in these disciplines. Much of this teaching and research activity has limited or no explicit links to the 'Blue Economy' at present and the coding of degrees and researchers meant that quantifying the linkages that do exist was beyond the scope of this project.

Nonetheless, some universities offer named coursework degrees of explicit relevance to the 'Blue Economy' in areas such as climate change, maritime engineering, maritime policy and marine and coastal science. At least one such degree is offered across institutions: the Sydney Institute of Marine Science partnership between four Sydney-based universities offers a joint coursework Master of Marine Science and Management. There is potential for additional short courses and coursework programs in niche areas of explicit relevance to the 'Blue Economy' to be developed and delivered across several institutions to take advantage of the economies of scale and overcome the barriers of the geographical spread of both subject experts and students using online education or block mode delivery. However, there are operational challenges associated with this approach. The operational difficulties and financial disincentives associated with developing and delivering joint PhDs across Australian universities are considerable. Such degrees are unlikely to be widely adopted, despite the burgeoning popularity of joint PhDs between an Australian and international universities.

Some universities provide their research higher degree students with the option of enrolling in a limited number of coursework postgraduate subjects to broaden their skills base at no additional cost. However, taking advantage of this option seems to be largely at the discretion of individual students guided by their supervisors. The Quantitative Marine Science program at the University of Tasmania is an important exception and an exemplar for other degrees requiring in-depth expertise in more than one discipline. Both a breadth and depth of expertise will be important to meet the needs of employers who expect their staff to be nimble and adaptable.

The need for professionals with deep expertise in more than one discipline has been stressed by the Chief Scientist of Australia, Alan Finkel https://www.chiefscientist.gov.au/sites/default/files/29-July-Council-of-Deans-of-Science-DR-ALAN-FINKEL-AO.pdf He calls them "Pi" workers, an extension of the 'T–shaped' worker, promoted by IBM for many years. "Pi" workers have mastered a first discipline extremely well but are prepared to apply this capacity beyond their primary field and thus have two 'Ils' (two fields of deep disciplinary knowledge and technical skills) while retaining the dash (broader attributes required to function in workplace). A 'Pi' worker is a quick and adaptive learner with the flexibility and breadth of perception required by contemporary employers. The 'Blue Economy' will need many more "Pi" workers.

Nonetheless, we found little evidence of explicit efforts to interest students whose first

degree is engineering, mathematics, social science and law in a career in the marine sector. This gap needs to be addressed using several different approaches and their success evaluated against appropriate baselines.

4.2. The quantitative skills of graduates, especially their skills in mathematics, engineering, technology

Some universities have made considerable efforts to increase the quantitative skills of marine scientists largely through short courses and advanced coursework. This approach seems to mainly be aimed at increasing the skills of non-mathematicians, rather than attracting people with advanced quantitative skills to apply them in a marine science context. The latter approach will require explicit initiatives at the high school and undergraduate level to encourage students to take advanced mathematics along with science subjects, relevant to marine science. The Bachelor of Advanced Science at James Cook University, an elite program for high-achieving students, is an example of this approach. This degree offers each student the opportunity to select the major/s they feel passionate about (such as marine biology), while simultaneously developing the analytical and modelling skills that are in high demand.

4.3. Cross disciplinary training, especially in the mix of natural and social sciences critical for environmental scientists

The increase in linkages between universities and industry has increased the drivers and opportunities for postgraduate coursework and research training becoming more cross-disciplinary and problem focussed. The current students we surveyed identified "cross-disciplinary" as the third most common discipline of study. Some universities and especially some marine science research centres and institutes also use group projects, short-course and workshop opportunities to foster cross-disciplinary skills. However, quantifying the scope and depth of these changes was beyond the scope of this project.

A deterrent to cross-disciplinary research higher degree projects is the difficulty in finding appropriate examiners. However, a social-ecological approach to environmental problems is increasingly used and was mentioned explicitly in eight of the ~150 PhD projects listed in the 2018 Annual Report of the ARC Centre of Excellence in Coral Reef Studies https://www.coralcoe.org.au/publications/annual-reports. We expect that cross-disciplinary PhDs will become much more common (and accepted) in future.

BELOW: **Thomas Moore_EAC voyage** – Image: MNF

4.4. The ability of graduates to engage with stakeholders

The students and graduates we surveyed were generally satisfied with the training they had received in oral communication. The increase in linkages between universities and industry has increased the need for postgraduate coursework and research training to become stakeholder driven and engaged. Students are actively encouraged to present their work to non-experts though competitions, social media and popular articles.

4.5. The skills needed for employment

The transferable skills prioritised by the employers we surveyed were problem solving, time management, written communication, teamwork, and oral communication. Over one third of employers anticipated that the skill needs of their organisation will change over the next 10 years, with the main focus of changes being around the greater need for skills in working across disciplines and the quantitative skills required to work with big data, artificial intelligence, and machine learning. Employers also anticipated an increased need for adaptability, flexibility, and the ability to work in teams across disciplines on large complex projects.

All universities surveyed made specific mention of formal, informal and/or ad-hoc training offerings (workshops, seminars, coursework, informal support, etc.) that help students develop the transferable skills sought by employers and/or required to complete their postgraduate degrees. Most institutions made specific mention of training offerings that contribute to the development of communication skills and quantitative skills/statistical analysis but fewer than half of the submitting universities mentioned offerings explicitly to help students develop skills in networking, teamwork, project management, business-oriented thinking and leadership, considering that many of these skills are intrinsic in their research degree.

There is some cross-university collaboration in skills development. The e-Grad school, developed by the five universities of the Australian Technology Network (ATN), is a successful example operating at a national scale. Western Australian universities collaborate on delivering explicit training for PhD students for jobs outside academia after submitting their thesis for examination through iPREP WA, a program designed to help participants recognise that skills they developed in the PhD, such as problem-solving and critical thinking skills, provide them with the confidence and experience to apply for jobs outside academia. iPREP participants work in cross-disciplinary teams on an industry defined problem and are trained in developing a business mindset, and skills in teamwork, communication, personal branding, delivering business and personal 'pitches', networking with industry and understanding the job market.

Much of the skills training of research higher degree students occurs early in candidature when their career plans are undeveloped (or unrealistic). Thus it can be difficult for HDR candidates to identify and market their skills to employers. Universities use e-portfolios and/or other audit tools, graduate certificates, micro-credentials and information on each doctoral graduate's Australian Higher Education Graduation Statement to record and recognise the skills development that occurs during postgraduate training. Some universities are explicitly training their students to explain and promote their skills to prospective employers and to understand what they are capable of as well as what they area trained to do.

Both graduates and students both over-and under-emphasised the relative importance of transferable skills, technical knowledge and life experience to employers

Most graduates considered their skills in research, oral communication, and leadership had been relatively well-developed through their training, while skills in dealing with diversity and business acumen were relatively poorly developed. Graduate assessment of their development of problem solving, project management, technical skills and time management skills during their postgraduate training was variable, presumably a reflection on both institutional and individual differences in training opportunities and uptake.

The personal attributes that employers prioritised most frequently were a positive attitude, honesty, initiative, dependability, and adaptability. Only

about a sixth of employers anticipated that the personal attributes sought by their organisation would change over the next ten years. Employers reported difficulties finding graduates with personal qualities such as empathy and emotional intelligence. Given that some employers use psychometric testing to differentiate between short-listed job applicants, students need to be made more aware of the importance of personal attributes in the selection process.

Less than half of the universities made specific mention of informal or formal training to highlight the importance of personal attributes sought by employers and/or foster their development. Some universities considered that these attributes are fostered implicitly through compulsory training in research integrity, university research and social culture, industry placements and internships, cross-disciplinary collaborations, and student mentorship programs.

Recent graduates advised current students who aspire to a career in Australia's marine sector to network and collaborate across disciplines, and make time to help others to develop teamwork and interpersonal skills.

4.6. The job-readiness of graduates

Most employers considered job-readiness to be important. They defined job readiness as being able to communicate effectively (in particular, to be able to write well), and having well developed skills in time management and teamwork.

In considering Masters or PhD graduates for employment, marine sector employers generally placed emphasis on transferable skills, technical knowledge and life experience, although transferable skills were generally rated higher than life experience. Although there were some differences in the relative importance of these attributes across sub-sectors, further analysis also suggested considerable variation between individual employers within a sub-sector. Both graduates and students variously over-and under-emphasised the relative importance of transferable skills, technical knowledge and life experience to employers. Students need advice on how to research the proprieties of their target employers.

A key message from graduates to current students who aspire to a career in Australia's marine sector is to get industry experience through internships or volunteer opportunities.

Most students and graduates had employment experience related to their degree. Many students and graduates reported that one or more components of their postgraduate training involved a non-university supervisor, took place in a non-university setting and/or involved research relevant to, or defined by, industry. Although many universities offer work placements as a way for students to gain experience in the workplace, this approach tends to be more developed at the undergraduate level than in postgraduate programs explicitly relevant to marine science, except in aquaculture.

Image: MNF

4.7. Need for more formal connections between industry and universities

Several universities have recently created industry advisory boards and/or target scholarships to areas of industry need on projects developed in collaboration with industry.

Despite most universities being involved in the national APR.Intern program and the Western Australian universities offering iPREP WA, marine sector graduates and students reported low participation in internships (a situation confirmed by data from APR.Intern), cadetships, and/or work placements and nearly half the students who had not completed an internship did not plan to undertake one.

The cause of the limited engagement of marine industries in initiatives such as the APR.Intern program and CSIRO iPhD program is not known. Most of the employers we interviewed had never heard of APR.Intern. These initiatives are very recent developments and it will take time and targeted outreach to engage employers, especially those without a history of hiring PhD graduates. Mewburn et al. (2018) found a large 'hidden job market' for PhD graduates in the Australian workforce and demand for research skills, particularly in industries traditionally assumed to have low demand for PhD graduates that are potentially ready to embrace more graduates with research skills, echoing the innovation agenda. They used machine learning to analyse advertisements for professional jobs in Australia. Only 21% non-academic job advertisements asked for a PhD qualification whereas 43% of the job advertisements analysed required a high level of research skills and capabilities indicative of a PhD.

4.8. The awareness of graduates of the drivers of research and development in the commercial world compared with academia

The academic drivers of research and development are clearly very different from those in the commercial world. For example, the fact that neither 'publish' or 'publications' appeared in the word clouds created from the recent graduates' advice to current students and the employer definitions of job readiness is stark evidence of profound cultural difference. There are ethical, financial and reputational imperatives for supervisors encouraging research students to publish their work. In addition, students need to keep their career options open. Nonetheless, it is important that supervisors understand and respect the differences between academic and non-academic cultures so that they can advise each student appropriately. Edith Cowan University explicitly covers this topic in compulsory supervisor training.

Some universities organise industry mentorship programs for their postgraduate students. Others offer careers workshops and other training to postgraduate students to help them understand the future of work, plan for their career, know the job market, understand what they are capable of, and market themselves. Students need to understand the importance of investigating the priorities of their target employers. This research indicated some misunderstandings of the relative importance of technical knowledge, transferable skills, personal qualities and life experience to employers in different marine sub-sectors. Involving prospective employers in career development is clearly important.

4.9. Concluding remarks

Australian universities have significantly improved the capacity of postgraduate training to meet the needs of the marine sector employers since the NMSP was launched in 2015. Most of these improvements are generic rather than targeted to the 'Blue Economy' and have been driven by national government drivers. The next stage of addressing the training needs of the 'Blue Economy' should be the development of bespoke initiatives based on the many good ideas provided by the employers, graduates, students and universities who contributed to this study.

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6. Appendices |

Appendix 1 – Employer questionnaires

Online survey

"Hello! To assess how postgraduate training can better meet the needs of Australia's "Blue Economy", we are conducting this online survey with employers in the marine/aquatic/maritime sector to understand their professional staff needs. The survey should take approximately 5 minutes to complete. Your participation is entirely voluntary and you are free to end your participation at any time. All of your responses will be kept anonymous – they are never linked nor identifiable to your name."

"Do you consent to participating in this survey?" (Yes / No)

1. *How would you categorise your organisation?*

a. Non-profit sector (e.g. NGO)
b. Publicly funded research organisation/Marine cooperative research centre (e.g. CSIRO, Australian Institute of Marine Science)
c. Environmental consulting
d. Fishing (Commercial wild capture fisheries, recreational fishing, marine-based aquaculture)
e. Offshore Oil and Gas exploration and extraction
f. Emerging marine industry (Deep Sea Mining/Ocean Energy/Bioprospecting)
g. Water-based transport of passengers and freight
h. Insurance
i. Boat and ship building, repair and maintenance services/infrastructure
j. Marine tourism and recreational activities
k. Marine safety
l. Federal/state government department
m. Local government/council
n. Marine construction (not related to oil/gas)
o. Other (please specify):

2. *In what disciplines have the recently-qualified professional staff in your organisation been trained? Please consider only those staff who completed a postgraduate degree (Masters/PhD) within the last 5 years. (Select all that apply)*

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics
e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries

l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

*3a. In considering a Masters/PhD graduate for employment with your organisation, how do you prioritise the following **transferable skills/competencies**? Pick your top five (5).*

a. Critical thinking and reflective practice
b. Problem solving, analytical thinking
c. Computer/digital and technical literacy
d. Quantitative skills (e.g. statistics, modelling)
e. Business-oriented thinking
f. Research skills
g. Technical skills (e.g. field skills)
h. Networking
i. Ability to work across disciplines
j. Written communication skills
k. Oral communication skills (listening, presentation)
l. Teamwork
m. Dealing with diversity (sensitivity, competence working with different cultures/ethnicities etc.)
n. Self-management, time management, goal-setting
o. Leadership
p. Project management
q. Other (please specify):

3b. Additional comments:

*3c. Will the key **transferable skills** needed by your organisation change over the next 10 years?*

3c. If Yes: In what way do you expect them to change?

*4a. In considering a Masters/PhD graduate for employment with your organisation, how do you prioritise the following **personal attributes**? Pick your top five (5).*

a. Resilience (ability to tolerate and overcome adverse events/experiences)
b. Initiative, motivation (drive)
c. Empathy
d. Positive attitude, enthusiasm, passion
e. Innovation
f. Honesty, integrity, morality
g. Dependability, reliability, responsibility
h. Adaptability and flexibility

i. Professionalism
j. Self-confidence
k. Respect for others
l. Independence
m. Attention to detail
n. Other (please specify):

4b. Additional comments:

*4c. Will the key **personal attributes** needed by your organisation change over the next 10 years?*

4c. If Yes: In what way do you expect them to change?

*5a. In considering a Masters/PhD graduate for employment with your organisation, how do you prioritise the following **disciplinary knowledge**? Pick your top five (5).*

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics
e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries
l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

5b. Additional comments:

*5c. Will the key **disciplinary knowledge** areas needed by your organisation change over the next 10 years?*

5c. If Yes: In what way do you expect them to change?

6. In recruiting a recent Masters or PhD graduate please rate the level of importance you place on each of the following:

a. Technical knowledge
b. Technical skills
c. Transferable skills
d. Life experience
e. Professional experience

7. What is the name of your organisation?

8. What is your role/position in your organisation?

9. How many employees are in your organisation?

a. 1 – 4 employees (micro)
b. 5 – 19 employees (small)
c. 20 – 199 employees (medium)
d. 200 or more employees (large)

10. Approximately what percentage (%) of your organisation's employees are permanent/ongoing vs. temporary/project/contract?

a. Permanent/ongoing: ____ %
b. Temporary/project/contract: ____ %

11. On average, how many people do you hire each year who have recently (within the last 5 years) graduated from a Masters/PhD?

12. In the last year how many people have you hired with:

a. A Bachelors degree?
b. A Bachelors (+ Honours) degree?
c. A Masters degree?
d. A PhD?
e. Other qualifications?

13. What was your organisation's total turnover for the last financial year (in Australian dollars)?

a. Less than $50 000
b. $50 000 to less than $200 000
c. $200 000 to less than $2 million
d. $2 million to less than $5 million
e. $5 million to less than $10 million
f. $10 million or more

14. In the context of university training and the needs of employers in themarine/ aquatic/maritime sector, is there anything else you would like to tell us?

Telephone interview questions

1. *When considering recently qualified (within 5 years) Masters/PhD graduates for employment with your organisation, how important is:*

a. Disciplinary background as a selection criterion?
b. Research experience as a selection criterion?

2. *On a scale from 1 (not important at all) to 5 (very important), how important do you consider:*

a. Coursework in defining disciplinary background?
b. Research in defining disciplinary background? 3

Not important at all 1 — — 2 — — 3 — — 4 — — 5 Very important

3. *What level of qualification do you generally look for in candidates you are considering for employment?*

a. Bachelors
b. Bachelors (+ Honours)
c. Masters
d. PhD
e. Other (please specify):

4. *What do you see as the **advantages** of recruiting bachelor, master and PhD graduates?*

5. *What do you see as the **disadvantages** of recruiting bachelor, master and PhD graduates?*

6. *What, if anything, do you see as the added value of recruiting staff with a PhD?*

7. *What evidence of transferable skills do you look for in candidates you are considering for employment?*

8a. *When recruiting professional staff with a research background, how prescriptive is your organisation about the field of research required?*

8b. How is that field of research selected?

9a. *How important is it that your newly hired professional staff are job-ready?*

9b. What do you mean by job-ready?

10. *What is your biggest challenge in recruiting and keeping job-ready graduates?*

11a. *Do you have a graduate entry training program?*

11b. If 'Yes': Can you tell me about it and its role in the selection of new employees?

12a. *Does your organisation participate in an internship program?*

12b. If 'Yes': Can you tell me about it and its role in the selection of new employees?

13. *From this perspective of what we have been talking about (the professional employment perspective), how do you expect the needs of your organisation to change over the next 10 years?*

14. *Is there anything else you would like to talk to us about?*

Appendix 2 – Graduate questionnaire

Graduate online survey

"Hello! We are conducting this online survey with individuals who have recently graduated (within the last 5 years) from a Masters or PhD program in Australia, with the intention of working in Australia's marine/aquatic/maritime sector. We would like to learn about your postgraduate training and understand your views on your training in the context of the skills, attributes and knowledge you think are needed by non-university employers in the marine/aquatic sector. The survey should take about 5 – 10 minutes to complete. Your participation is entirely voluntary and you are free to end your participation at any time. All of your responses will be kept anonymous – they will never be linked nor identifiable to you."

"Do you consent to participating in this survey?" (Yes / No)

1. *Have you recently graduated (within the last 5 years) from a Masters or PhD program in Australia, with the intention of working in Australia's marine/aquatic/maritime sector?*

2. *What sector would you prefer to work in? Pick your top five (5) and rank in order of preference from most (1) to least (5) preferred:*

a. Non-profit sector (e.g. NGO)
b. Publicly funded research organisation/Marine cooperative research centre (e.g. CSIRO, Australian Institute of Marine Science)
c. University
d. Environmental consulting
e. Fishing (Commercial wild capture fisheries, recreational fishing, marine-based aquaculture)
f. Offshore Oil and Gas exploration and extraction
g. Emerging marine industry (Deep Sea Mining/Ocean Energy/Bioprospecting)
h. Water-based transport of passengers and freight (Ports & shipping)
i. Insurance
j. Boat and ship building, repair and maintenance services/infrastructure
k. Marine tourism and recreational activities
l. Marine safety
m. Federal/state government department
n. Local government/council
o. Marine construction (not related to oil/gas)
p. Other (please specify):

*3a. How confident are you that you will be able to be successfully pursue a career in (your most preferred sector)? (**Not confident/ Moderately confident / Very confident / Don't know**)*

3b. Why do you feel this way?

*4a. In the context of working in (your most preferred sector), which of the following **transferable skills/competencies** do you think are most important to employers (who are seeking to hire Masters and PhD graduates)? Pick the top five (5).*

a. Critical thinking and reflective practice
b. Problem solving, analytical thinking
c. Computer/digital and technical literacy

d. Quantitative skills (e.g. statistics, modelling)
e. Business-oriented thinking
f. Research skills
g. Technical skills
h. Networking
i. Ability to work across disciplines
j. Written communication skills
k. Oral communication skills (listening, presentation)
l. Teamwork
m. Dealing with diversity (sensitivity, competence working with different cultures/ethnicities etc.)
n. Self-management, time management, goal-setting
o. Leadership
p. Project management
q. Other (please specify):

4b. (For the 5 skills selected) How well has your postgraduate training enabled development of the 5 skills you selected? (Rate each on a 5-point Likert scale) (Extremely poorly 1 ĐĐ 5 Extremely well)

4c. Additional comments:

5a. In the context of working in (your most preferred sector), which of the following ***personal attributes*** *do you think are most important to employers (who are seeking to hire Masters and PhD graduates)? Pick the top five (5).*

a. Resilience (ability to tolerate and overcome adverse events/experiences)
b. Initiative, motivation (drive)
c. Empathy
d. Positive attitude, enthusiasm, passion
e. Innovation
f. Honesty, integrity, morality
g. Dependability, reliability, responsibility
h. Adaptability and flexibility
i. Professionalism
j. Self-confidence
k. Respect for others
l. Independence
m. Attention to detail
n. Other (please specify):

5b. Additional comments:

6a. In the context of working in (your most preferred sector), what ***disciplinary knowledge*** *do you think is most important to employers (who are seeking to hire Masters and PhD graduates)? Pick the top five (5).*

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics

e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries
l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

6b. Additional comments:

*7. In the context of working in your most preferred sector (most preferred from Question 2), what are the **strengths** of your postgraduate training?*

*8. In the context of working in your most preferred sector (most preferred from Question 2), what are the **weaknesses** of your postgraduate training?*

9. How could your postgraduate training have been modified to better meet your employment needs?

10a. Do you have employment experience that is relevant to your postgraduate degree?

10b. (If Yes) Please provide details.

11. At which academic institution did you complete your postgraduate degree?

12. What was your main discipline/field of study? (choose one)

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics
e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries
l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

13. What qualification did you complete?

a. Masters (Coursework)
b. Masters (Research)
c. PhD
d. Other qualification (please specify):

14. In what year did you graduate?

– Question 15 For Masters (Research) and PhD graduates only

15. Did your postgraduate research project tackle a research problem relevant to (and/or defined by) industry? (Yes/No)*

*Note: **industry** refers to any potential end user of research including but not limited to: businesses, governments, government business enterprises, non-government organisations, not-for-profit groups and community organisations

16. Did your postgraduate training involve a non-university supervisor?

17. Did one or more components of your postgraduate training take place in a non-university setting (e.g. government, business, NGO, etc.)?

18a. Did you undertake a cadetship, internship, or work placement as part of your postgraduate degree? (Yes/No)

18b. (If Yes) Please provide details.

19a. What is your current employment status?

a. Employed (Part-time)
b. Employed (Full-time)
c. Unemployed

19b. (If employed) What type of employment do you have?

a. Permanent/ongoing
b. Temporary/project/contract
c. Other (please specify)

19c. (If unemployed) Are you currently looking for work? (Yes / No) (then skip to Q26)

20. Are you currently employed in a position that uses the skills and/or disciplinary knowledge gained during your postgraduate training? (Yes / No)

21. What is the name of the organisation that employs you?

22. What is your role/position in this organisation?

23. Please describe your role, responsibilities and/or activities in this position.

24. How long have you been in this position?

25. How many employees does your organisation employ?

a. 1 – 4 employees (micro)
b. 5 – 19 employees (small)
c. 20 – 199 employees (medium)
d. 200 or more employees (large)

26. What advice would you give current postgraduate students aspiring towards a career in the marine/aquatic/maritime sector?

27. Where do you live/work?

28. What is your gender?

29. In what year were you born?

30a. In what country were you born?

For those who say 'Australia'

30b. Do you identify as an Aboriginal Australian and/or Torres Strait Islander?

a. Aboriginal Australian
b. Torres Strait Islander
c. Aboriginal Australian and Torres Strait Islander
d. Neither

Thank you for completing this survey! If you would like to be entered into a draw to win a $500 visa gift card, please enter your e-mail address here:

Appendix 3 – Student questionnaire

Postgraduate student online survey

"Hello! We are conducting this online survey with students who are pursuing a Masters or PhD in Australia with the intention of working in the marine/aquatic/maritime sector in Australia. We would like to learn about your postgraduate training and understand your views on your training in the context of the needs of employers. The survey should take about 5 – 10 minutes to complete. Your participation is entirely voluntary and you are free to end your participation at any time. All of your responses will be kept anonymous – they are never linked nor identifiable to you."

"Do you consent to participating in this survey?" (Yes / No)

1. *Are you currently pursuing a Masters or PhD in Australia with the intention of working in the marine/aquatic/maritime sector in Australia?*

2. *What sector would you prefer to work in after obtaining your degree? Pick your top five (5) and rank in order of preference from most (1) to least (5) preferred:*

a. Non-profit sector (NGO)
b. Publicly funded research organisation/Marine cooperative research centre (e.g. CSIRO, Australian Institute of Marine Science)
c. University
d. Environmental consulting
e. Fishing (Commercial wild capture fisheries, recreational fishing, marine-based aquaculture)
f. Offshore Oil and Gas exploration and extraction
g. Emerging marine industry (Deep Sea Mining/Ocean Energy/Bioprospecting)
h. Water-based transport of passengers and freight (Ports & shipping)
i. Insurance
j. Boat and ship building, repair and maintenance services/infrastructure
k. Marine tourism and recreational activities
l. Marine safety
m. Federal/state government department
n. Local government/council
o. Marine construction (not related to oil/gas)
p. Other (please specify):

*3a. How confident are you that you will be able to be successfully pursue a career in (your most preferred sector)? (**Not confident/ Moderately confident / Very confident / Don't know**)*

3b. Why do you feel this way?

4. *Does/Will/Has your postgraduate training involve(d) a research project that tackles a research problem relevant to (and/or defined by) industry*? If so, please provide details.*

*Note: **industry** refers to any potential end user of research including but not limited to: businesses, governments, government business enterprises, non-government organisations, not-for-profit groups and community organisations

5. What postgraduate qualification are you currently pursuing?

a. Masters (Research)
b. Masters (Coursework)
c. PhD
d. Other qualification (please specify):

– Question 6 for Masters (Research) and PhD candidates only

6. In what phase of your degree are you?

a. Planning phase (definition of research theme and questions)
b. Executing phase (data collection/analysis)
c. Finishing phase (Writing up)
d. Examination phase (thesis has been submitted for review)

*7a. In the context of working in your most preferred sector (from Q2), which of the following **transferable skills/competencies** do you think are most important to employers (who are seeking to hire masters and PhD graduates)? Pick the top five (5).*

a. Critical thinking and reflective practice
b. Problem solving, analytical thinking
c. Computer/digital and technical literacy
d. Quantitative skills (e.g. statistics, modelling)
e. Business-oriented thinking
f. Research skills
g. Technical skills
h. Networking
i. Ability to work across disciplines
j. Written communication skills
k. Oral communication skills (listening, presentation)
l. Teamwork
m. Dealing with diversity (sensitivity, competence working with different cultures/ethnicities etc.)
n. Self-management, time management, goal-setting
o. Leadership
p. Project management
q. Other (please specify):

*For MPhil/PhD candidates who responded 'c. Finishing phase' **or** 'd. Examination phase':*

7b. (For the 5 skills selected) How well has your postgraduate training enabled development of the 5 skills/competencies you selected? Rate each on a 5-point Likert scale (Extremely poorly 1 ← → 5 Extremely well)

*8a. In the context of working in your most preferred sector (rank 1 from Q2), what **disciplinary knowledge** do you think are most important to employers (who are seeking to hire Masters and PhD graduates)? Pick the top five (5).*

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics
e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries
l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

8b. Additional comments:

*9a. In the context of working in your most preferred sector (rank 1 from Q2), which of the following **personal attributes** do you think are most important to employers (who are seeking to hire Masters and PhD graduates)? Pick the top five (5).*

a. Resilience (ability to tolerate and overcome adverse events/experiences)
b. Initiative, motivation (drive)
c. Empathy
d. Positive attitude, enthusiasm, passion
e. Innovation
f. Honesty, integrity, morality
g. Dependability, reliability, responsibility
h. Adaptability and flexibility
i. Professionalism
j. Self-confidence
k. Respect for others
l. Independence
m. Attention to detail
n. Other (please specify):

9b. Additional comments:

10a. Do you have employment experience that is relevant to your postgraduate degree?
10b. (If Yes) Please provide details.

11. At which academic institution are you pursuing a postgraduate degree?

12. What is your main discipline/field of study? (choose one)

a. Marine biology
b. Social Science
c. Mathematics, statistics and/or modelling
d. Genetics, genomics (and other 'omics), bioinformatics
e. Marine engineering
f. Oceanography
g. Marine geology
h. Marine ecology, microbial ecology
i. Chemistry
j. Physics
k. Fisheries
l. Environmental Science and Management
m. Computer Science
n. Economics
o. Law, policy, governance
p. Cross-disciplinary
q. Other (please specify):

13. Does/will your postgraduate training involve a non-university supervisor?

14. Has/Will one or more components of your postgraduate training take(n) place in a non-university setting (e.g. government, business, NGO, etc)?

15a. Have you undertaken a cadetship, internship, or work placement as part of your postgraduate degree? (Yes / No)

15b. (If Yes) Please provide details.

15c. (If No) Do you plan to? (Yes / No)

16. What is your preferred role after obtaining your postgraduate degree?

a. I want to stay in a research role
b. I do not want to stay in a research role
c. I don't know yet / no preference

17. What is your gender? (Male/Female/Other)

18. In what year were you born?

19a. In what country were you born?

For those who say 'Australia'

19b. Do you identify as an Aboriginal Australian and/or Torres Strait Islander?

a. Aboriginal Australian
b. Torres Strait Islander
c. Aboriginal Australian and Torres Strait Islander
d. Neither

Thank you for completing this survey! If you would like to be entered into a draw to win a $500 gift card for Amazon Australia, please enter your e-mail address here:

Appendix 4 – University invitation

Dear [Vice Chancellor],

This letter is an invitation to your university to make a submission to inform a report commissioned by the National Marine Science Committee to improve **Australia's Postgraduate Training System to Meet the Needs of the 'Blue Economy'** (marine/aquatic/maritime sector). We are keen to learn how your institution is responding to the issues that have been identified by employers, postgraduate students and recent graduates in specially commissioned surveys and interviews.

The National Marine Science Plan (NMSP), launched in August 2015, is a call to action to all those who will benefit from a strong marine/aquatic/maritime sector. Successfully implementing this Plan will require a strong and skilled work force of professionals with postgraduate training.

The National Marine Science Committee established a Working Group, which I chair, to conduct a project to investigate the compatibility between Australia's postgraduate training and the needs of employers in the nation's marine/aquatic/maritime sector (**e.g. consulting, research, fishing, non-profit sector, offshore oil and gas, marine insurance, tourism, government, boat/ship building, construction, ports and shipping**).

I hope that your university will make a submission addressing the questions identified in the attached document. Our definition of marine science is not limited to marine biology but includes relevant cross-disciplinary studies such as **engineering, social sciences, law, information technology, and business** and I hope that your submission can be informed by your staff working in these disciplines. The closing date for submissions is **March 15, 2019**. Submissions should be uploaded to the following Dropbox folder: [insert link].

Is postgraduate training meeting the future needs of Australia's Blue Economy?

We would appreciate it if your submission could be framed around answers to the following questions. Note that our definition of marine science includes all disciplines relevant for working in the marine sector (engineering, social sciences, law, information technology, mathematics, business). Please frame your responses with this definition in mind.

Section A: Overview information on the current offerings of your institution

1. Briefly describe your institution and explain how it is engaged in postgraduate coursework and research training in marine science. Your answer should include information on:

   a. The coursework and research training programs offered
   b. The nature of the student body for each of these programs including the effective full-time student load, percentages of international and domestic students, percentages of women and minority groups
   c. Fields of Education and Research covered by the programs
   d. The extent to which each of these programs includes:
      I. Coursework (please provide details)
      II. Transferable skills programs (please provide details)

Section A: Overview information on the current offerings of your institution

2. The students and graduates we surveyed considered that some key transferable skills were poorly developed through their postgraduate training: leadership, project management, business-oriented thinking, quantitative skills, networking and teamwork.

   Q: What training and/or opportunities do you offer (or could you offer) to help Masters and PhD students aiming for careers in the marine sector to further develop these skills?

3. Employers highlighted that they often have difficulty finding graduates with:

- Sufficiently well-developed quantitative skills;
- Social and interpersonal skills (e.g. teamwork, networking); and
- The ability to effectively communicate the importance, relevance and broader benefits of research to specific audiences (industry, government)

Q: What training and/or opportunities do you (or could you) offer to help Masters and PhD students aiming for careers in the marine sector to further develop these skills?

4. Employers that we surveyed identified that in the future, there will be greater need for knowledge in disciplines such as law, engineering, genetics, and social science.

Q: What is being done (or could be done) at your institution to attract students to pursue training in these disciplines in a marine science context?

5. Employers that we surveyed emphasized that there will be greater need for graduates who have the adaptability, and flexibility to work across disciplines on complex projects.

Q: What is being done (or could be done) at your institution to highlight the importance of these attributes to postgraduate students, and foster the development of these attributes through postgraduate training?

6. Students and graduates we surveyed appear to undervalue the importance of the following personal attributes that were identified as important by non-university employers from their preferred sector: positive attitude, honesty, initiative, and dependability.

Q: What is being done (or could be done) at your institution to highlight the importance of these attributes to postgraduate students, and foster the development of these attributes through postgraduate training?

Section C: How does your institution provide opportunities for Masters and PhD students to work with industry and government?

7. How does your institution provide opportunities for Masters and PhD students to develop links to, training in, and experience with industry and government workplaces? In your answer, consider including information on:

a. Any internship/work placement/cadetship programs that your university offers, and their availability across different disciplines.

b. Any links your university has with industry and government employers who hire university graduates in STEM fields

Section D: How could world class postgraduate and research training in marine science in Australia be delivered cost-effectively and to a diverse student body?

8. What features of Australian marine science training must be retained to ensure that our graduates are internationally competitive?

9. How should the marine research training system be structured within universities to produce high quality researchers that can work in cross-disciplinary teams?

10. What do you see as the opportunities for cross-institutional collaboration in the delivery of specialist advanced coursework and transferable skills training?

11. How can barriers to participation in postgraduate marine programs be overcome so that more candidates from non-traditional backgrounds, including Indigenous students, undertake training?

12. Finally, is there anything else you'd like to bring to the attention of the NMSC Working Group

Appendix 5 – Supplementary tables and figures

Table A1. Descriptions of graduate and student samples.

Category	Graduates	Students
Number of respondents	65	362
Percent male respondents	32.3%	56.2%
Age (mean +/- SD)	32.7 ± 6.1	31.8 ± 7.7
Coursework Masters	31.6 ± 8.5	28.4 ± 7.7
Research Masters	32.3 ± 5.8	33.8 ± 10.3
PhD	33.4 ± 4.9	32.4 ± 7.1
Percent PhD	64.6	73.7
Percent Masters (Coursework)	23.1	17.5
Percent Masters (Research)	9.2	8.9
Percent Australians	50.8	30.7

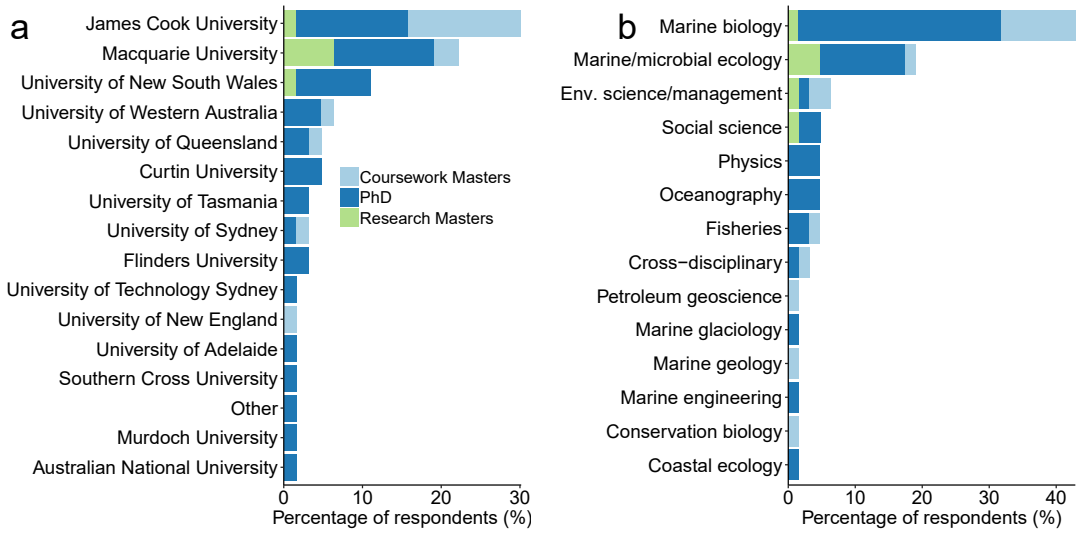


Figure A1. Frequency distributions of: (a) institutions and (b) disciplines of study of Masters and PhD graduate respondents (n = 65).

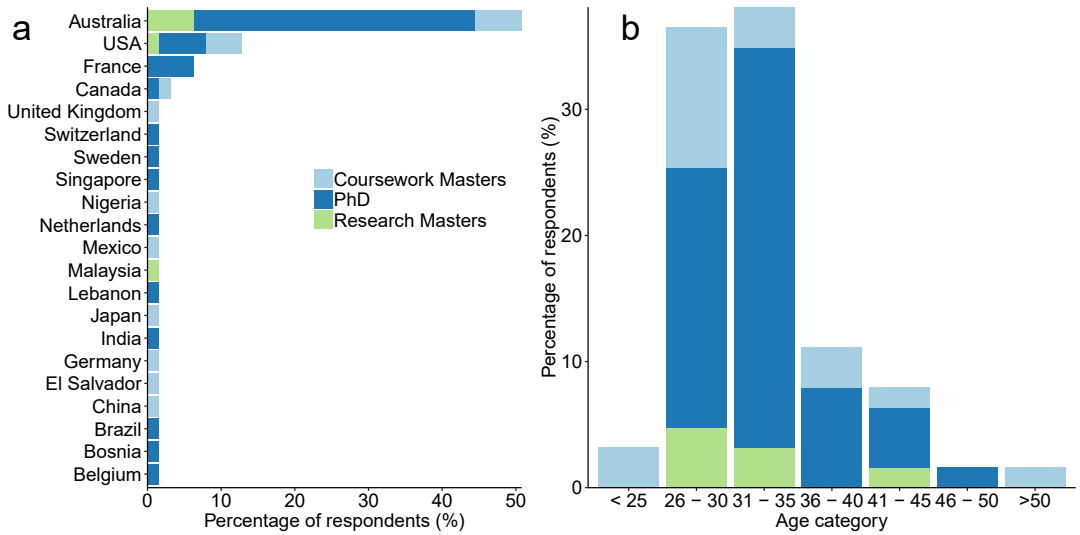


Figure A2. Frequency distributions showing: (a) nationality and (b) age of Masters and PhD graduate respondents (n = 65).

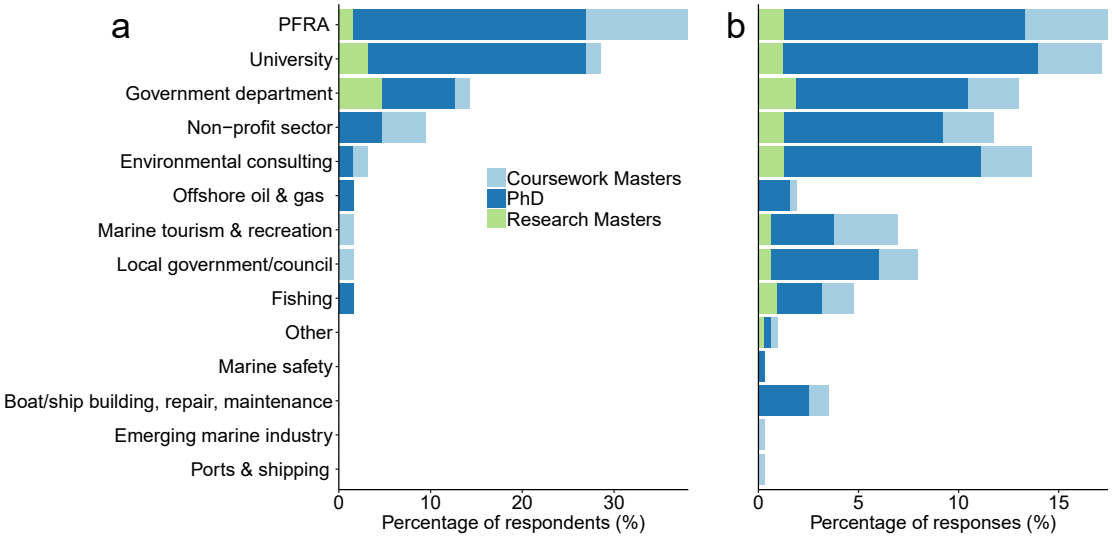


Figure A3. Preferred sub-sectors of employment of Masters and PhD graduates (*n* = 65) from Australian universities who aspire to a career in Australia's marine sector, showing: (a) their first choice; and (b) their top five choices.

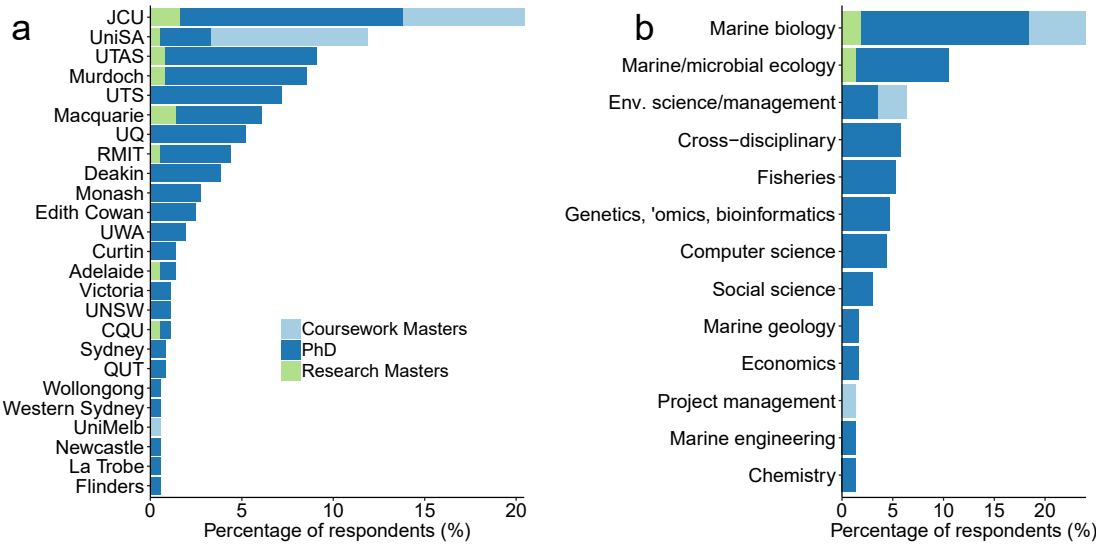


Figure A4. Frequency distributions showing (a) institutions and (b) disciplines of study of Masters and PhD student respondents (*n* = 362). JCU: James Cook University; UniSA: University of South Australia; UTAS: University of Tasmania; UTS: University of Technology Sydney; UQ: University of Queensland; UWA: University of Western Australia; UNSW: University of New South Wales; CQU: Central Queensland University; QUT: Queensland University of Technology; UniMelb: University of Melbourne.

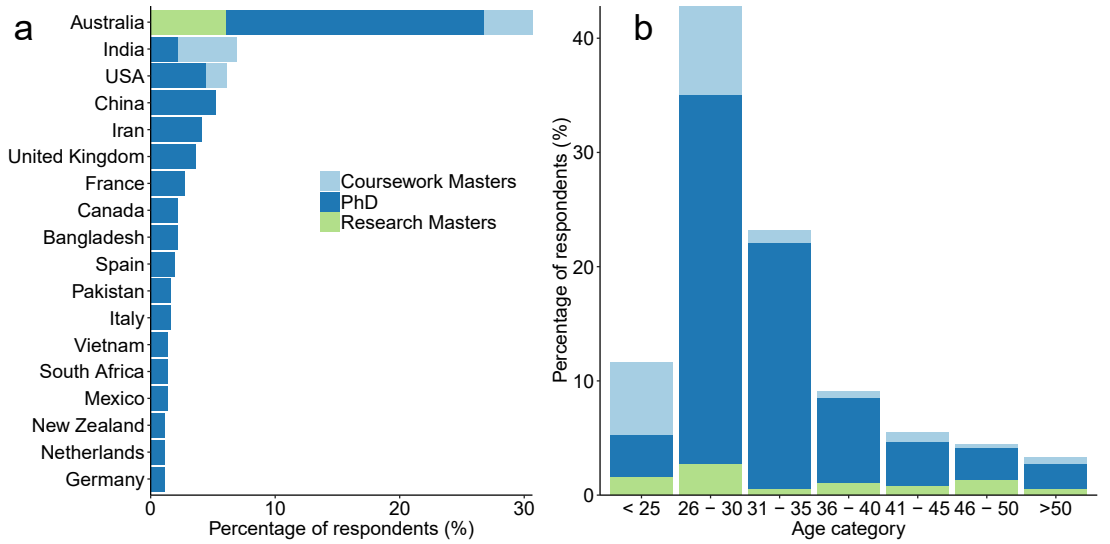


Figure A5. Frequency distributions showing (a) nationality and (b) age of student respondents (n = 362).

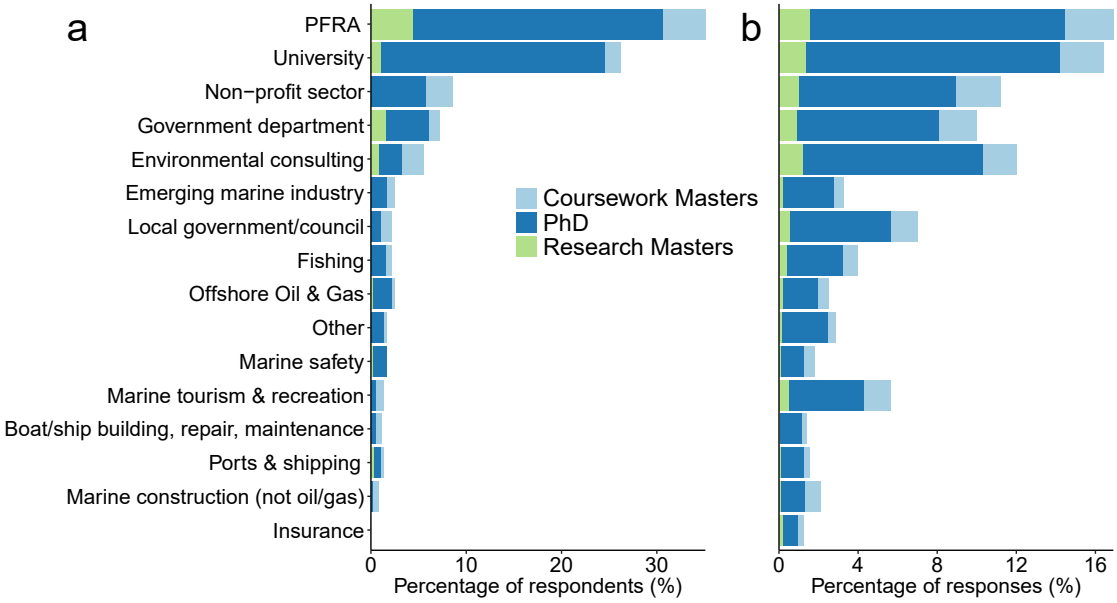
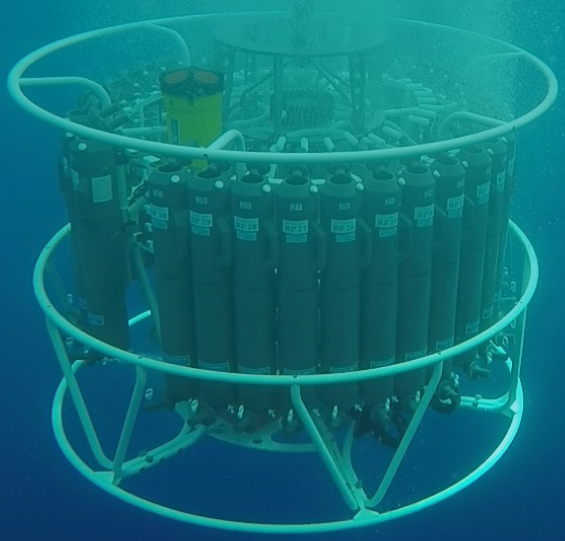


Figure A6. Preferred sub-sectors of employment of Masters and PhD students (n = 362) aspiring to a career in Australia's marine sector, showing: (a) their first choice; and (b) their top five choices.



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