Prospective RV *Investigator* SE Ecosystem Survey

Source: CSIRO, Thomas Moore

Impact Assessment

April 2021

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Glossary

AFMA	Australian Fisheries Management Authority
AMPs	Australian Marine Parks
AODN	Australian Ocean Data Network
AUV	Autonomous Underwater Vehicles
BCR	Benefit cost ratio
BRAN	Bluelink Reanalysis
BRUVs	Baited Remote Underwater Videos
CBA	Cost Benefit Analysis
CPUE	Catch per unit effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EEZ	Exclusive Economic Zone
EPBC	Environment Protection and Biodiversity Conservation
FIE	Fishery-Induced Evolution
FIS	Fishery Independent Surveys
FRDC	Fisheries Research and Development Corporation
HSE	Health Safety Environment
IMOS	Integrated Marine Observing System
ITSS	Indigenous Time at Sea Scholarship
MNF	Marine National Facility
MPA	Marine Protected Area
MRI	Marine Resources and Industries
NERA	National Energy Resources Australia
NESP	National Environment Science Program
NSW	New South Wales
O&G	Oil and Gas
RV	Research Vessel
SE	South east
SESSF	Southern and Eastern Scalefish and Shark Fishery
SPF	Small Pelagic Fishery
SLO	Social licence to Operate
STEM	Science, technology, engineering and mathematics
TAC	Total Allowable Catch
TBL	Triple Bottom Line
UoM	University of Melbourne
UNSW	University of New South Wales
UTAS	University of Tasmania
wrt	With respect to

1 Executive summary

CSIRO's key Challenge(s) addressed	a. Resilient and valuable environments b. Food security and quality

The Challenge

See **Section 3** for further details

Global ocean warming is a matter of growing concern. The marine waters of Australia are undergoing rapid change. Recent research suggests that the southeast (SE) marine waters are one of a series of global ocean hotspots, that are warming at a rate four times the global average. The shift is potentially affecting fisheries, biodiversity, and marine industry. With climate change expected to intensify in the future, the influence of these changes on industry and the Australian community is expected to become more dominant.

Science Challenge

Anecdotal evidence suggests that species distributions, productivity, and biodiversity in the SE Australian marine waters have changed, but there is a significant gap in understanding why this change has occurred. Several hypotheses have been proposed, but the causes are not clear.

Previous biophysical and ecosystem surveys of the SE continental shelf conducted 25 years ago have provided insights about what was there, but not what has changed.

CSIRO's Proposed Response

CSIRO is proposing a new survey to revisit the previous biophysical and ecosystem survey of the Australian SE continental shelf to document changes in the 25 years since it was last examined.

This will:

a. extend picture of the marine ecosystem on the continental shelf, to fill gaps in understanding and knowledge; and

b. expand it to the continental slope to establish a baseline for future surveys.

Policy Challenge

Policymakers and regulators have been facing many challenges in implementing effective management and decision-making processes, due to uncertainties and lack of understanding about the multi-dimensional factors associated with the wild-capture fisheries in these waters. Commercially collected data is the main source of information used to manage fish stocks in SE Australian waters. This data suggests that the commercial fish species composition has changed. The problem confronting managers is to understand the underlying factors responsible for these changes.

CSIRO's Proposed Response

CSIRO is engaged closely with fishery managers and advisory committees at several levels of government. It has supported the development of many critical policies, strategies, and assessments. As Australia's national science organisation, CSIRO is well-positioned to provide unbiased technical know-how to key players for contextual management decision and informed policy making, thereby supporting the journey of responsibly shaping the future of the marine industry in Australia.

Collaboration Challenge

There is broad reliance on the SE marine ecosystem by a range of industries and users of the environment, which contribute to the well-being and prosperity of the nation. However, there is no central authority for coordinating research and addressing knowledge gaps.

CSIRO's Proposed Response

CSIRO adopts a collaborative and consultative process to engage stakeholders and deliver the right information to the intended audiences. For this work, CSIRO will work with government agencies, universities, and the marine industry to ensure that the proposed surveys are well designed, executed, and implemented to deliver against the intended purpose.

Skills Challenge

It is not feasible for one lab, agency, or organisation to address these complex issues alone; the skills offered by other sectoral players need to be harnessed.

CSIRO's Proposed Response

CSIRO will leverage multi-disciplinary expertise and national leadership while harnessing the collective capability of marine science and research communities to deliver the targeted outcomes.

<table>
<tr><td>Scope</td><td colspan="3">Phase 1: Parks Australia and Southern and Eastern Scalefish and Shark Fishery (SESSF); Phase 2: Other Australian fisheries (including, but not limited to, Small Pelagic Fishery, SW fisheries, state fisheries); Phase 3: Wider marine industry (including, but not limited to, Renewables, Oil & Gas, Tourism, etc.)</td></tr>
<tr><td>Timeline</td><td colspan="3">FY2022 – FY2026</td></tr>
<tr><td colspan="4">Targeted Financial Investment 6,000,000*
(in FY2021 $)</td></tr>
<tr><td>Potential Impacts
See Table 4 for further details</td><td colspan="3">For summary of Impacts as per CSIRO’s triple bottom line (TBL) Benefit Classification Impacts – Table 4</td></tr>
<tr><td></td><td>ECONOMIC</td><td>ENVIRONMENTAL</td><td>SOCIAL</td></tr>
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• Risk management
• Policies and programs
• Data capital for future use
• Productivity and efficiency
• Australia’s competitiveness</td><td>• Conservation of marine biodiversity
• Climate resilience
• Climate adaptation</td><td>• Food security
• Marine industry confidence
• Recreational fishing (RF)
• Indigenous culture and heritage
• Innovation and human capital</td></tr>
<tr><td>Key Recommendations
See Section 8 for further details</td><td colspan="3">Targeting a portfolio of investors to potentially lower the risk of having inadequate funding support to execute this work.
Industry and Government engagement, co-investment, and co-design/execution must be strategically planned from the outset to:
– accelerate the innovation cycle
– translate the initiative into a more coordinated effort
– utilise skills and infrastructure from key stakeholders (academia and industry)
– catalyse its uptake to deliver impact.
• Keep customer needs at the heart of technical interventions, to maintain engagement; have a robust uptake plan, and utilise support from change managers to deliver intended impacts.
• Potential high costs associated with the uptake of new interventions by the marine industry is recognised as a significant roadblock. The value proposition of the outcomes must be clear and attractive to achieve industry interest and buy-in.
• An impact planning workshop with internal and external stakeholders should be held to establish critical indicators for the purposes of baselining, planning, monitoring, and evaluating impact.</td></tr>
<tr><td>Confidence Rating in assessment</td><td colspan="3">Low
Since this is a proposal-stage assessment to estimate impacts for due diligence purposes, the confidence rating in the assessment is rated as low. As CSIRO’s research progresses, the current study should be revisited and refined, drawing on more details for impact planning, monitoring and reporting purposes.</td></tr>
<tr><td>Capability and Capacity building</td><td colspan="3">• Collaboration with the University of Tasmania (UTAS), the University of Melbourne (UoM), the University of New South Wales (UNSW)
• The Indigenous time at Sea Scholarship (ITSS), which offers Aboriginal and Torres Strait Islander university students the opportunity to join voyages of RV Investigator
• Training the next generation of marine scientists</td></tr>
<tr><td>Collaborators and sources to corroborate Impact</td><td colspan="3">AFMA, Fishwell Consulting, Fisheries Research and Development Corporation (FRDC), Parks Australia
Universities: University of Tasmania, University of Melbourne, University of New South Wales
Museums: Australian, Victoria, NSW
State agencies: Victoria, NSW, Tasmania</td></tr>
<tr><td>Further Information</td><td colspan="3">Research Team: Rich Little
Impact Case Study: Anne-Maree Dowd, Harmeet Kaur</td></tr>
</table>

* Unless mentioned otherwise, all dollar figures are in AUD

How does the marine industry view CSIRO's proposal?

Tractuum interviewed key stakeholders – potential investor (AFMA), beneficiary and technical partner (Fishwell Consulting) to get insights about their perspective of CSIRO's proposal. The summary from these discussions is given below:

Investor Interview

The Australian Fisheries Management Authority (AFMA) recognises that the proposed work is of strategic importance to marine stakeholders to better adapt management and monitoring plans for the climate change-driven needs of the changing ecosystem. The area of interest contains many commercial fisheries, species and environment that have started to show the impacts of climate change. For the most optimal utilisation of resources, CSIRO must select commercially important species that are most sensitive to climate change, and of high relevance to investors under the proposed project.

The need for fishery independent information is critical to understanding fish stock status and impacts on sustainability. In some cases, the form and structure of traditional Fishery Independent Surveys (FIS) that provided estimates of abundance for stock assessments are not meeting management needs and there is a requirement to develop cost effective alternatives to support sustainable management into the future. As any potential investments into this work would be based on the overall value proposition, the economic, social and environmental benefits must be both clear and attractive to stakeholders. It is highly recommended that the scope of the work be broadened to benefit marine sectors other than the current target group of Commonwealth fisheries. This will enhance the opportunity for wider stakeholder support (both financial and in-kind) for the project; catalyse its uptake; and improve the returns on the invested resources. It is also suggested that other stakeholders, e.g state fisheries, government agencies such as Parks Australia, the tourism sector and Petroleum sector., be included as beneficiaries, rather than limit the focus to Commonwealth South east fisheries. Benefits to indigenous communities (e.g., building capacity, maintaining access to traditional fish species etc.), recreational fisheries, charter fisheries, marine protected areas and the tourism industry present key avenues for delivering social impacts.

From a Commonwealth Fisheries specific perspective, the potential outcome in the form of building cost-effective independent monitoring systems undoubtedly would be of interest to the stakeholders. Engaging with the marine industry through suitable platforms from the outset could potentially provide new ideas and insights to improve the design of the project and build trust to drive its adoption.

Beneficiary Interview

The survey results would be of vital importance to the marine industry for conducting effective fishery asset and environmental management, and for implementing effective strategies to adapt against climate change. Baseline information does not exist currently, and hence the proposed work will help provide contextual knowledge for management decision making and supporting monitoring plans. Most of the current work is focused on characterisation aspects, rather than establishing longer-term monitoring questions, as targeted by this project. Improving understanding about what is happening outside the fishery boundaries will invariably help build effective strategies around protecting likely trajectories of fish species under focus. It is therefore recommended that habitat changes are added to the focus on fisheries in the scope of work. Since effective fisheries management is one of the key goals for the work, the chosen sampling methodology must be well suited to, and accepted by, the industry. Technical challenges associated with the selection of such a well suited and acceptable sampling method must be addressed early-on by the project team.

Other organisations are conducting similar projects; however, they are on a smaller scale and lack the required integration to drive a systemic shift. Similarly, other vessels could operate to conduct some of the proposed work, but the chances of their operating in remote areas is bleak. The proposed work also has the potential to offer more avenues for the performance of complementary work in the future to support the marine industry.

Costs associated with the implementation of new methodologies and negative impacts on changing livelihoods are recognised as key roadblocks in the pathway of adoption of deliverables from this work. Similarly, having regard to the traditional inflexibility of the marine industry, regulatory support is critical to establish stakeholder confidence and drive uptake, otherwise the required changes will not be adopted.

Technical Partner Interview

Project collaborators recognise the proposed work as a national approach to improve industry understanding about climate change-induced factors causing economic and social harm to Australia. Fisheries are changing significantly, both in terms of total allowable catch (TAC) as well as fish species. There is a need to furnish the underlying knowledge-base on Australia's changing marine ecosystems and fisheries now and in the future. This will empower fishers/managers to be proactive and shift relevant management reference points to better address the sustainability of fisheries. The work will also answer pertinent scientific questions on how climate change affects the marine industry.

The prospective economic and social "cost of inaction" to the wider marine industry - as well as relevant coastal communities - is substantial. The proposed work has the potential to deliver new knowledge, climate model tools, and data, which are ready for uptake as actionable intelligence to enable government/industry to be climate-ready; better plan their operations; mitigate associated risk; and make the most of new opportunities.

The work will also address certain concerns of environmental groups who sometimes hold commercial fisheries responsible for the shifts actually caused by climate change (e.g., depletion of certain fish stocks).

Although the proposed survey is not expected to have direct economic impacts, the new knowledge will assist a range of stakeholders to better position themselves to tackle climate change-related challenges, where current standard processes are not working effectively. Currently, the industry broadly considers this as a fisheries problem; however, the underlying issue of climate change affects everyone.

It is unlikely that this work will be undertaken in the near future without the involvement of CSIRO. The initiative requires a national organisation to spearhead this initiative and work across state and territory borders. CSIRO's access to in-house interdisciplinary skills, together with RV *Investigator* research vessel and brand recognition, positions the organisation well to conduct this work. The project must be well-planned, to obtain strategic information that delivers the most value with limited resources.

The marine industry is a multi-billion-dollar industry that contributes significantly to the prosperity of the nation; from potential solutions to improve the value of the catch, driving sustainability of fisheries and the downstream supply chain, generating community benefits, maintaining access to seafood markets, addressing food security, optimising fisheries supply chain, etc., the proposed work offers a range of economic, social, and environmental benefits for Australia.

2 Introduction and Background

Australia is the third-largest marine nation in the world, with a significant dependence on the oceans for its prosperity, health and wellbeing. The nation's marine estate is home to some of the world's most iconic and diverse marine habitats and organisms, and includes several world heritage-listed areas. With possession of a marine jurisdiction of 13.86 million km^2, it has both the responsibility to safeguard its unique and globally significant ecosystems, and the privilege to develop and use both known and yet to be discovered resources.

Anthropogenic changes to the marine ecosystem have created dire economic, environmental, and social consequences for the wider marine industry, including (but not limited to) fisheries, the oil and gas industry, marine parks, tourism, and offshore renewables. Most stressors are both concurrent and cumulative, and underline the need for integrated, and multidisciplinary solutions.

Australia's oceans are undergoing rapid change, warming at a rate faster than most of the rest of the world's oceans. Recent research has identified that the southeast (SE) marine waters of Australia are one of a series of global ocean warming hotspots, with the East Australian current extending pole-wards resulting in warming at a rate of four times the global ocean surface average. Extreme events, such as marine heatwaves, are further compounding the effects of this warming; have harmed Australia's seagrass, kelp forests, mangroves, and coral reefs; and could be influencing the distribution and local abundance of commercial fish species. Embedded in this region lies the South-east Marine Park Network, consisting of 14 Australian Marine Parks off the coast of Victoria, South Australia and Tasmania, covering 388,464 square kilometres. These parks contain a diverse range of fish species, crabs, coral, sea urchins, and sponges. It is critical for the effectiveness of these parks as protectors of these biological communities that a clear understanding of how they are affected by the changing ocean environment is attained. Also, in these waters lie important fisheries, and observations from these fisheries over the past 20 years have indicated a change in the abundance and composition of the main fish species.

CSIRO proposes to conduct a series of marine surveys to document potential changes in the SE Australian marine ecosystem in the 25 years since it was last examined; and to identify the key factors affecting the ecosystem and livelihoods that rely on it, particularly the wild-capture fisheries. By bringing together key stakeholders and a broad array of capabilities, these surveys could be instrumental in understanding changes in the marine ecosystem. The purpose of this impact assessment is to estimate the potential triple bottom line (TBL) impacts of CSIRO delivering proprietary knowledge to answer urgent questions for the marine industry (fisheries and conservation managers, industry, and stakeholders). As discussed, the proposed work will address the current knowledge gaps to betterunderstand, prepare, and adapt against the threats of oceanic warming in marine waters, see Section 4 for more details.

Ongoing management of the conservation and biodiversity of Australian fisheries requires industry and government to be climate-ready and plan their operations to mitigate risks and make the most of new opportunities. The proposed work offers a significant potential to a range of government agencies and marine industries to better adapt their operations. The work will capitalise on investments already made, through integrating the available historical information and building on it. The possibility of developing a cost-effective monitoring system, in the next phase of this work, would make future follow-up surveys feasible at much lower costs for the benefit of everyone involved in the industry.

Australia's *National Marine Science Plan 2015 - 2025* underlines the critical need for undertaking baseline assessments and early benchmarks to understand changes to the environment and provide effective management. Fishery Independent Surveys (FIS) have been the main source of information on fish stock assessment. However, these surveys are slowly being abandoned due to their inability to meet current industry needs. Current scientific efforts are patchy and lack the coordinated approach required to address this "mission-sized" problem. The proposed work is expected to create knowledge and tools that would contribute to addressing all the seven grand challenges identified in the National Marine Science Plan, while also benefitting a broad range of marine industry stakeholders.

Phase 1 of the work targets uptake of deliverables by Parks Australia and fisheries to address the current ecological, economic, and social sustainability challenges.

The marine waters of the Australian SE are located along with the densely populated states of New South Wales (NSW), Victoria and Tasmania, and contain important wild-capture fisheries that provide the bulk of fresh fish to Melbourne and Sydney markets. Fisheries are locked-in systems that are inflexible in terms of space and species. Industry currently uses procedures that were historically appropriate, but which now require changes to better tackle current and future marine ecosystems. The Commonwealth-managed[1] Southern and Eastern Scalefish and Shark Fishery (SESSF) and Small Pelagic Fishery (SPF) have a combined annual catch of over 50,000t, valued at >$80 million per annum. General concerns about the future of these fisheries and the broader marine ecosystem have prompted a series of government initiatives, responses, and implementation of regulations. Fisheries closures in Commonwealth-managed waters have been instituted to protect vulnerable habitats and species. In 2012, the Australian Commonwealth SE Marine Park Network was established to protect the region's marine ecosystems and biodiversity. Despite active fisheries and conservation management, and historically low fishing effort, recent results show that 29 out of 43 largely demersal stocks in the SESSF are experiencing declining catch rates and stock abundance. Although declines are historically the result of fishing, the reasons for these more recent changes - despite closures and management limits on catches are unclear. Climate change has been identified as a potential factor influencing the lack of response in stocks.

1 https://www.csiro.au/~/media/OnA/Files/Climate-projections-Australian-fisheries-factsheet.pdf?la=en&hash=BB40D4513491373C50C4D8267ADD1616B7ECE9A7

3 Challenge and response

Challenge

There are several challenges central to this science proposal. These include determining the causal effects of changing wild-capture fisheries; managing these effects in the future; and collaboratively tackling these challenges having regard to the diversity of interests and values in the marine ecosystem.

Science Challenge

There is a significant gap in understanding the effects of warming SE marine waters of Australia, and its interaction with wild-capture fisheries. Observations from these fisheries over the past 20 years have indicated a change in the abundance and composition of the main fish species, manifested in their commercial catch rates. The physical and ecosystem factors are likely to be either directly affecting the main species, or indirectly affecting other species with which they compete or rely upon. Concurrent with the declining catch rates and stock abundances, there have been unprecedented levels of catches and catch rates of other species such as ocean jackets and latchet. The general conclusion has been that the marine ecosystem has experienced, and is currently experiencing, significant change. Several hypotheses have been proposed, but none are conclusive.

Policy Challenge

Policymakers and regulators have been facing many challenges in implementing effective management and decision-making processes, due to numerous uncertainties and a lack of understanding about the multi-dimensional factors associated with the wild-capture fisheries in these waters. FIS no longer meet management needs and the industry requires viable options for sustainable management.

In 2015, an expert scientific panel recommended an adaptive approach that included the development of research, monitoring, and evaluation framework, baselines, and critical early benchmarks for effective management[2]. The panel suggested that this should be done in partnership with the marine research community, as per a recommendation in the *National Marine Science Plan 2015–2025* to establish and support a 'National Marine Baselines and Long-term Monitoring Program', to develop a comprehensive assessment of Australia's marine estate, and to help manage Commonwealth and State Marine Reserves.

Collaboration Challenge

There is wide-ranging reliance on the SE marine ecosystem for the well-being and prosperity of the nation. However, there is no central authority for coordinating research and addressing knowledge gaps. Stakeholder controversies and division on critical issues are common due to lack of awareness and varied interests. Any prior research is patchy and lacks the requisite integration to tackle the user and stakeholder needs.

Skills Challenge

It is not feasible for one lab, agency, or organisation to address these complex issues alone; the skills offered by other sectoral players need to be harnessed. Establishing an understanding of the underlying mechanisms requires a broad range of capabilities, deep technical expertise, and national and international leadership.

CSIRO's proposed response

CSIRO proposes to conduct a series of surveys in response to these challenges.

Science challenge: Response

1. Revisit previous biophysical and ecosystem assessments of the Australian SE continental shelf and document changes in the 25 years since it was last examined.
2. Expand the survey (using new data collection technologies) to new areas:
    a. on the continental shelf, where there are gaps about the understanding and knowledge; and
    b. on the continental slope, to establish a baseline for future surveys.

The proposed work aims to provide evidence-based answers to the following broad questions:

1. What do the marine ecosystems (fish community composition) on the Australian SE continental shelf and slope look like?
2. What are the trophic relationships, and the overall biological productivity, of the ecosystem?
3. How have these (fish community composition/trophic relationships) changed since the continental shelf was last examined?
4. What factors have contributed to any putative changes, and what contribution have human activities made to any changes?
5. Based on the new knowledge and available facts, what is the prospect for the ecosystem in the future?

2 https://www.sciencedirect.com/science/article/pii/S2212096317301109

The surveys will test a series of hypotheses related to the above questions. These include (but are not limited to):

1. **The Climate Hypothesis:** The physical conditions in the water column have caused species range shifts, changes in productivity and/or other changes in biological systems resulting in changes in species abundance, composition, and productivity.
2. **The Trophic Hypothesis:** Variations in the food web structure have occurred, resulting in changes to species abundance and composition.
3. **The Benthic Habitat Hypothesis:** The benthic disturbance has changed the preferred habitat of fish species and their abundances, leading to a change in the species composition.
4. **The Fishery-Induced Evolution (FIE) Hypothesis:** Reduction in the abundance of species caused by high levels of fishing mortality has resulted in shifts in reproductive parameters and overall productivity (e.g., smaller fish maturing and reproducing earlier in their life-history).

The proposed work will provide new information to improve understanding about the underlying causes of changes affecting the SE marine ecosystem. This will help adapt management responses to protect marine biodiversity and enable recovery of both fish populations and impacted ecosystems. It will also establish critical baselines as the reference for future changes and impact assessments.

Policy Challenge: Response

CSIRO is engaged in fishery management and advisory committees at several levels of government. The agency has supported the development of the Commonwealth Harvest Strategy Policy, the Marine Protected Area (MPA) policy, the SESSF Harvest Strategy, as well as conducted stock assessments on behalf of the Australian Fisheries Management Authority. The organisation is also working actively to address commitments under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) Act, blue economy and international agreements. CSIRO's engagement in research includes leading key components of the marine chapters of the Australian State of the Environment, and developing monitoring and evaluation frameworks for Australian marine parks.

CSIRO endeavors to address the Policy Challenge by understanding the needs of both government agencies and industry under the proposed work. As Australia's national science organisation, CSIRO is well-positioned to provide unbiased technical expertise to key players for contextual management decision making and informing policies thereby supporting the journey of responsibly shaping the future of the marine industry in Australia. The project findings could potentially also be used as a reference for the State of the Environment Report, and help with implementation of monitoring programs to support this work.

Collaboration Challenge: Response

As Australia's National Science agency and a trusted advisor, CSIRO acts in an impartial manner among a broad base of marine stakeholders, including government, industry, and the broader community. CSIRO's response to the identified Collaboration Challenge is to take a collaborative and consultative approach to its stakeholder engagement in the marine system, with the aim of delivering the correct information to the relevant audience. On the research front, CSIRO also plans to collaborate with universities and the marine industry to ensure that the surveys are well designed, executed, and implemented to deliver the intended purpose. With its broad stakeholder networks, CSIRO can focus and coordinate the survey efforts for the benefit of all key stakeholders.

Skills Challenge: Response

CSIRO has the capability and wherewithal to lead this endeavour. While it may not have all the skills in-house to answer the proposed questions, it does have the national leadership and ability to harness the collective capability of the marine science community. The project will also drive capability and capacity building in the emerging marine science to improve its maturity level, and better address these marine sector challenges.

Counterfactual

Based on views expressed by external stakeholders during case study interviews, it is unlikely that this research can be conducted in the next 5-10 years without the involvement of CSIRO. Non-action has the potential to compound the negative impacts from a range of challenges identified above, for the Australian marine industry.

It is unlikely the work would be conducted by another domestic organisation, or by a capable international organisation, as there are limited national scientific research organisations that are able to successfully integrate efforts from a wide range of scientific disciplines and marine industry actors, something which is necessary to successfully deliver targeted outcomes from this work. Some universities and state government agencies could contribute, but most lack the ability to coordinate and

deliver scalable solutions at the national level. Some private enterprise organisations may also be capable, but usually lack the level of trust and degree of independence of a public institution like CSIRO. International organisations could undertake this work, but most often lack expertise in the Australian context; the capability of working with Australian governments; and possibly interest in the problem (See Appendix A for further details).

CSIRO Challenges

The proposal addresses two of the six **CSIRO Challenges**, deemed as areas of great significance to Australians in the current environment:

1. **Resilient and valuable environments**: Enhancing the resilience, sustainable use and value of our environments (through the Resilient and Valuable Environments Challenge), which includes the Australian marine estate, the world's third largest Exclusive Economic Zone (EEZ), contributing $74 billion to the economy annually; and
2. **Food security and quality**: Ensuring that the resources are sustainable, secure, and competitive

Investment Objectives

This proposal has been developed to identify and collect data that clarifies the potential effects of climate change on important commercial fish species, and the productivity of their associated marine ecosystems, and drive uptake of new knowledge for improved management and economic growth.

Additionally, it aims to develop scientific talent and literacy by providing learning opportunities in the form of internships for students and Early Career Researchers (ECRs).

CSIRO's strategic objectives through the proposed work are to:

1. Conduct and deliver world-class scientific research solutions by CSIRO's Oceans & Atmosphere to manage Australia's marine areas and atmospheric environment, including :

   a. Understanding oceans and climate by delivering globally consistent and authoritative information and services that enable Australian governments,industries, and communities to predict and respond to weather, climate and ocean variability and change,and extreme events; and

   b. Providing scientific knowledge and tools to support commercial development of Australia's marine resources (e.g. fisheries, offshore oil and gas etc.),while mitigating environmental impacts andconserving marine biodiversity

2. Develop the best talent, by providing high-quality STEM programs for teachers, students and the community. The new learning opportunities are offered in the form of internships for students and ECR.
3. Manage (and utilise) National Research Infrastructure through interns working on Australia's Marine National Facility (RV *Investigator*) to develop scientific and leadership skills.

Key Potential Partners

Table 1: Potential scientific partners (including but not limited to) in the RV *Investigator* Ecosystem Survey project

SECTOR	ORGANISATION	NAME	ROLE IN THE PROPOSED PROJECT
Fisheries	Fishwell Consulting	Ian Knuckey	Technical partner
Fisheries	Southeast Trawl Fishing Industry Association	Simon Boag	Beneficiary
Fisheries	AFMA	Ryan Murphy	Investor + Beneficiary
Conservation / climate change	Parks Australia	Cath Samson	Investor + Beneficiary
Australian Government (funded program)	National Environment Science Program		Investor + Beneficiary
Other Beneficiaries			
Oil & Gas (infrastructure decommissioning)		NERA (National Energy Resources Australia)	
Renewable Energy		Star of the South	
Environment/ Fisheries/investor potentially		Department of Agriculture, Water and Environment	
Government		State industry bodies	
Fisheries		Fishwell Consulting	
Fisheries		Fisheries Research and Development Corporation (FRDC)	
Fisheries		The Tasmanian Department of Primary Industries, Parks, Water and Environment	
Fisheries		Commonwealth Fisheries Association	
Fisheries		State Fisheries agencies (Tasmania, New South Wales, Victoria)	
Fisheries		Australian Fisheries Management Forum	
Research		Institute for Marine and Antarctic Studies	
Research		The Blue Economy CRC	
Research		Integrated Marine Observing System (IMOS)	
Research		Research Providers Network	
Advisory/ Research		Commonwealth Research Advisory committee	

4 Purpose of Impact assessment

The purpose of this assessment is to estimate the potential TBL impacts of CSIRO delivering proprietary knowledge to answer urgent questions for the marine industry (fisheries and conservation managers, industry, and stakeholders). As discussed, the proposed work will address the current knowledge gaps to better understand, prepare,and adapt against the threats of oceanic warming in SE marine waters.

Worldwide there has been an unprecedented focus on demonstrating impacts generated from R&D investments, but traditionally little effort has been put into establishing base-line information to measure it. **A recent survey suggests that early impact measurement and management practices are key contributors to market growth; 88% of respondents reported that it drove better than expected returns on financial investments, and 99% reported meeting or exceeding their impact expectations**[3]. This provides an additional boost to the incorporation of impact estimation, planning, monitoring, and evaluation frameworks as a part of project activities.

Impact assessments require structured and coordinated measurement to estimate and monitor progress (for investors); benchmark investment effectiveness (for portfolio managers); measure progress (for enterprises or investees); and catalyse adoption (for beneficiaries) for the benefit of key stakeholders. **Impact measurement efforts will provide a useful resource to investors planning research expenditure**.

CSIRO is highly focused on delivering value and impact through innovation and research. **This assessment provides a blueprint to determine the value of proposed research for strategic research investment decision making** (See Fig 1). It helps to address key deficiencies associated with conducting ex-post impact assessments that lack baseline information and are heavily dependent upon underlying assumptions. Ex-ante impact estimation and planning, as incorporated in this study, ensure that important indicators are measured along the project journey and reported in an evidence-based manner for the benefit of all stakeholders.

This report can be read as a stand-alone item or alongside other CSIRO Ocean and Atmosphere evaluations. The information is provided for accountability, communication, engagement, continuous improvement, and future application purposes. The audiences include scientific audiences including CSIRO (especially program and leadership teams); Commonwealth, state, and local governments; and key stakeholders (See Table 1).

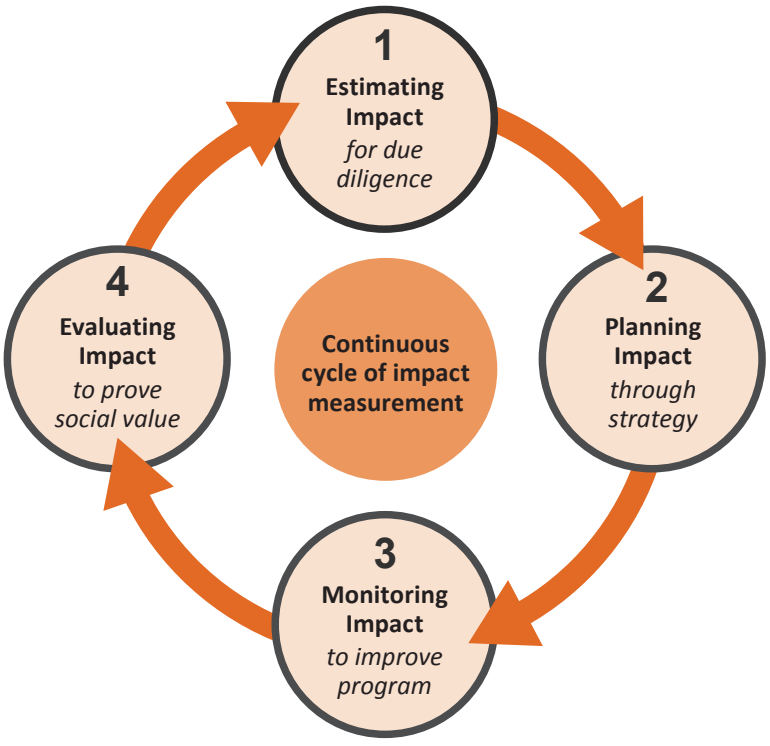


Figure 1: Continuous cycle of impact measurement[4]

3 https://www.pionline.com/esg/global-impact-investment-market-going-strong-despite-pandemic-giin

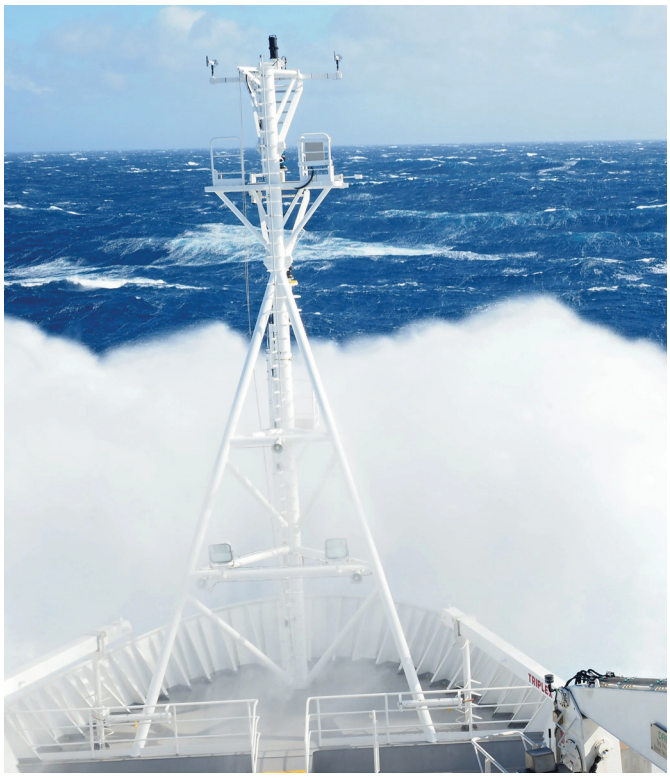
4 www.hbs.edu/socialenterprise/Documents/MeasuringImpact.pdf

5 Why Australia and why now?

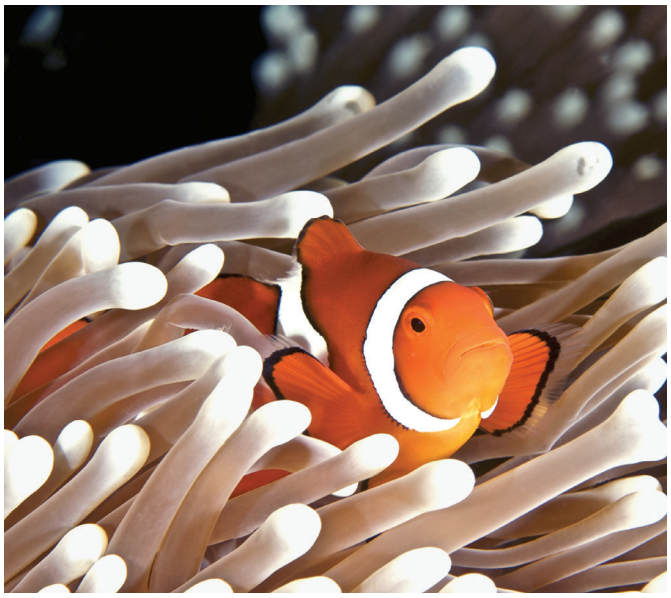
Australia's marine industry is recognised as a high-value and high potential growth sector which is projected to contribute up to $100 billion annually to the national economy by 2025. Australia's vast oceans are considered as the 'heritage, heart and economic future' of the nation. The marine industry contributed $74.2 billion to the national economy in 2013-14, representing 4.8 % of the national Gross Domestic Product and ~400,000 jobs. It is difficult to estimate accurately the substantial social and environmental benefits it generates.

Australia's climate— famously a land of droughts and floods – is one of the most variable on earth. 'Climate variability and change' has been identified as one of the seven grand marine challenges in the *National Marine Science Plan*. Understandably, safeguarding the longer-term health of marine assets is imperative to realise the full potential of the blue economy. Currently, there are significant gaps in the understanding of marine systems. These undermine the ability to provide robust solutions for government and industry. The last survey of the SE marine continental shelf was conducted 25 years ago. Now is the time to revisit the area to document changes, and to help industry and government plan, invest, and create new opportunities in climate-affected industries.

The *National Marine Science Plan* (2015-2025) recognises this need in its priority initiative for a National Marine Baseline and Long-term Monitoring Program.[6] Hence the proposed work is seen by the team as CSIRO's answer to the 'call to action' for Australia to deliver significant economic, social, and environmental impacts as a Marine Nation[5].



Source: MNF, Stewart Wilde



5 https://blueeconomycrc.com.au/about/

6 https://www.marinescience.net.au/nationalmarinescienceplan/

Impact Pathway

Enablers

Years 2021

INPUTS
What we invest

National priority led opportunity (driver)

Investment
- CSIRO Business Unit (BU) funding and in-kind support
- External investment by the marine industry

Capabilities
Background IP
Technical
Technology transfer experts
Communication experts
Business Development
Impact specialists
Change managers
Knowledge brokers

Infrastructure
- Access to infrastructure and resources to execute projects (e.g., RV *Investigator* marine research vessel)

Technical Partners (See Table 1)
Beneficiaries (See Table 1)
Investors (See Table 1)

Regulatory Support

SLO

Innovators

Years 2022–2027

ACTIVITIES
What we do

World-class scientific research
- ***Stage 1:*** Survey and determine changes in biophysical and ecosystem assessments of the Australian southeast continental shelf in the last 25 years
- ***Stage 2:*** Expand the survey to new areas:
  - on the continental shelf, with current knowledge gaps
  - on the continental slope to establish a baseline
  - using new data collection technologies
- Data Analysis and reporting

Research Infrastructure / Assets
- Update ecosystem models
- Update climate models

Sustainability of CSIRO
- Investor proposals
- Grant applications to accrue funding

Marketing
- Partner and customer engagement plans
- Customer uptake plan
- Communication plan
- Public dissemination plan

Impact estimation, planning and monitoring

Translation
- Industry engagement
- Customer engagement
- Organizing and participation in industry events like symposiums, conferences etc

Capability and Capacity Building
- Industry awareness programs
- Participation in discussion forums
- Advice for policy decisions

Education and Outreach
- PhD and Post Doc training

OUTPUTS
Our deliverables

New Knowledge
- Snapshot of what the marine system is doing for comparison
- New knowledge on the causes and consequences of ocean warming four times global average. Answers to the following key questions:
  - What is the fish community composition on the Australian Southeast continental shelf and slope?
  - What are the trophic relationships, and the overall biological productivity of the ecosystem?
  - How have they changed since it was last examined?
  - What factors have contributed to any putative changes; and
  - What is the prospect for the future?
- Comparative assessment caused by environmental variabilities
- Marine baselines for robust and fit-for-purpose long-term planning, monitoring and future measurements

Infrastructure/Assets
- New and improved climate and ecosystem models for forecasting
- An integrated platform that acts as a vehicle for skills, data, infrastructure and network connections

Networks and data sharing
- Partner and customer connections
- Industry consultations
- New data-sharing networks
- Symposiums and conferences

New Investments

Execution and Monitoring plans
- Business plan
- Investor pitch decks
- Impact management plan
- Uptake and adoption plans (domestic and global)

Capacity and capability building services
- Cross-disciplinary skill building
- Training programs

Awards, IP and publications
- Industry roadmaps
- Reports
- Intellectual property
- Case studies
- Media articles
- Publications
- Awards

Scalers

Years 2027–2040

OUTCOMES
The uptake, adoption, or consumption of our work

Phase 1: Parks Australia and SESSF
Phase 2: Other Australian fisheries (incl., but not limited to, Small Pelagic Fishery, SW fisheries and, state fisheries)
Phase 3: Wider marine industry (incl but not limited to renewable, oil & gas, tourism, etc.)

Short Term Outcomes

Adoption of data, tools & solutions by marine industry to:
- Review fisheries scientific management procedures to improve:
  - accuracy of catch limits
  - cost-effectiveness of management and decision making
- Address declining commercial fish abundances in the region
- Provide more accurate outlook of vulnerable fish stocks
- Develop and promote sustainable, cost-effective and

World class facilities
- High-performance data services to synthesise, analyse and access data for evidence-based decision-making.

Sustainable operations, cultural health, safety and wellbeing
- New collaborations and investments to propel uptake and advanced research

Medium-Term Outcomes

Client and stakeholder benefits
- Improved public awareness and confidence to drive adoption of new knowledge, data, and ecosystem and climate models
- Application of data and results to other fisheries and marine industries
- Cost savings for industry from implemented changes
- Expansion of work to other regions of Australia
- Uptake of CSIRO technical capability by government and policy makers for informed decision-making
- Shift of focus from patchy projects to strategic research planning

Capacity and capability building
- Improved capabilities for data coordination and discoverability of coastal data from multiple sources
- Customer awareness and stakeholder engagement programs targeted to address industry and government needs
- Evidence based impact reporting

CSIRO
- Capability building within CSIRO and Australia to fill gaps in marine science
- Increased focus, strategic planning and investment in this space
- Recognition of CSIRO's competitiveness
- CSIRO recognised as a partner of choice to address similar problems in domestic and global markets

Long Term Outcomes

Practice change
- Adoption of the knowledge and resource base to support new National Marine Reserve System
- Increased problem resolution efficiency through maximising coordination and wider stakeholder engagement through national and regional collaborative platforms
- Utilization of enhanced capability to deliver long-term investment returns (ROI)
- Increased management coherence and stakeholder confidence in marine industry through data sharing and accessibility
- New funding/ investment to further knowledge, technology and innovation to advance the blue economy
- Improved transparency, trust leads to increased coherence in a contested space
- Informed policy making

Uptake of knowledge by other nations

Lift Australia's science capacity and capability
- Improvement in robustness of climate and ecosystem models through industry participation
- Creation of new industry opportunities through addressing implications induced by environmental change and variability
- Improved industry participation and co- investment to support advanced research

Social awareness/ SLO
- Provide marine industry with the data and tools to support community awareness and acceptance of delivered solutions

IMPACTS
Benefits to economy, environment, society

Projected Impacts

ECONOMIC
- National economic performance: Enhance Australia's competitiveness and maintain and grow market access
- Management of risk and uncertainty of environmental changes and provide early warning signals
- Policies and programs
- Data capital for future use
- Productivity and efficiency
- Australia's competitiveness

ENVIRONMENTAL
- Conservation of marine biodiversity
- Climate resilience
- Climate adaptation

SOCIAL
- Food security
- Marine industry confidence
- Recreational fishing (RF)
- Indigenous culture and heritage

Figure 2: RV *Investigator* SE Ecosystem survey Impact Pathway

7 Impact Pathway discussion

Five major components define the Impact Pathway: Inputs, Activities, Outputs, Outcomes, and Impacts. These components are each outlined in detail below.

Inputs

This section provides information on the key drivers and resources invested in the project. This includes (but is not limited to):

National priority-led opportunity

(See **Section 5** above)

Investment

– For projected investment requirements, from CSIRO and external funders (industry partners/government), see Table 2

- Four surveys at approximately $1,500,000 per survey, requiring a total investment of approximately $6,000,000 spread over a period of 4 years (i.e., 2022-2026)
- CSIRO would potentially invest approximately $1,500,000 of this total
- The team projects the following **potential investments** from collaborators:
  – NESP (National Environmental science Program)
  – AFMA
  – Other financial contributions from:
  Fisheries Research and Development Corporation [FRDC]
  Parks Australia
  Other investors

Capabilities

– Background IP

- Capability to execute and deliver similar projects. For example, over the past decade, CSIRO has played a prominent role in the development of a suite of world-leading global and regional oceanographic models (such as Bluelink) for use in Australian waters. These have improved the industry's understanding about past and present ocean states and predict ocean dynamics.

– Access to high calibre and multidisciplinary CSIRO and partner capabilities, which include:

- *Technical*
  CSIRO: Fisheries scientists, stock assessment scientists, benthic ecologists, fish biologists, ecosystem modellers, statisticians, plankton ecologists, biological oceanographers, physical oceanographers, acoustic scientists, remote sensing scientists, taxonomists

  There could potentially be a need to raise the average staffing levels (ASL) to provide required manpower and skillset to execute the proposed work.

Technical Partners (e.g., Fishwell Consulting)

- *Technology transfer experts*
- *Communication experts*
- *Business Development*
- *Impact specialists*
- *Change managers*
- *Knowledge brokers to translate scientific knowledge to user (stakeholders / public / end-users) understandable form by providing linkages, knowledge sources, and in some cases knowledge itself*

– Staffing from

- Universities:
  University of Tasmania (UTAS),
  University of Melbourne (UoM),
  University of New South Wales (UNSW)
- Museums: Australian, Victoria, NSW
- State agencies: Victoria, NSW, Tasmania

Infrastructure and Resources

– Access to infrastructure and resources to execute projects:

- RV *Investigator* ship-time four x 4-week voyages over 3-4 years
- Post voyage support from interdisciplinary technical experts
- Customers/beneficiaries/end-users buy-in
- Regulatory and Legal Support
- Social Licence to Operate (SLO)

– Other requirements

- Letters of support from key stakeholders
- CSIRO's leadership support

Table 2: Projected financial and in-kind support for the project

CONTRIBUTOR/TYPE OF SUPPORT	2022	2023	2024	2025	2026
Cash					
External funding		1,000,000	1,000,000	1,217,500	1,217,500
In-kind					
CSIRO	65,000	750,000	750,000		
Annual Total	65,000	1,750,000	1,750,000	1,217,500	1,217,500
Project Total	6,000,000				

Activities

There are a range of key actions that are required to mobilise the available resources and achieve intended outputs for the successful completion of the project. These include (but are not limited to):

Technical Research and Development (R&D)

The technical activities required to complete this project include:

Stage 1: Survey design and preliminary analysis:

CSIRO has undertaken a range of activities to ensure that its science program will fully capitalise on the capability of the RV *Investigator*, can be implemented with high effectiveness and efficiency, and ensure that the overarching science objectives will be met. Voyage planning has involved a multidisciplinary team of scientists in a coordinated effort funded by the CSIRO Marine Resources and Industries (MRI) program. During its pre-voyage planning CSIRO has:

- Actively explored and identified policy needs with stakeholders with regard to fisheries, marine parks, infrastructure decommissioning, and carbon sequestration processes in a changing environment
- Interpreted policy needs to formulate science questions, and translated these needs into questions that can be answered and tested, and hypotheses that can be tested
- Used the hypotheses to structure objectives that are tractably addressed by combining new field data with legacy data and models
- Planned data collection to address the science questions by designing a field program to effectively and efficiently use the RV *Investigator* — capitalising on its capability in 24/7 operation
- Identified the available and relevant legacy data. There are several sources of legacy ecosystem data that prospectively provide important leverage for this project as they can be used to compare, for example, fish species composition, abundance, maturity, length, age, and diet over a ~25-30 year interval.
- CSIRO has accessed the following digital data (or digitised it where necessary) and assessed its content, quality and suitability to address the science questions:
    1. CSIRO SEF ecosystem database (regional ecosystem level data, 1993 - 1996; 2000)
    2. CSIRO Southern Program (local ecosystem level data, 1985 - 1990)
    3. NSW Fisheries Kapala database (fisheries data off NWS, 1947 - 1963)

  Developed a statistically robust survey design built on legacy data which optimises sample and data collection in space and time for future sampling (e.g. marine park monitoring)

  Ensured suitability (including historical compatibility) of sampling gear and methods. Quantitative, reliable, and efficient sampling tools have been selected to ensure efficiency at sea, and to enable comparisons between new and historical data to be made with confidence

  Completed marine environmental characterisation – including hindcasting for legacy data. The project used the Bluelink Reanalysis (BRAN) tool to create maps of environmental conditions when legacy surveys were conducted (monthly intervals for key depth strata) so that environmental conditions can be compared to those during the planned surveys.

Stage 2: The Voyage

Survey and determine changes in biophysical and ecosystem assessments of the Australian SE continental shelf in the 25 years since the last survey

- on the continental shelf, with current knowledge gaps; and
- on the continental slope to establish a baseline
- using particular data collection technologies, such as
  - Demersal trawl sampling using standard gears and methods (identical to previous studies) to provide quantitative samples of demersal fishes
  - Sampling the ecosystem and foodweb structure to capture:
    - primary production from phytoplankton and benthic algae
    - secondary production from zooplankton
    - diets of target species from stable isotope analysis of carbon and nitrogen in tissue samples
    - diets of fishes from stomach content analysis
  - Water column sampling including
    - chemical nutrients
    - physical: salinity, temperature, depth
    - fine-scale acoustic and optical sampling complemented with multi frequency vessel-mounted bio acoustic recordings
  - Photographic sampling to determine types and distributions of seabed habitat
  - Tissue and water column samples to provide genetic, genomic, and environomic information

- Undertake experimental research on ecological processes.
- Monitor key indicators to measure the effects of variability and change
- Develop modelling tools (e.g., building and updating ecosystem and climate models and run them for future time frames to estimate how species abundance and distribution might change and how ecosystems might restructure for evidence-based management)
- Data Analysis and reporting

- Other related activities will include (but are not limited to):

- identifying, collecting, and analysing data critical to the future management of the fisheries
- developing assessments for quantifying the combined impact on fisheries and adapting harvest strategies for improved management
- utilising ocean climate records to measure and monitor variability and change and better model climate processes.

Stage 3: Post-voyage technical R&D activities

Stomach content analysis

- Comparison of fish and benthic assemblages across sampling strata
- The long-term dynamics of seabed habitats and key fish species
- The effects of fishery management (past and future) on seabed habitat
- Changes in trophic structure and other modelling approaches

Funding proposals

- Investor/ grant proposals to seek industry support: in-kind and financial

Business Development (BD)

- Working with BD specialists to deliver the following:
  - Stakeholder Communication and Engagement plan (including customers, partners and supporters)
  - Customer uptake plan
  - Public dissemination plan

Impact

- Impact estimation, planning and monitoring

Marketing and Communication

- Development of written promotional material and video production
- Deliver regular communications with the Australian government, regulators, marine industry, universities, and other key stakeholders
- Networking to share findings and advance research

Technology Transfer / Translation

Industry networks for testing and validation of research deliverables. This is a critical activity for the delivery of robust models and baselines and a pre-cursor for building customer confidence

Customer uptake (fisheries/ marine industry/ government)

- Industry awareness through organizing and participation in industry events like symposiums, conferences etc
- Adoption scale-up

Capability and Capacity Building

- The project will provide training opportunities for future generations of marine researchers and contribute to building a pipeline of science, technology, engineering, and mathematics (STEM) talent to support Australia's growing blue economy by:
  - Providing opportunities for Aboriginal and Torres Strait Islander STEM students under Indigenous Time at Sea Scholarship (ITSS) program (an undergraduate and postgraduate scholarship, established in late 2019)
  - Contributing to the National STEM agenda
  - Training tomorrow's marine researchers and technicians.

Education and Outreach

- Deepen the public's understanding of marine and atmospheric research and of the MNF's value and contribution to solving key challenges by:
  - Making research accessible through appealing and creative storytelling showcasing contributions, impact and value
  - Building opportunities to enable Australians and audiences around the world to engage with research and people
- Presenting technical findings from the work at conferences (domestic and international) and industry networking
- Responding to industry enquiries
- PhD and Post-doctoral training.

Outputs

The research solutions, services, and/or capabilities expected to result from the activities include (but are not limited to):

New Knowledge disseminated through

- Client reports
- Symposia and conferences
- Peer-reviewed scientific papers
- Media articles

Infrastructure/ Assets

- New and improved climate and ecosystem models for forecasting effects of ocean warming in SE marine waters
- Provision of a focussed, better coordinated, and integrated platform delivered by CSIRO, to provide access to technical expertise, data, infrastructure, and network connections required to serve the multi-dimensional needs of key stakeholders in the marine industry

Networks and data sharing

- Data submitted to the Australian Ocean Data Network (AODN) repository

New Investments

- Industry co-investment and new grants to drive uptake and advancement of research solutions

Execution and Monitoring plans

- Business Plan
- Investor pitch decks
- Impact Management Plan
- Uptake and Adoption plans (domestic and global)

Capacity and capability building services

- Cross-disciplinary skill building
- Training programs including:
  - Indigenous Time at Sea Scholarship (ITSS) program, offering Aboriginal and Torres Strait Islander university students the opportunity to join voyages of RV *Investigator*

Endorsement

- An activity for the UN Decade of Ocean Science
  - The Decade of Ocean Science (Decade) will help to mobilise partnerships and increase investment in priority areas of ocean science where the action is urgently needed
  - The Decade will build on existing partnerships and technologies and create new ones to enhance and expand the global scientific capacity required to quickly collect issue-specific information to meet the constantly-evolving needs of ocean and coastal zone managers and a rapidly developing blue economy
  - A core objective of the Decade will be to improve the scientific knowledge base through capacity development within regions and groups that currently are limited in capacity and capability
  - Throughout the Ocean Decade, partners around the world will carry out a diverse type of Decade actions ranging from small, local actions to global research programs
  - Together, all Decade Actions – large and small – will form part of the collective movement to achieve the 'desired' ocean 2030. The team plans to apply for endorsement of this research as a contributing activity to the Ocean Decade

Awards, IP and publications

Outcomes

The short- to medium-term shifts from the successful delivery of the Southeast Marine Ecosystem Survey proposed by CSIRO to stakeholders, are covered in Table 3. This includes potential outcomes in the form of transition towards industry development, job growth, environmental sustainability and economic prosperity for Australia. The outcomes would be the result of a collective effort between CSIRO, key industry partners, customers, and supporters.

Table 3: Potential short-medium- long term outcomes anticipated from the delivery of project outputs

	Driven by the scale of adoption (by Industry, Government, Community)*		
OUTCOME	**SHORT-TERM**	**MEDIUM-TERM**	**LONGER-TERM**
Beneficiaries	**Parks Australia + SESSF**	**Other fisheries + wider marine industry**	
Evidence-based • management planning • monitoring • decision making • TAC revisions • Baselining			
Uptake of Outputs for review and revision of the SE Marine Park Network management plan			
Increased cost savings from the uptake of proprietary knowledge to address similar challenges faced by other fisheries in Australia			
Increased industry confidence through the uptake of research solutions for improving commercial outcomes			
Policy decision making			
Uptake by Government to support grand challenges and recommendations outlined in the National Marine Science Plan			
Supported by new knowledge, tools and stakeholder awareness			
Increased stakeholder (industry, Government) support and integration (resulting in reduced duplication of efforts)			
Increased research by way of Government-Industry collaborations			
The shift from focus on inconsistent project deliverables to systemic changes through improved stakeholder coordination and integration			
Increased coherence and reduced contested decisions among marine industry key stakeholders			
Increased knowledge of the key factors that underpin marine ecosystems to understand the limits to resilience and adaptation			
Increased community confidence to obtain Social licence to Operate [SLO]			
Increased uptake of new and improved research capabilities (e.g., ecosystem and climate resilience models) with improved ROI			
Increased Australian capability and capacity base in this space to improve response to ocean warming, climate events, aquatic animal health and develop improved risk management			
Increased R&D investment			
Spillover benefits to other industries (e.g., oil and gas, tourism, etc.)			
Increased global engagements			
Increased recognition of CSIRO's competitiveness in this space			

*Denotes scale of adoption

Short term uptake (0-3 years)

Medium term uptake/ adoption (3-5 years)

Longer term adoption (5-10 years)

Impacts

Overall impact = Direct impact + Sector level impact

- **Direct Impact**: **Σ** (benefits generated through directly working with customers and partners)
- **Sector level Impact**: **Σ** (benefits generated through raising industry's benchmark understanding and awareness, and sparking new innovations)

Projected Impacts

Table 4: Summary of forecasted project impacts using CSIRO's TBL benefit classification approach

IMPACTS	DESCRIPTION*
Economic	
• National economic performance: Enhance Australia's competitiveness and maintain and grow market access	- Improvement in the sustainability of fisheries and utilisation of marine jurisdictions, to provide new opportunities to supply-demand requirements of domestic and export markets. Note: the proposed work does not have direct economic contributions
• Management of risk and uncertainty of environmental changes and provide early warning signals	- Uptake of new knowledge, including ecosystem and climate resilience models, for improved management and forecasting, thereby improving capacity to respond to impending changes
• Policies and programs	- Uptake of evidence-based data by regulatory decision-makers to inform policies and programs
• Data capital for future use	- New and evidence-based data assets that can be used in multiple ways by industry stakeholders - Creation of new high-skilled jobs to execute this work
• Productivity and efficiency	- Improved speed of decision-making and process operations due to the availability and utilisation of data, new knowledge, and tools
• Australia's competitiveness	- Establish Australia's competitiveness in this space through global consultations and collaborations
Environmental	
• Conservation of marine biodiversity	- Understanding the changing context in which Marine Parks are set. New knowledge to understand and mitigate the conservation of marine biodiversity against the effects of fishing and climate change
• Climate resilience	- Uptake of new knowledge, including ecosystem and climate resilience models, for improved management and forecasting
• Climate adaptation	- New knowledge used for informed decision making, (e.g., catching fewer overfished fish species under threat)
Social	
• Food security	- Uptake of work to build seafood capacity for addressing domestic and export demand
• Marine industry confidence	- Building platforms, awareness, and integration of key stakeholders to drive benefits, build industry coherence and confidence
• Recreational fishing (RF)	- Increase returns, and lowering of the environmental footprint, of recreational fishing (RF). The orientation of RF for both sustainable management of resources and economic development
• Indigenous culture and heritage	- Capability and capacity building: Opportunity for Aboriginal and Torres Strait Islander university students to join voyages of RV *Investigator* ITSS program
• Innovation and human capital	- New skills and capabilities from insights imparted by new knowledge

** NB: Since the project is at the early proposal stage, identification of indicators for the forecasted impacts has not been conducted*

Estimating benefits

Example adoption case 1: Uptake by Parks Australia

As mentioned earlier in the assessment, CSIRO's project outputs are expected to provide significant inputs and contextual knowledge for Parks Australia for evidence-based management decision making and supporting monitoring plans.

Example adoption case 2: Uptake by SESSF

As covered in Table 4 above, the proposed work has the potential to deliver a series of social, economic, and environmental impacts for the benefit of Australia. Since the work is strategic in nature, the majority of changes will be gradually adopted as 'practice-change' by the industry; and as such, any measurable benefits will be realised into the future, rather than as immediate returns. Also, until the scope and specific applications are more clearly defined, it is not possible to quantify the potential benefits from adoption of deliverables. Due to these factors, it is not feasible to conduct Cost Benefit Analysis (CBA) at this stage.

Table 5: Key challenges

CHALLENGE	DESCRIPTION
Reduced effectiveness of current marine parks in conserving biodiversity	Lack of ability to support climate change adaptation and mitigation, among other factors has potentially affected Parks Australia's ability to manage and conserve biodiversity. Is important to note that at this stage, there is lack of data-based evidence to support this claim. Also, due to the remote, deep nature of the parks opportunities to implement climate change, adaptation and mitigation measures may be limited
Failure to catch TACs	In 2015/2016, catches of 23 of the 34 species groups were less than 50% of the TAC. Of the major quota species, only four had catches above 80% of the TACs set, namely Flathead, Gummy Shark, Pink Ling, and School Whiting
Declining Catch per unit effort (CPUEs) Due to changing productivity, abundance and distribution	• Unstandardised CPUE has declined over years, reaching an all-time low in 2015 • Optimised CPUE standardisations indicate declining standardised catch rates of 29/43 SESSF stocks
Lack of recovery of overfished species	• Historically overfished species have shown little sign of recovery, despite over a decade of lowest catches • Fisheries have their jurisdictional boundaries, and the operations are performed as per quotas to fish those species. If there is a migration towards the south, then the fisheries do not have the licence to catch any new species that occur due to these shifts. This has led to the downsizing of operations, making them sub-optimal in the current environment • The controls in place to protect the overfished species also limit the catching capacity of other fishes that are not overfished. For example, in an effort to protect overfished school sharks, gummy sharks are underfished, and hence are available in abundance. This and other similar phenomena affect the economic viability of the fishing operation

The industry challenges identified above represent a 'cost of inaction' worth millions of dollars. It is important to note that these issues are multidimensional and complex. The adoption of deliverables from CSIRO's proposed work in the form of new knowledge, models, and consultations to revamp monitoring and management programs will not resolve these issues in isolation. Nonetheless, they will provide varying levels of attribution to advance understanding about underlying factors, thereby better positioning the industry to improve adaptation strategies against climate-induced changes.

The focus on fisheries and biodiversity represents a small test-group that will help advance the uptake to a wider base of stakeholders that includes more fisheries (e.g., Small Pelagic Fishery), as well as other marine industry sectors (such as oil and gas, recreational fishing, etc.).

Phase 1 Targeted outcome: Uptake of proprietary knowledge by SESSF fisheries

The SESSF occupies global ocean warming hotspots (four times ocean warming rates vs global average). Being a large fishery, different parts of SESSF undergo different levels of changes (depending upon temperature, rainfall patterns, ocean acidification, shifting ocean oxygen levels, etc.).

There is a need to establish an understanding about the ways it is affecting the marine habitats, ecosystems and species productivity and distribution. It is a complex multi-species, multi-gear fishery, distributed over a large geographical area. Added to this is the complexity of a quota system which covers 34 species or species groups, held by individuals and companies who are not necessarily fishing concession holders.*

SESSF CHALLENGE	CSIRO'S PROPOSED RESPONSE
• ecological, economic, and social sustainability concerns • future management of the fishery in a variable environment • understanding the impact of ocean warming on the fishery to better adapt harvesting strategies	• deliver data that helps clarify the impact that climate change will have on the productivity, abundance, and distribution of species that are caught, and the habitats and ecosystems that support them • assist with development of improved assessments and management plans based on this new knowledge, data, and models • provide support with validating other routinely performed industry fishery surveys

Uptake of new knowledge, data ecosystem and models (ecosystem and climate) by SESSF to:

4. Estimate stock status of important commercial fish species for more accurate setting of catch limits (i.e. TAC)
5. Smarter and efficient decision making based on evidence-supported data around revision of current TAC limits
6. Develop and promote consistent, cost-effective and climate resilient fishery management strategies

As mentioned above, uptake of proprietary knowledge by SESSF fisheries as a key beneficiary presents a critical test case. This is expected to:

- demonstrate and improve efficacy of the delivered interventions
- strengthen industry confidence to scale-up uptake of this work by wider customer base for improved management and decision-making
- drive uptake of knowledge by government for informing policy
- integrate and better position CSIRO and key stakeholders to deliver the intended impacts from this work.

Potential benefits to wider industry

– The effects of trawling on the seabed are a major issue worldwide. Standard methods used to evaluate the ecosystem effects of trawling are comparisons of fished vs. unfished areas, or assessment of areas previously fished, but then placed within marine protected areas. Typically, however, these surveys lack replicability and are not of appropriate temporal or spatial scales to provide robust results.

The proposed surveys will be stratified across a range of fishing effort intensity and habitat heterogeneity. The modelling approaches undertaken in the study will provide an improved understanding of the biological structure of marine communities, trophic function and relationships, and their response to disturbance. The conclusions will be robust, significant in an international context, and relevant to the management of fisheries

elsewhere in Australia. These also have the potential to contribute to the global monitoring of the effects of management of trawling areas. The study will assist in setting priorities for the assessment of the management options necessary to ensure that trawling fishing is conducted in an environmentally sustainable manner which is adaptive to environmental change.

The modelling approaches undertaken in the study will provide an improved understanding of the biological structure of marine communities and their response to disturbance, trophic function and relationships, and provide a tool to evaluate management scenarios of fishing impact (e.g., levels of effort/spatial closure):

- There is significant potential for the new and improved understanding (knowledge, models, and baselines) generated by the surveys to be adopted by stakeholders other than those in fisheries for decision making and adaptive planning for their businesses. These include climate-sensitive industries such as offshore oil and gas, aquaculture, and renewable energy.
- Uptake of project deliverables by the oil and gas industry presents a significant flow-on benefit. This industry will start working on the decommissioning process in a few years, and the new knowledge can provide important context for the decommissioning process (e.g., whether to leave existing infrastructure in place). This potentially can save resources worth billions of dollars for the industry.
- Information produced by the surveys also has potential to be used in the development of stock rebuilding plans. In particular, for recovering stocks with a high amount of habitat fidelity, rebuilding plans may require further periodic benthic surveys to measure the status of recovering species.
- There are multidimensional factors that impact climate models. New knowledge will advance the capability of the accuracy of these models while improving their reliability and robustness. For example, some models that only examine the physical environments preferred by species predicted that there would be reasonably large declines for the majority of fish populations around Australia. However, once all the other processes that occur in ecosystems (e.g., feeding, movement, habitat use, etc.) were included in the models, the picture is more complicated – some species decline, but others benefit and grow in abundance, though perhaps living in new locations.

8 Impact Determinants

IMPACT = *F* (Proprietary Knowledge, Adoption scale)

The impact is a consequence of cutting-edge solutions capable of delivering integrated economic, social and environmental benefits and adopted at scale.

IMPACT DETERMINANTS	RECOMMENDATIONS
Proprietary knowledge	
1 Financial: The proposed project aims to address a significant national priority, has a large scope, and requires high investment. Lack of funding presents a key roadblock in the pathway of execution of this work at this stage. In general, Australia lags in R&D investment compared with other leading nations. A review of the national innovation system in 2008[8] indicated that Australia has under-invested in marine research and maritime industries.	- Since the proposed work has a mission-sized scope, planning for optimal utilisation of resources at the outset is critical to accomplish targeted deliverables and get industry buy-in. The value proposition needs to be clear and attractive for potential investors. - In today's tight economic environment, targeting a portfolio of investors could lower this risk to some extent. Industry and Government partnership, co-investment, co-design/execution, and buy-in would accelerate the innovation cycle and help to translate this initiative into amore coordinated effort and utilise skills and infrastructure from key stakeholders (academia and industry) to deliver scientifically sound solutions.
2 Technical Expertise/ Resources: Having access to a portfolio of relevant interdisciplinary skills is essential to build proprietary knowledge – a key enabler to deliver success and impact from this work. Lack of these resources is a major impediment in the pathway of realising intended outcomes.	- Leveraging CSIRO's unique attributions such as access to multidisciplinary skills; stakeholder connections (customers/academic institutes/industry/government); and the ability to integrate key players to would add efficiency to the innovation cycle while delivering more out of every dollar invested.
Adoption	
3 Adoption Costs Fisheries by nature are conservative and inflexible. The high adoption cost of the proposed solutions, as well as required operational shifts from traditional ways, present key inhibitors in the pathway of uptake and adoption. The prospective changes also have the potential to change the livelihoods of coastal communities and seen as another key roadblock.	- It is important for CSIRO to focus on devising affordable and low-intensity pathways for the implementation of the proposed work by industry. In the absence of cost-effective solutions, the scale of adoption will remain a key hindrance in the journey of delivering impact. To obtain industry traction, the value proposition of the work needs to be clear and compelling against the current practices. During stakeholder interviews, industry respondents have also highlighted interest in testing the viability of the development of low-cost independent monitoring systems to secure longer-term stakeholder benefits from the proposed work.

8 *Venturous Australia—building strength in innovation: 2008* Report on the Review of the National Innovation System

IMPACT DETERMINANTS	RECOMMENDATIONS
Adoption	
4 Customer/ end-user confidence for the uptake of delivered outputs To achieve any measurable impact, strong customer traction to test, validate, adopt, and advance the robustness of new knowledge, data, baselines, and models is paramount. Delivery of impact is driven by stakeholders. Despite technical strengths, some research solutions never get adopted mainstream (= no/low impact) due to lack of industry confidence.	- Industry's current systems were historically appropriate, but there is a need to adapt to predicted ecosystem shifts. Hence, a robust engagement plan and early involvement of beneficiaries are highly recommended. - Keeping customer needs at the heart of technical interventions, together with a robust uptake plan from the outset, is critical to delivering intended impacts. Tracking indicators that align with customers' needs gives involved stakeholders the opportunity to talk in a common language, ensure alignment with targeted objectives, and build trust. - Articulating the significance of work to the involved stakeholders and co-designing processes from concept to uptake helps build confidence and improves the ability to deliver and scale impacts. Conducting a mission-sized, complex, expensive, high-risk, and high-consequence piece of research without stakeholder buy-in is high-risk and and thus needs to be a key area of focus. - Industry engagement activities (such as participation in/ organisation of forums, advisory groups, as well as panel discussions) would improve visibility of this work and present it appropriately to the intended audience.
5 Stakeholder integration Achieving impact in addressing complex problems cannot be done alone – it requires diverse stakeholder (internal and external) collaboration. This is a critical step towards making the whole greater than the sum of the parts.	- To achieve any measurable 'systemic shift' through the utilisation of proposed capability, it is important to improve coordination and integration among the key stakeholders. Achieving deep engagement is the key to effective adaptive governance. - Development and implementation of a strategic engagement and communication approach would help build partner and end-user traction to deliver targeted impacts. - CSIRO needs to leverage its interconnected web of relationships with different sectors to deliver the objectives of this survey.
6 Regulatory Uptake of the proposed proprietary knowledge by regulators for informed policy decision-making is a key requirement for driving the overall marine industry confidence and delivering the intended practice change.	- As a conscientious technology developer, CSIRO is focused on the scientifically validated and socially responsible implementation of research solutions for the benefit of Australia. The marine industry is governed by stringent regulations. CSIRO should work closely with governments and industry to render its technical expertise to tackle the Policy Challenge.

IMPACT DETERMINANTS	RECOMMENDATIONS
Adoption	
7 SLO	- The communication and engagement plan must be strategically developed, and include a public engagement, awareness, and information dissemination plan to inform community discussion regarding 'social licence to operate'. This also has the potential to provide insights to inform future research and the development of social licence.
Impact	
8 Impact planning, monitoring, and reporting Lack of/informal/inconsistent and weak impact measurement are key impediments for the pathway of delivering intended goals from impact planning and monitoring. In most cases, activities undertaken to execute impact management over the life of the project can appear to add to overall project costs; hence, it is deemed prudent by stakeholders to not spend limited research funds on these.	- Incorporating impact management from the start provides a structured and coordinated approach to identify, predict, monitor, and track the TBL impact anticipated from the proposed work (nature, extent, and CSIRO's attribution) for the benefit of Australia. It is recommended that an Impact planning workshop be conducted with the industry partners to help achieve this objective. Many recent reports and surveys suggest that early impact measurement and management practices are key contributors to drive market growth and deliver better economic returns while meeting/exceeding impact expectations. - This is an important step towards laying a strong foundation to build stakeholder confidence while providing an opportunity to identify assumptions, areas in need of further evidence, and risks associated with the pathway for delivering impacts.
9 Scope of work	- External stakeholder interviews highlighted the need to widen the scope of the work to benefit the broader base of marine industry customers beyond the current target fisheries group. This will also help justify the investment; maximise the return; and attain wider industry traction and customer buy-in to enable the success of this work.

9 Conclusion

RV *Investigator* SE Ecosystem Survey impact assessment is a future-looking evaluation that highlights the potential impacts of CSIRO's proposed work. As discussed, the triple bottom line (TBL) impacts delivered from this project will be driven by technical competitiveness of furnished solutions; end-user traction and buy-in; industry support; key stakeholder integration; and scale of adoption.

At this early stage, CBA for quantification of impacts is not possible. However, the Estimating Benefits section is included above to provide some idea about the 'cost of non-action'.

For achieving measurable impacts from the proposed work, it is critical to have clarity on CSIRO's research priorities and strategically planned path towards the delivery of impacts, while bearing in mind Australia's regulatory climate, industry interest, and agility. Some key questions that leadership and technical teams need to answer include:

i. Considering the importance, complexity, high-consequence, and high-investment nature of the proposed work, what would be the most strategically appropriate way forward?

ii. Can CSIRO target alternate funding channels or a portfolio of investors to secure funds for the execution of this work?

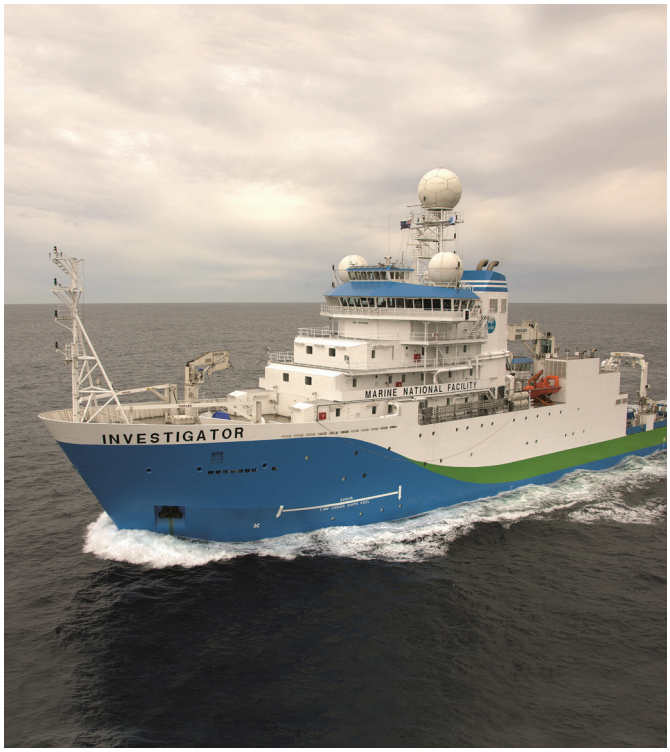
iii. Lack of industry confidence and customer buy-in, and the marine industry's generally conservative stance, have been identified as significant roadblocks to uptake and adoption. How does the project team plan to collaborate with key stakeholders like Parks Australia/Fishing Industry/AFMA/O&G industry/SARDI from the outset to co-design the project and mitigate this risk? How does the team plan on engaging with the wider industry and improve the visibility of the proposed work and its value proposition?

iv. How does CSIRO plan to support the team especially with regards to resources (right expertise) and translation support (BD support) to scale up efforts, resource utilisation and the likelihood of delivering positive impact for the benefit of all stakeholders?

v. How can CSIRO lower the risk and cost-intensiveness associated with the proposed work? Are there any learnings to draw from other countries that can be leveraged to advance technical competitiveness, build stakeholder confidence, lower adoption costs, or drive uptake of the proposed work?

The proposed work is aspirational, with the potential to address significant use cases for the benefit of Australia. At the current stage of the project, this impact estimation aims to provide a resource for investment decision-making for the benefit of investors and investees.

If CSIRO secures funding to execute this project, it is highly recommended that an impact planning and monitoring workshop be conducted post-finalisation of the project scope. This activity should be conducted in collaboration with the key stakeholders to outline the impact approach and identify the key indicators that need to be tracked along the journey of this work for impact baselining, ensuring mission alignment, and performance monitoring and evaluation purposes. This would also help with conducting evidence-based impact reporting at a later stage to demonstrate the value delivered by this work for the benefit of Australia.



Source: CSIRO

APPENDIX A – Why should this initiative be a strategic priority for CSIRO?

As Australia's national science agency, CSIRO has the unique responsibility and potential to deliver solutions to the marine industry challenges discussed above. Access to interdisciplinary scientific capabilities, RV *Investigator* marine research vessel, brand recognition and relationships form critical verticals to drive delivery and uptake of scientific solutions.

Some compelling reasons for CSIRO to lead this effort for the benefit of Australia include:

- The proposed work entails a 'mission'-sized scope with substantial resource input requirements in the form of background IP, cross-disciplinary skills, infrastructure, time, effort and key stakeholder support. The immense depth and breadth of requirements render it infeasible for most other organisations to execute it alone.

  In addition, CSIRO has access to RV *Investigator* marine research vessel, which forms a critical supporting infrastructure asset required to accomplish this work.

  CSIRO – given its access to a portfolio of in-house skills and the ability to act as a vehicle to harness capabilities of industry and academic organisations – is well placed strategically to deliver solutions effectively, efficiently, and collaboratively.

- The true success of this work will be highly dependent upon the integration of various industry actors. Until now, most of the efforts to address this knowledge gap have been sporadic, with a lack of the platforms required to make the 'whole' more than the sum of its parts. This also underlines the need to pool the results of past efforts and capitalise on previous projects to deliver the targeted national capability. CSIRO, with its national and global brand reputation and network connections, is well placed to enable and strengthen this integration.

- Any measurable impact from this work will be highly dependent upon the uptake of the new knowledge for informed decision-making (policy and commercial) across the marine industry. This calls for significant end-user confidence and network to scale adoption. CSIRO's reputation as Australia's innovation catalyst is a significant enabler to drive the confidence imperative to translate this new research and critical data into knowledge, innovation, technology and tools for a new growth wave of the marine industry.

- Australia lags in R&D investment compared with global leaders in this space. The COVID-19 pandemic has further tightened the resourcing for all sectors. In the current economic environment, it becomes increasingly important that every invested dollar efficiently accelerates the innovation cycle.

  Access to multi-dimensional in-house expertise and strong background IP gives CSIRO the capability to provide a 'one-stop-shop' to the key stakeholders while maximising the productive utilisation of invested resources by a reduction in effort and wasted time in unnecessary governance/logistics.

Target Audience

The project will be disseminated to three main audiences:

1. **Scientific audience.** The principal means by which the project details and its results are disseminated to the scientific audience will be through scientific publications, and conference talks and proceedings. CSIRO envisages submission of a publication in a high-impact science journal, and subsequent papers submitted to disciplinary-specific journals.
2. **Industry Stakeholders.** The principle means by which the project details and its results are disseminated to stakeholders will be through:
   a. scientific reports;
   b. information sheets; and
   c. national and international working groups and committees.
3. **General public**. The general public will be informed of the project through traditional media and on-line media, including videos and social media.

APPENDIX B – References

1. https://www.csiro.au/~/media/OnA/Files/Climate-projections-Australian-fisheries-factsheet.pdf?la=en&hash=BB40D4513491373C50C4D8267ADD1616B7ECE9A7
2. https://www.sciencedirect.com/science/article/pii/S2212096317301109
3. https://www.pionline.com/esg/global-impact-investment-market-going-strong-despite-pandemic-giin
4. www.hbs.edu/socialenterprise/Documents/MeasuringImpact.pdf
5. https://blueeconomycrc.com.au/about/
6. https://www.marinescience.net.au/nationalmarinescienceplan/
7. http://www.eurocbc.org/envimpact_trawlseabed_review.pdf
8. Venturous Australia—building strength in innovation: 2008 Report on the Review of the National Innovation System

APPENDIX C – Employment contributions

It should be noted that any additional employment (typically stated as 'jobs created') is not an economic benefit. Just as for any other resource, use of additional labour resources imposes an opportunity cost on Australian society, because those workers cannot be used elsewhere to produce goods or services. In addition, some workers will simply transfer from other jobs (potentially including from CSIRO positions), so the net creation of jobs will be zero. Those workers who are employed in new positions will obtain a wage, but the cost of the wage is borne by employers, so the net benefit to society is zero, except for any additional profit (producer surplus) that is generated. Nevertheless, estimates of job creation opportunities are generally of interest to decision-makers, and they can be reported separately from the cost-benefit analysis to provide a comprehensive outline of expected impacts.

In principle, the engagement of an unemployed worker with no other clear job prospects imposes no opportunity cost on society. In a situation of structural (i.e., non-cyclical) unemployment, therefore, society can benefit from the creation of new jobs that are filled by the unemployed. But this benefit can only be realised if the skills of the currently unemployed workers match the competencies required in the newly-created jobs. Further, any benefit to the newly employed workers, and hence society, would be offset to some extent by their loss of leisure (i.e., non-work) time, which can also result in social benefits through activities such as child-minding, gardening, relaxation, exercise, etc., that are valued by the worker.

Taxes have a depressive effect on the economy by reducing aggregate demand and/or output. They, therefore, reduce job opportunities and profits. To the extent that the RV *Investigator* SE Ecosystem Survey is funded by CSIRO and other funding sources through government taxation, there will be some potential loss of jobs in the economy. In other words, it cannot be claimed without qualification that there will be a straightforward increase in employment levels attributable to the assessed work.

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