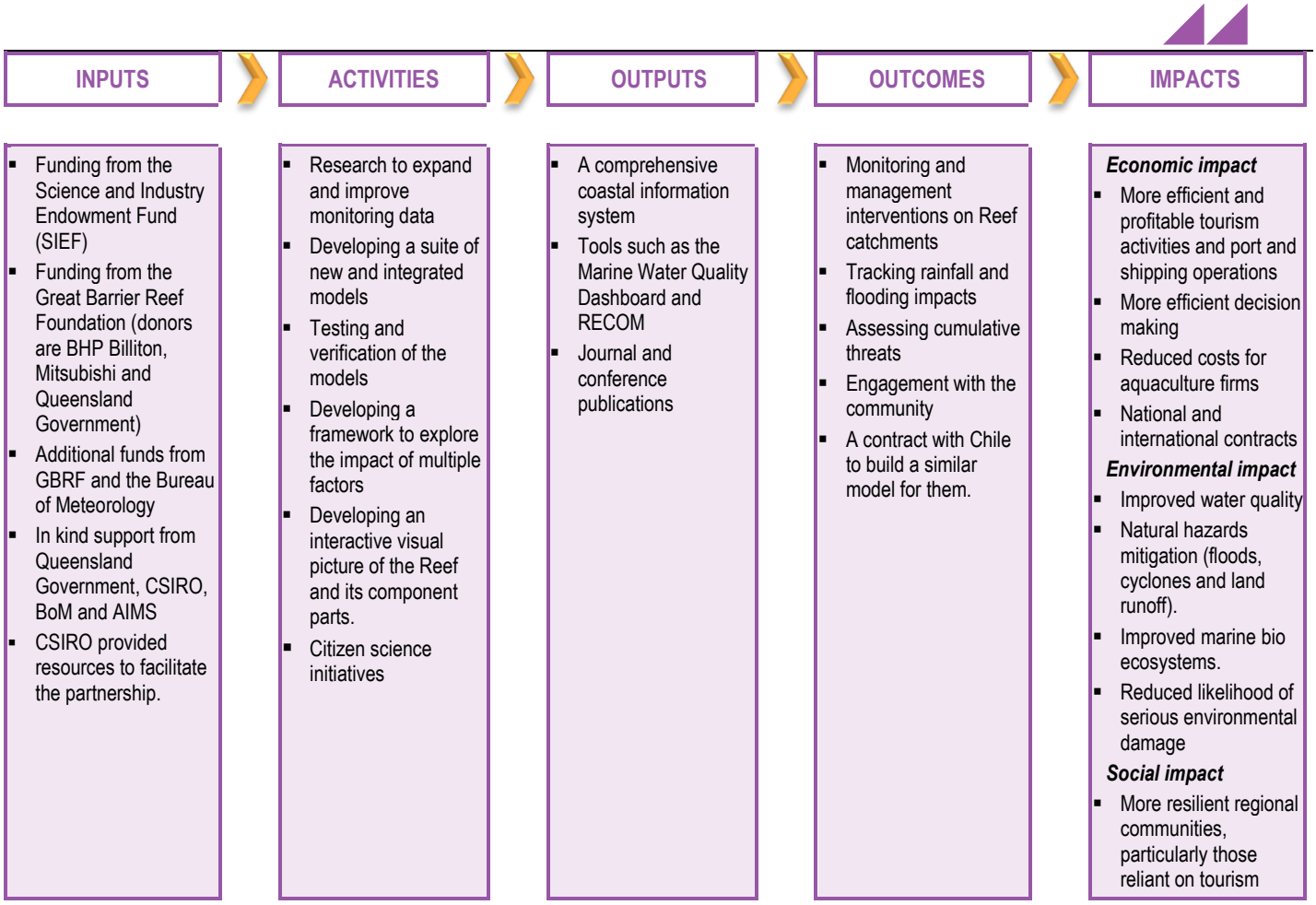
FIGURE 1.1 CSIRO CASE STUDY EREEFS - IMPACT FRAMEWORK DIAGRAM



SOURCE; ACIL ALLEN

1.1 Background

1.1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from CSIRO's and its partners' research on the Great Barrier Reef (the Reef).

Audiences for this study are likely to include Ministers and their offices, the public, and CSIRO's customers. The document will also be used within the CSIRO by groups such as the Science, Strategy, Impact and Investment Committee (SICOM) and the Business Unit Review team.

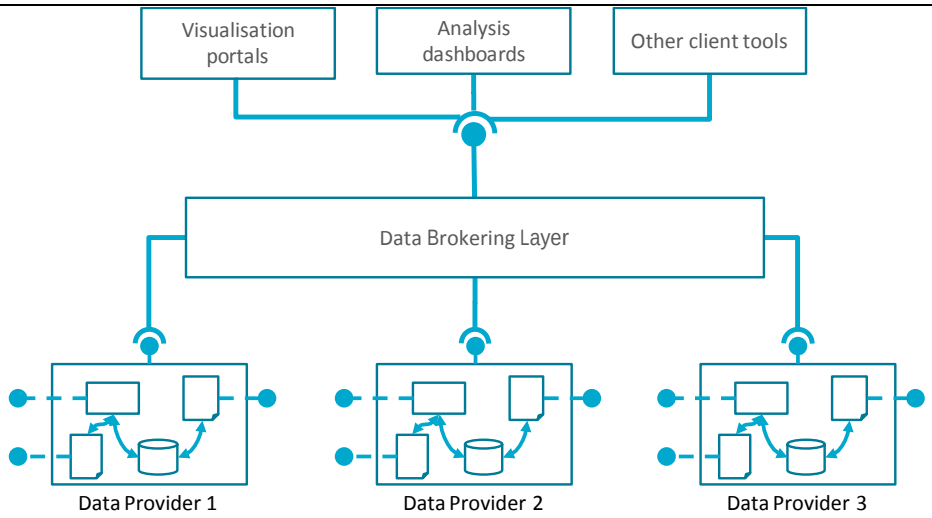
1.1.2 Project origins and inputs

The Great Barrier Reef, the world's largest coral reef system, is one of the seven wonders of the natural world and was the first coral reef to be included on the UNESCO World Heritage List. The reef is not only a natural wonder it is a source of considerable economic activity. The majority of the value added and employment generated is from tourism. A 2013 report estimated that there was almost $5.2 billion in value-added and about 64,000 FTE (full time equivalent) jobs generated by that sector.[1]

However, the Reef is under threat. For example, the Great Barrier Reef Marine Park Authority's 2014 Outlook Report stated that:

[1] *Economic contribution of the Great Barrier Reef*, Great Barrier Reef Marine Park Authority, Townsville, Deloitte Access Economics, 2013.

FIGURE 1.5 SCHEMATIC DIAGRAM OF THE EREEFS INFORMATION PLATFORM

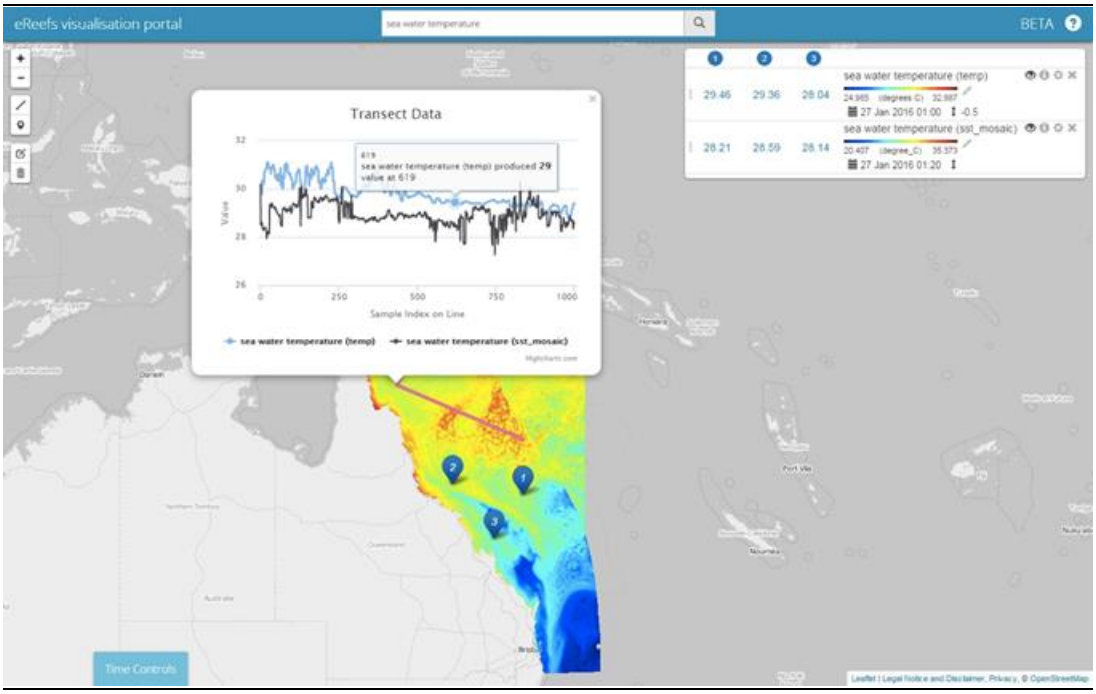


SOURCE: CSIRO

An eReefs visualisation portal was developed to allow access to the various outputs of the eReefs information system in a visual and intuitive manner. The portal allows users to discover, visualise, interrogate and extract data from various eReefs products. Currently, the visualisation portal allows access to the CSIRO hydrodynamic model outputs (4km and 1km), the CSIRO Biogeochemical model outputs (4km and 1km) and the BoM Ocean Colour data. It will soon incorporate data from the Queensland Government, including river flows and catchment model outputs. Users can overlay various data products on a mapping interface and interrogate the data in various ways. Currently, users can add markers to the map which provides the user with data from each layer. This means that data from different data providers, different variables or even different dates or depths from the same data products can be viewed simultaneously. In addition, users can draw a line through the data to generate a graph of data for each layer along that line. Additional user tools are nearing completion, including advanced charting tools, a depth profile tool and data download functionality.

Figure 1.6 illustrates the kind of information that the eReefs visualisation portal can provide to users.

FIGURE 1.6 EREEFS VISUALISATION PLATFORM



SOURCE: CSIRO

The tools developed as part of this project are accessible via the web. Users around the globe will be able to access comprehensive information about the conditions of the Reef in real-time on their laptop, tablet or mobile. Users will be able to see the effects of storms, cyclones and floods on reef water quality. The data collected can also be downloaded by researchers for use in their own research.

Hydrodynamic models can be used to develop customised products such as sailing forecasts and tidal information to assist port and shipping operations, as well as enabling forecasts of hazards such as jellyfish blooms and aiding emergency responses.

1.3.1 Publications

CSIRO's research for the eReefs project has led to more than 45 publications, including 17 in peer-reviewed journals, 14 conference papers or abstracts and 6 reports. Some examples are listed below:

— Mongin, M., M. E. Baird, B. Tilbrook, R. Matear, A. Lenton, M. Herzfeld, K. A. Wild-Allen, J. Skerratt, N. Margvelashvili, B. Robson, C. M. Duarte, M. S. M. Gustafsson, P. J. Ralph and A. D. L. Steven 2016. *The exposure of the Great Barrier Reef to ocean acidification*. Nature Communications 7: 10732.

— Baird, M. E., N. Cherukuru, E. M. Jones, N. Margvelashvili, M. Mongin, K. Oubelkheir, P. J. Ralph, F. Rizwi, B. Robson, T. Schroeder, J. Skerratt, A. D. L. Steven and K. A. Wild-Allen (2016). *Remote-sensing reflectance and true colour produced by a coupled hydrodynamic, optical, sediment, biogeochemical model of the Great Barrier Reef, Australia: comparison with remotely-sensed data*. Environmental Modelling and Software Journal 78: 79-96.

— Herzfeld, M. and P. A. Gillibrand (2015). *Active open boundary forcing using dual relaxation time-scales in downscaled ocean model*s. Ocean Modelling 89: 71-83.

— Herzfeld, M. (2015). *Methods for freshwater riverine input into regional ocean models*. Ocean Modelling 90: 1-15.

— Jones, E. M., M. A. Doblin, R. Matear and E. King (2015). *Assessing and evaluating the ocean-colour footprint of a regional observing system*. Journal of Marine Systems 143: 49-61.

— Mongin, M. and M. Baird (2014). *The impact of photosynthesis, calcification and water circulation on carbon chemistry variability above a coral reef: a modelling study*. Ecological Modelling 284: 19-34.

1.3.2 Innovation and commercialisation

Even though work on this project is still underway, the level of take up of the technology they have developed is pleasing. The indications are that CSIRO's 'route to market' approach of providing open access to the platform they have developed is proving to be successful. The marine water quality dashboard developed by BoM is one example, the development of RECOM and the contract with Chile are examples of how others also see considerable value in the outputs of CSIRO's research.

The eReefs project is delivering an information archive which includes products from in-situ monitoring, satellite remote sensing and environmental modelling. Notably, these data products are being delivered not only as downloadable data, but also as data services. This enables third parties from around the world to build customised tools and interfaces that make use of this data in novel and innovative ways, whether that be to create an application for a mobile device or a text based report.

CSIRO believes that the data infrastructure and the visualisation framework for modelling capabilities such as RECOM are innovative and world leading.

1.4 Status of Outcomes and Impacts

There are already a number of users of the eReef models, including:

— The Great Barrier Reef Marine Park Authority

— The Queensland government

— The Bureau of Meteorology (and the users of its on line marine water quality dashboard)

The latter provides an online marine water quality dashboard that enables users to access to a range of water quality indicators for the Reef, using near real-time data.[5]

There has also been interest in eReefs outputs by the insurance sector and electricity utilities. The aquaculture sector are also likely to find the models useful for their business as it can be used to map how an aquaculture facility could impact on water quality. This information would need to be provided to authorities if a discharge license was being sought. Obtaining such information by conventional in situ monitoring could cost an order of magnitude more than obtaining from the model. Tourism and port operators are other potential users of the output from eReefs.

The models developed by eReefs can be applied around the globe. However they would first need to be calibrated and verified using local information. In fact, CSIRO has already negotiated an agreement with Chile to create a similar model for their coast region to help them protect the sustainability of their salmon breeding program (see **Box 1.1**). While the agreement with Chile is likely to generate income for CSIRO, we have not sought to quantify that benefit at this stage.

BOX 1.1 THE ACUA PACIFICO AGREEMENT

Acua Pacifico is a project to be undertaken for the Chilean government to develop an integrated sanitary and environment information system for the Salmon aquaculture industry in the Patagonian region. Acua Pacifico will utilise much of the philosophy, architecture, data, modelling and visualisation tools developed under eReefs.

SOURCE: CSIRO

The eReefs project will generate economic, social and environmental impacts. The research will significantly transform reef management, protection and assist in the long-term preservation of the Great Barrier Reef. The eReefs project will:

— Build an ongoing comprehensive coastal information system for all of Australia, enabling improved environmental decision-making.

— Increase Australia's long-term knowledge of coastal trends and marine ecosystems, and the effects of environmental trends on the Reef and surrounding marine ecosystem.

[5] http://www.bom.gov.au/marinewaterquality/

— Provide vital tools, like the Marine Quality Dashboard, for decision-makers across the entire spectrum, from the paddock to the reef.
— Enable customised products such as sailing forecasts and tidal information to assist port and shipping operations.
— Enabling forward planning, reporting and emergency response preparation.
— Assist tourism through the use of social and economic data relating to populations, tourism trends, and forecasts of sea state conditions and hazards such as jellyfish blooms.

The benefits of this project are likely to be considerable. Below we briefly discuss the potential economic, social and environmental outcomes and impacts of the eReefs project.

1.4.1 Economic outcomes and impacts

As noted in Section 1.1.2, the GBR generates significant economic activity. As can be seen from **Table 1.2**, the direct expenditure, value added and employment in four sectors has significant links to the health of the reef.

TABLE 1.2 ECONOMIC CONTRIBUTION OF THE GBR

Sector	Direct expenditure ($m)	Value–added ($m)	Employment (FTE)
Tourism	6,401.6	5,175.6	64,336
Recreation	332.4	243.9	2,785
Commercial fishing	192.5	160.3	975
Scientific research & management	106.1	98.0	881
Totals	**7,041.5**	**5,677.8**	**68,987**

SOURCE: ECONOMIC CONTRIBUTION OF THE GREAT BARRIER REEF, GREAT BARRIER REEF MARINE PARK AUTHORITY, TOWNSVILLE, DELOITTE ACCESS ECONOMICS, 2013.

The tools delivered by the eReefs project will help inform public policy decisions designed to protect the health of the Reef. The Federal Government has estimated that around $2 billion is likely to be spent by state and commonwealth governments on protection, management and research into the reef over the coming decade.

The Federal Government has already committed $140 million to the Reef Trust, which will invest in projects to improve water quality and coastal habitat as well as tackling crown-of-thorns starfish. The Queensland Government has pledged a further $100 million over five years to be spent on projects to protect the reef.

The use of tested and validated models instead of in situ testing could provide significant savings for proponents of aquaculture projects seeking approvals for their projects. Aquaculture is a rapidly growing industry. The value of Australian aquaculture production increased by around 25 per cent between 2004–05 and 2012–13 to just over $1 billion. In 2012–13 aquaculture products comprised 43 per cent of Australian seafood production by value and 35 per cent by weight. The Food and Agriculture Organization of the United Nations (FAO) has predicted that by 2018, farmed fish production will exceed wild fisheries production for human consumption, and that by 2021 more than half of the fish consumed globally will be produced by aquaculture.[6]

Other potential economic benefits flowing from the eReefs project include helping ports operate more effectively and helping to prevent ships running aground. The costs of groundings can be considerable. For example, the cost of restoring the Reef in the Douglas Shoal area where the Chinese carrier Shen Neng 1 ran aground in April 2010 has been estimated to be $50 million (largely the cost of removing the anti-fouling paint left on the Reef).[7]

[6] http://www.agriculture.gov.au/fisheries/aquaculture/the_aquaculture_industry_in_australia?wasRedirectedByModule=true
[7] The paint contains a banned substance called tributyltin, known as TBT.

1.4.2 Social outcomes and impacts

The main social outcomes arise from the improved ability of visitors to the Reef to increase their enjoyment of the natural environment offered by the Reef and the ability of recreational fishermen to continue to fish in a sustainable manner in permitted regions of the Reef. Another potential benefit might be an improved search and rescue capability, which could shorten the time to find persons who have suffered a mishap at sea and improve the likelihood of a better outcome.

Protecting employment will help to create more resilient regional communities. ACIL Allen has not sought to assign a value to these impacts.

1.4.3 Environmental outcomes and impacts

An improved understanding of water quality and the health of the Reef coupled with a clearer picture of the direct and indirect impacts of on land activity on the Reef will help policy makers design and implement more effective and efficient policies and programs to reduce the likelihood of serious environmental damage to the Reef. This in turn will lead to improvements in the water quality on the Reef and improved marine bioecosystems.

ACIL Allen has not sought to assign a value to these impacts.

1.4.4 Counterfactual

In the absence of CSIRO, research on managing and protecting the Great Barrier Reef would still have been undertaken, but in coming to these decisions the various governments involved would have sought advice from other researchers in either universities or the private sector. However, neither universities nor the private sector would have yielded the diverse and multidisciplinary range of resources and capabilities that CSIRO was able to quickly mobilise. In particular, the modelling and decision support capabilities that are unique to CSIRO, and have been developed over a long period of time, which were essential to the success of the eReefs project.

Prior to the eReefs project monitoring of the Great Barrier Reef was inadequate. The disaggregated and sparse data available in the absence of CSIRO's research would not have been as useful for informing decision making. The 2015 Queensland audit office report on catchment monitoring, modelling and validation found these to be less than satisfactory.

The number of research organisations with the necessary marine science skills is relatively limited in Australia. The main alternative agency available is Australian Institute of Marine Science (AIMS), Australia's tropical marine research agency. AIMS has research expertise, particularly in monitoring and ecological responses, and some modelling capability. However, during the early stages of research which formed the basis of what is now eReefs, it became clear that AIMS would struggle to realise this project on their own, and that a collaborative effort represented the best chance nationally to deliver an operational receiving waters model.

1.4.5 Attribution

The eReefs project was a collaborative one with a large number of groups contributing their expertise or cash support for the work undertaken. However, over ninety per cent of the research for this project was done by CSIRO. ACIL Allen believes that without the breadth and scale of CSIRO's scientific expertise the delivery of the results would, at best, have been significantly delay or, at worst, not delivered at all.

The concept of the eReefs models was jointly developed by CSIRO and the GBRF. However, CSIRO portfolio of skills played an important role in providing all the project participants with the necessary confidence that the desired results could be delivered. This was essential to ensure that the participants were all willing to make the relatively significant investments needed to carry out the project.

Based on the above considerations, ACIL Allen has conservatively attributed 75 per cent of the benefits derived from the eReefs project to CSIRO.

1.4.6 Adoption

The models developed by the eReef project are still being developed and refined. However, the demand for them from a number of users is already very strong and adoption is likely to be rapid. The Queensland Government has asked the CSIRO to use the regional models to inform the development of the next generation of water quality targets and guideline values. The Queensland Government recognises the value of eReefs. The Director of Landscape Sciences, Queensland Department of Science, Information Technology, Innovation and the Arts has stated that:

*...through eReefs we are actually able to build a better platform … so that we can understand from the terrestrial, from the catchment side, through the estuaries and then out to the reef, (*and create*) one integrated modelling tool.*[8]

The CSIRO's success in negotiating an agreement to create a similar model for Chile is a sign that the outputs of the research are likely to be of considerable interest around the world.

The Bureau of Meteorology has, of course, already operationalised the outputs of eReefs in its on-line marine water quality dashboard. The web site allows users to access to a range of water quality indicators for the Reef, using near real-time data.

1.5 Assessment of impacts

1.5.1 Impacts to date

The models developed are already in use by the Great Barrier Reef Marine Park Authority, the Queensland government and the Bureau of Meteorology. The first two use the information to inform their decision making. The latter provides an online marine water quality dashboard that enables users to access to a range of water quality indicators for the Reef, using near real-time data.

The eReefs project will generate economic, social and environmental impacts. The value of tourism and fisheries alone on the Great Barrier Reef is considerable. Even a small increase in Australia's ability to protect that economic activity will have significant economic benefit.

1.5.2 Potential future impacts

Work in ongoing to make use of new and higher resolution data from earth observation satellites. The results of this work is expected to be progressively operationalised. The 'open access' approach being adopted by CSIRO as their route to market should help ensure that there is rapid uptake of the outputs of the research. Researchers working on the eReefs project have reported considerable interest from applications developers to make use of the framework developed by CSIRO.

The fact that one overseas jurisdictions has already contracted to make use of the research outputs also bodes well for the prospect of future income streams being generated by this project.

1.5.3 Cost Benefit Analysis

Costs

As shown previously in Section 1.1.2, by 2017 CSIRO will have contributed a total of $7.85 million in in-kind support to the eReefs project ($3.22 million in 2012 to 2013 for phase 1, $4.19 in 2014 to 2015 for phase 2 and $0.44 million in 2016 to 2017 for phase 3).

Benefits

Greater returns to government investment in the protection and management of the GBR

As discussed previously in Section 1.4.1, the Federal Government has estimated that $2 billion is likely to be spent by state and commonwealth governments on the protection and management of, and research into, the Great Barrier Reef over the coming decade. Assuming that this investment will,

[8] Dr Paul Lawrence, Director Landscape Sciences, Queensland Department of Science, Information Technology, Innovation and the Arts, EReefs video, https://vimeo.com/148551957

in the absence of the eReefs project, generate benefits of $1.50 for each dollar spent, the expected net benefits of the investment will total $1 billion over the next 10 years.[9]

Suppose that the tools delivered by the eReefs project will positively inform public policy decisions affecting the $2 billion worth of investments in the protection and management of the reef so that the net benefits generated with be increased by 5 per cent. This translates into additional benefits of $50 million over 10 years (or an average of $5 million a year).

Reduction in the likelihood of catastrophic events that will impact tourism

Table 1.2 shows that the reef generates in excess of $5 billion a year in tourism value added. Suppose that the knowledge generated and disseminated by the eReefs project lowers the probability of a catastrophic event that reduces the economic value of tourism in the GBR by 50 per cent in any given year. If the probability of such an event is lowered by 0.5 percentage points (say, from 1 per cent to 0.5 per cent[10]), the expected benefit that will be generated will be approximately $12.5 million per year. In essence, the investment in the eReefs project is akin to purchasing an insurance policy to help protect the Reef and the national income it generates.

Enhanced growth of aquaculture in the GBR

According to the Deloitte Access Economics report cited in Section 1.4.1, the gross value of aquaculture in the regions around the GBR was $69.6 million in 2010-11. Assuming that the ratio of value added to gross value product is the same for aquaculture and other types of commercial fishing, the value added of aquaculture in those regions was approximately $33.4 million in 2010-11.

Section 1.4.1 argued that the use of tested and validated models developed as a result of the eReefs project instead of in-situ testing could help facilitate project approvals for proponents of new aquaculture projects along the Queensland coast. If we assume that this results in annual growth in the value of aquaculture production in regions around the GBR that is 2 percentage points higher than it would otherwise have been, the benefits generated would be around $0.7 million a year.

Reduced incidence of damage from shipping incidents

More than 9,600 ship voyages were recorded in the Reef between 2012 and 2013, and 3,947 individual ships called in at Reef ports in 2012.[11] At the current growth rate of 4.8 per cent per annum, the projected increase in ship numbers calling into these ports will exceed 10,000 by 2032.

According to the GBRMPA, more than 600 shipping incidents were recorded in the region between 1987 and 2009, an average of approximately 30 incidents a year. Suppose that the information generated and disseminated by the eReefs project reduces the number of incidents by 5 per cent a year and that the average cost of each incident is $200,000, then the annual benefit is estimated to be $0.3 million a year.

Assessment of costs versus benefits

Using 2015-16 as the base year of the cost-benefit analysis and adjusting project costs for CPI inflation, the present value of CSIRO's project costs is approximately $8.38 million in 2015-16 dollars under a 7 per cent real discount rate.

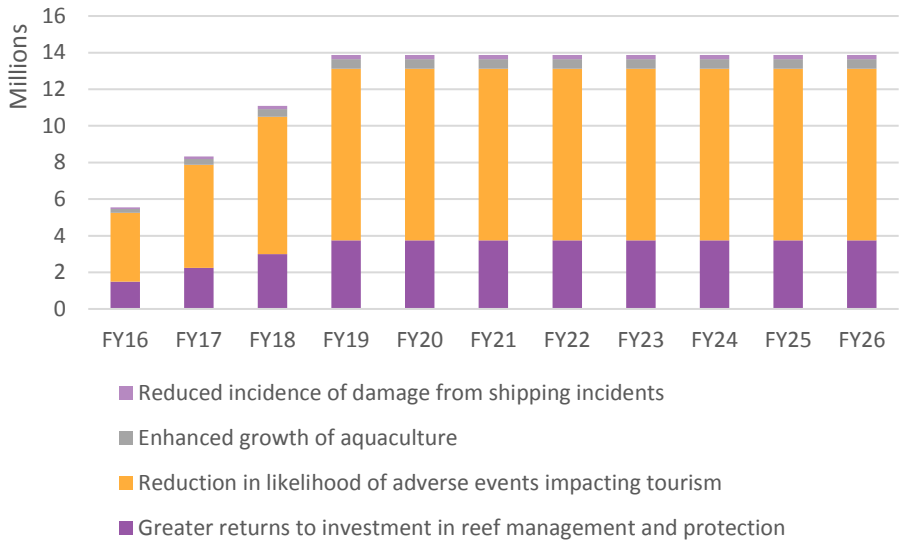
Taking into account the time lags associated with the diffusion of knowledge generated by the eReefs project, the total benefits of the project is expected to reach $18.5 million per year by 2018-19. Using the previously discussed attribution rate of 75 per cent, the annual benefit that can be attributed to CSIRO is estimated to be $13.9 million per year from 2018-19 onwards (see **Figure 1.7**). The present value of this stream of benefits to 2025-26 is approximately $89.2 million in 2015-16 dollars under a 7 per cent real discount rate.

[9] Given the enormous economic value of the GBR and its vulnerability to multiple threats, government investment in its protection and management is likely to deliver comparatively high returns. ACIL Allen therefore views the assumption of a benefit-cost ratio of 1.5 for such investment to be on the conservative side.

[10] The October 2012 report by the Australian Institute of Marine Science which declared that coral cover had declined by 50% in just 27 years suggests that a 1 per cent probability of catastrophic damage to the Reef may be relatively conservative.

[11] Great Barrier Reef Marine Park Authority, *Great Barrier Reef Outlook Report 2014*

FIGURE 1.7 PROJECT BENEFITS, 2015-16 TO 2025-26 (2015-16 DOLLARS)



SOURCE: ACIL ALLEN CONSULTING

The net present value (NPV) of the eReefs project to CSIRO, the difference between the present value of project costs and benefits, is therefore $80.8 million in 2015-16 dollars under a 7 per cent real discount rate. The benefit-cost ratio (BCR), the ratio of the present value of project benefits to the present value of project costs, is 10.6.

Sensitivity analysis

ACIL Allen undertook sensitivity analysis to test the robustness of the CBA results to changes in assumptions and uncertain parameters. The results of the sensitivity analysis are shown in **Table 1.3**.

TABLE 1.3 RESULTS OF SENSITIVITY ANALYSIS

Variable	Central assumption	Low assumption	High assumption	BCR (low assumption)	BCR (high assumption)
BCR of government investment in GBR research	**1.5**	1.2	1.8	8.9	12.4
Improvement in net benefits of GBR research due to eReefs	**5%**	2.5%	7.5%	9.2	12.1
Reduction in tourism value due to a catastrophic event	**50%**	25%	75%	7.0	14.2
Reduction in probability of a catastrophic event due to eReefs	**0.5%**	0.25%	0.75%	7.0	14.2
Increase in annual value of aquaculture due to eReefs	**2%**	1%	3%	10.4	10.8
Cost per shipping incident in the GBR	**$200,000**	$50,000	$350,000	10.5	10.8
Reduction in shipping incidents enabled by eReefs	**5%**	2.5%	7.5%	10.6	10.7
Benefits of eReefs attributable to CSIRO	**75%**	50%	100%	7.1	14.2

SOURCE: ACIL ALLEN CONSULTING

The last two columns of the table show the effects of varying the key assumptions (and their associated parameter values) one at a time. As mentioned above, the BCR is 10.6 under the central

case (that is, with each variable assumed to have the parameter value shown in the second column of the table). The BCR ranges from 7.0 to 14.2 in the cases explored in the sensitivity analysis.

1.5.4 CSIRO's role as an Innovation Catalyst

The backbone of the eReefs information platform is an innovative information architecture that enables data from a range of sources to contribute to a central Data Brokering Layer (DBL). The information held within the DBL can be accessed by application developers or end-users.

An important aspect of the framework that has been developed by CSIRO is the ease with which it enables users to access to the models and datasets within the DBL. This has been done through a visualisation portal that allows users to search for data, discover the available services and data from multiple data providers and visualise that data in maps and charts. The visualisation techniques developed by the eReefs project are innovative and world leading.

The outputs of the project are already being used to inform decision making by the Queensland Government. The 'open access' approach being adopted by CSIRO as their route to market should ensure that there is rapid uptake of the outputs. The fact that one overseas jurisdictions has already contracted to make use of the research outputs also bodes well for the prospect of future income streams being generated by this project.