ACIL ALLEN CONSULTING

APRIL 2016

EREEFS CASE STUDY

EREEFS CASE STUDY 1

CASE STUDY SUMMARY

Key findings

- The results of the eReefs research will significantly transform our ability to manage and protect the Great Barrier Reef and assist in its long-term preservation. It has delivered powerful real-time visualisation and reporting tools that will provide users with real-time information about the condition of the Reef.
- The eReefs models are being used by the Great Barrier Reef Marine Park Authority and the Queensland government to aid decision making, and by the Bureau of Meteorology to deliver remote sensing products based on CSIROS algorithms.
- CSIRO has negotiated an agreement with Chile to create a similar model for their coast region to help them protect the sustainability of their salmon sanitation program
- Based on conservative assumptions, the net present value of benefits to 2025-26 from the eReefs project is $80.8 million in 2015-16 dollars under a 7 per cent real discount rate. The project has a benefit-cost ratio of over 10.

Innovation impact

The CSIRO eReefs project team has delivered highly innovative science, namely the eReefs information platform. The centrepiece is a whole-of-region, shelf-scale, numerical marine modelling system. The project team has also developed a highly innovative, web-based modelling environment called RECOM (RElocatable Coastal Ocean Model) that users can easily access to quickly establish a model of an area of interest such as an estuary, bay or coral reef.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the eReefs case study are summarised in **Figure 1.1**.

FIGURE 1.1 CSIRO CASE STUDY EREEFS - IMPACT FRAMEWORK DIAGRAM

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ Funding from the Science and Industry Endowment Fund (SIEF) ▪ Funding from the Great Barrier Reef Foundation (donors are BHP Billiton, Mitsubishi and Queensland Government) ▪ Additional funds from GBRF and the Bureau of Meteorology ▪ In kind support from Queensland Government, CSIRO, BoM and AIMS ▪ CSIRO provided resources to facilitate the partnership.	▪ Research to expand and improve monitoring data ▪ Developing a suite of new and integrated models ▪ Testing and verification of the models ▪ Developing a framework to explore the impact of multiple factors ▪ Developing an interactive visual picture of the Reef and its component parts. ▪ Citizen science initiatives	▪ A comprehensive coastal information system ▪ Tools such as the Marine Water Quality Dashboard and RECOM ▪ Journal and conference publications	▪ Monitoring and management interventions on Reef catchments ▪ Tracking rainfall and flooding impacts ▪ Assessing cumulative threats ▪ Engagement with the community ▪ A contract with Chile to build a similar model for them.	***Economic impact*** ▪ More efficient and profitable tourism activities and port and shipping operations ▪ More efficient decision making ▪ Reduced costs for aquaculture firms ▪ National and international contracts ***Environmental impact*** ▪ Improved water quality ▪ Natural hazards mitigation (floods, cyclones and land runoff). ▪ Improved marine bio ecosystems. ▪ Reduced likelihood of serious environmental damage ***Social impact*** ▪ More resilient regional communities, particularly those reliant on tourism

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.

Climate change, poor water quality from land-based run-off, impacts from coastal development, and some remaining impacts of fishing remain the major threats to the future vitality of the Reef.

In October 2012 the Australian Institute of Marine Science issued a report that declared that coral cover had declined by 50% in just 27 years, illustrating the significant cumulative impact of the various pressures on the Great Barrier Reef.[2]

Due to the Reef's scale and complexity it is not currently possible, to visualise, model, understand and communicate about the whole of the Reef system. A number of Commonwealth and State initiatives have been implemented to address the problems facing the Reef.

The eReefs project commenced in January 2012. It was the first effort to build a comprehensive coastal information system for the Reef. It uses the latest technologies to collect and collate data and new and integrated modelling, the eReefs project will produce powerful visualisation and communication tools to provide real-time and scenario information that can be used to aid assessments and inform decisions on a range of issues including about the quality of water in the Reef, hydrodynamics conditions for safe navigation or incident response, and the likely occurrence or spread of ecological pests such as the crown-of-thorns starfish.

The eReefs project is a public-private collaboration between Australia's leading operational and scientific research agencies, government, corporate Australia and Reef managers. Partners in the eReefs project are the Great Barrier Reef Foundation (BHP Billiton, Mitsubishi and the Queensland and Australian governments provide funds to GBRF), the Bureau of Meteorology (BoM), CSIRO, the Australian Institute of Marine Science and the Queensland Government. Funding for the project is provided by a variety of groups (see **Table 1.1**).

TABLE 1.1 SUPPORT FOR THE EREEFS PROJECT

Organisation	Phase 1 2012-13	Phase 2 2014-15	Phase 3 2016-17	Total	Type of Support
CSIRO	3.222	4.190	0.438	7.850	in-kind
Australian Institute of Marine Science (AIMS)	0.515	0.418	0.293	1.225	in-kind
Bureau of Meteorology (BoM)	3.016	1.094	1.265	5.376	in-kind
Queensland Department of Science, Information Technology and Innovation (DSITI)	-	0.380	0.580	0.960	in-kind
Great Barrier Reef Foundation (GBRF)	2.492	4.671	5.043	12.206	cash
Science and Industry Endowment Fund (SEIF)	2.000	1.600	0.400	4.000	cash
TOTAL	**11.245**	**12.353**	**8.019**	**31.617**	

SOURCE:CSIRO

The eReefs project has three Phases. Phase 1 ran from January 2012 to November 2015. The total cost of Phase 1 was $11.25 million. CSIRO contributed cash for phase 1 through its Science and Industry Endowment Fund (SIEF). Its direct contribution was an in-kind one (instrumentation, laboratories, etc.).

Phase 2 was completed at the end 2015. Phase 3 will be undertaken between 2016 and 2017. Expenditure for Phases 2 and 3 is expected to be around $20.4 million. Phase 2 and phase 3 contributions to the project are shown in **Table 1.1**.

1.2 Project activities

The key activities undertaken during Phase 1 include:

[2] http://www.aims.gov.au/docs/media/latest-releases/-/asset_publisher/8Kfw/content/2-october-2012-the-great-barrier-reef-has-lost-half-of-its-coral-in-the-last-27-years

— Developing a suite of new and integrated models across paddock, catchment, estuary, Reef lagoon and ocean. These models integrate the outputs of three component models (hydrodynamic, biogeochemical and sediment models).
— Expanding and improving the data used as inputs into the eReefs model. This includes determining how to make use of the latest in measurement technologies and data delivery tools (such as remote sensing, mobile and internet tools). It also involves determining how best to share and consolidate data from national and international sources.
— Developing better ways of bringing together datasets from multiple data providers. This data interoperability research is breaking new ground in allowing end users to discover and access related data products and services. This work underpins the delivery of visualisations and end user tools.
— Developing mechanisms to visualise the model results. This involves determining how best to show a wide range of different data sets to present an interactive visual picture of the Reef and its component parts. These visualisation tools can then be used to inform the broader community and other stakeholders about the health of the Reef and help users to make more informed decisions.
— Conducting in situ testing of various parameters to test algorithms and verify the models.

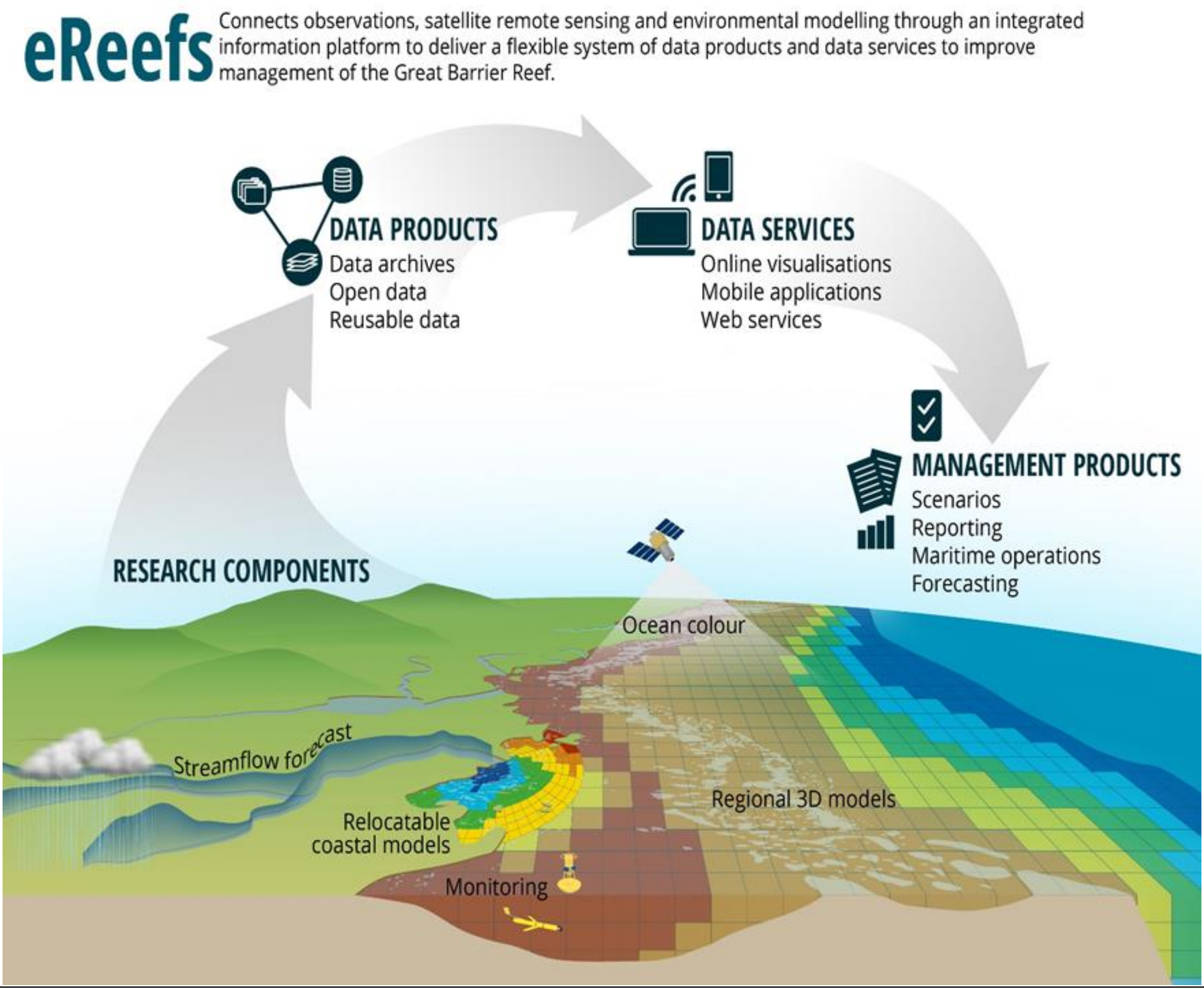
The R&D component for phase 1 was largely done by CSIRO. Other project partners provided support by sharing the data they had access to and assisting with the activities needed to operationalise the model. The models can be used to provide real time information, assess the impacts of changes in various parameters and or different 'what if' scenarios and provide two to three day forecasts at the continental shelf scale (resolution of 1 to 2 km).

Phases 2 and 3 are expected to continue to develop and refine the models so that they can accept higher resolution data (including from new satellites) as it progressively becomes available. The models will also progressively be improved to the point where they can be used to observe and forecast on the scale of estuaries, bays and individual reefs at resolutions of 10 to 100s of metres.

Figure 1.2 illustrates the kind of information that the Marine Water Quality Dashboard provides to users, namely:

— The level of chlorophyll in the water. This in turn provides information on the levels of algae in the water, which is an important factor in determining the health of sea grass and the coral reef itself. Algal growth is stimulated factors such as fertiliser run off.
— The amount of coloured dissolved organic matter (CDOM) in the water. CDOM levels provide an indication of the amount of fresh water entering the reef lagoon, which can have a detrimental impact on the health of the reef.
— The amount of suspended sediment in the water. High levels of sediment can occur after heavy and prolonged rain. Sediment can smother sea grass and be deposited on the reef and cause damage to the corals.

FIGURE 1.2 ILLUSTRATION OF INFORMATION PROVIDED BY EREEFS



SOURCE: CSIRO

1.3 Project outputs

The eReefs project is still underway. However CSIROs efforts in the development of eReefs are essentially compete and the remaining months are dedicated to transitioning to an operational mode and increasing engagement with end-users. Over the coming years, the project is expected to deliver increasingly powerful visualisation, communication and reporting tools that will enable users to have real-time information about the condition of the Reef. The Implementation Strategy for the Reef 2050 Plan noted that a:

Reef Integrated Monitoring and Reporting Program is integral to the success of the Reef 2050 Plan. The primary objectives of the Reef Integrated Monitoring and Reporting Program are to:

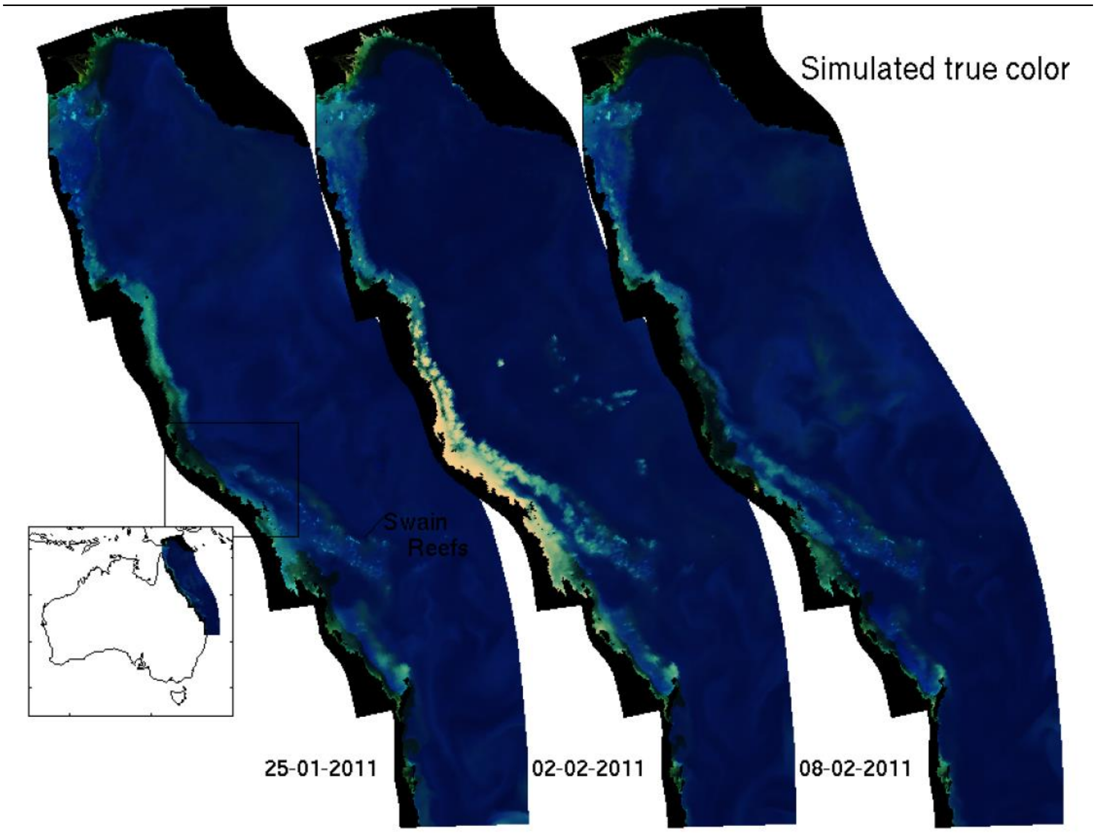
– *improve the effectiveness of adaptive management through an improved understanding of the condition and trend of the Reef's values and processes together with the drivers, pressures and activities affecting them; and*

– *inform performance evaluation of management actions against Reef 2050 Plan targets, objectives and outcomes.*[3]

This comprehensive real-time reef information system will provide an important tool for reef managers by helping them improve environmental decision-making. For example, the information can be used to understand how actions taken on land impact on water quality and the Reef. It can also be used to test what actions might be taken to improve water quality. The system's capability to forecast the outcomes of different scenarios is expected to greatly assist in setting water quality targets and support the implementation of the Reef 2050 Plan.

Figure 1.3 illustrates the continental scale modelling capability developed as part of eReefs. It shows the result of modelling of the Reef area the week before cyclone Yasi, during the cyclone and the week after. The impacts of the cyclone in terms of the amount of suspended particulates in the water is clear. It is worth noting that that turbulence would be impossible to see using satellite observations due to the cloud cover during the cyclone.

FIGURE 1.3 RESULTS OF EREEFS MODEL RUNS

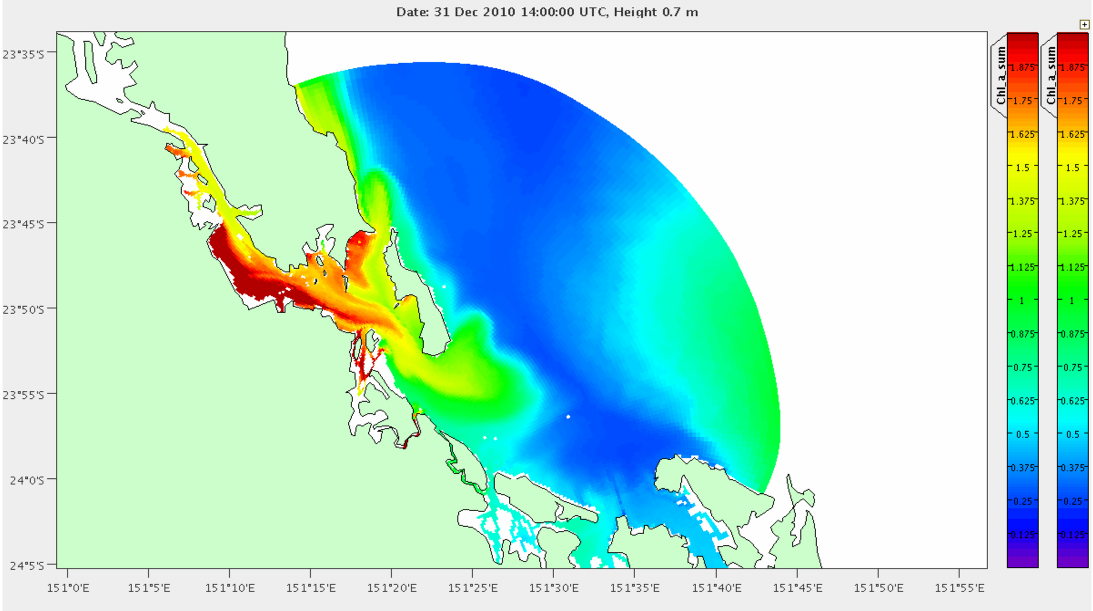


Note:
SOURCE: CSIRO

The eReefs project has also delivered a model that can look at much smaller areas, such as individual reefs, estuaries or bays. The Relocatable Estuary COastal Model (RECOM). RECOM utilises river and catchment model data and ocean boundary conditions from regional models and BoM meteorological data and can be used to examine biogeochemistry and or sediment parameters. **Figure 1.4** provides an example of the kind of information available from RECOM. It shows predicted chlorophyll concentrations in an estuary and adjacent nearshore coastal region.

[3] *Reef 2050 Plan—Implementation Strategy*, Australian and Queensland Governments, May 2015

FIGURE 1.4 EXAMPLE OF THE OUTPUT FROM RECOM



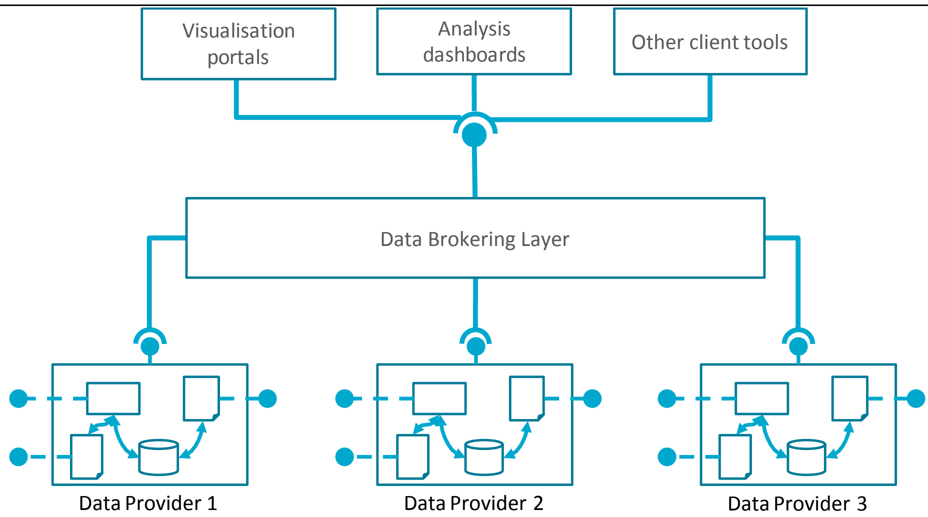
SOURCE: CSIRO

The eReefs project has developed a new framework for bringing together data products and services from disparate data providers. This work to develop the interoperability of many different data sources is essential for the generation of model outputs and visual products. CSIRO's research is also helping to progress the national and international discussion around how to achieve the aim of "Linked Open Data". The eReefs approach has resulted in the development of a collection of "Data Provider Nodes" (DPNs) and a "Data Brokering Layer" (DBL), which provide a structured method for describing and connecting data services. To achieve this, CSIRO developed a formal ontology[4] – the Data Provider Node Ontology (DPN-O) – and Data Provider Node definitions were created to sit on top of collections of data services. These DPN definitions are then registered in the DBL, which is then exposed via an Application Programming Interface (API). This approach allows multiple clients to connect to the information in a modular, flexible way, enabling the use of a large variety of tools (e.g. models, analysis tools, visualisations, etc.) to all connect via a single discovery point.

Figure 1.5 presents a very high level schematic view of the eReefs architecture. Multiple Data Provider Nodes (DPNs), which are described using the Data Provider Node Ontology (DPN-O) and collated through the Data Brokering Layer (DBL), which links to an API which can be accessed by users to discover data products and services contained within individual DPNs.

[4] In computer and information science, an ontology is a formal naming and definition of the types, properties, and interrelationships of the entities that really or fundamentally exist for a particular domain of discourse. An ontology compartmentalizes the variables needed for some set of computations and establishes the relationships between them.

FIGURE 1.5 SCHEMATIC DIAGRAM OF THE EREEFS INFORMATION PLATFORM

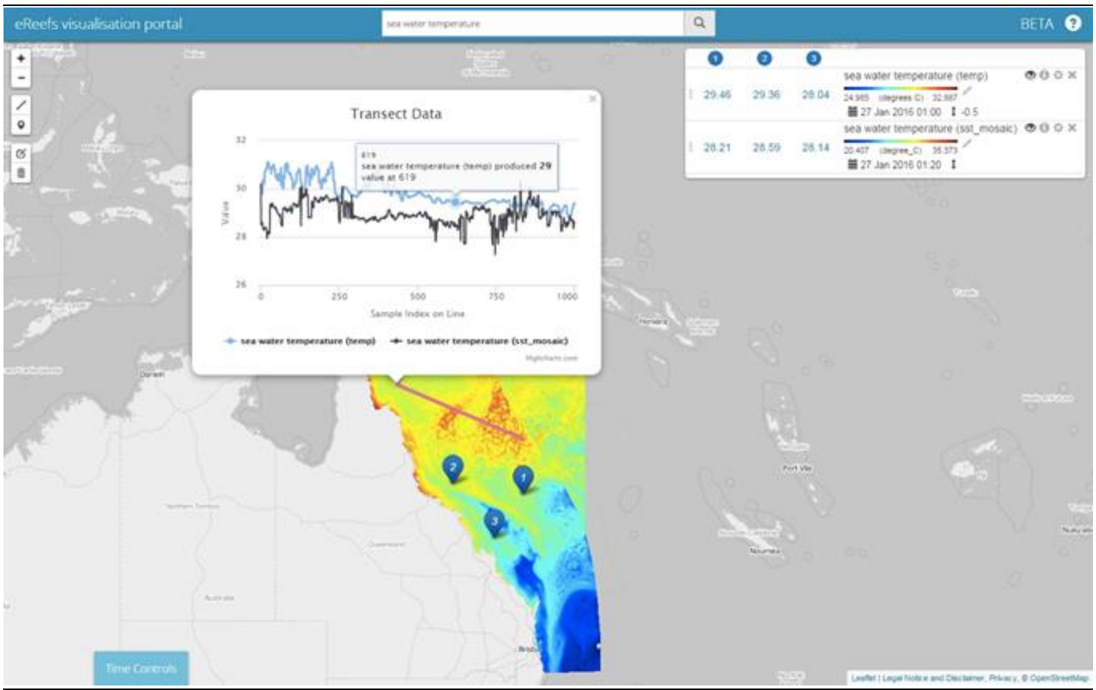


SOURCE: CSIRO

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.

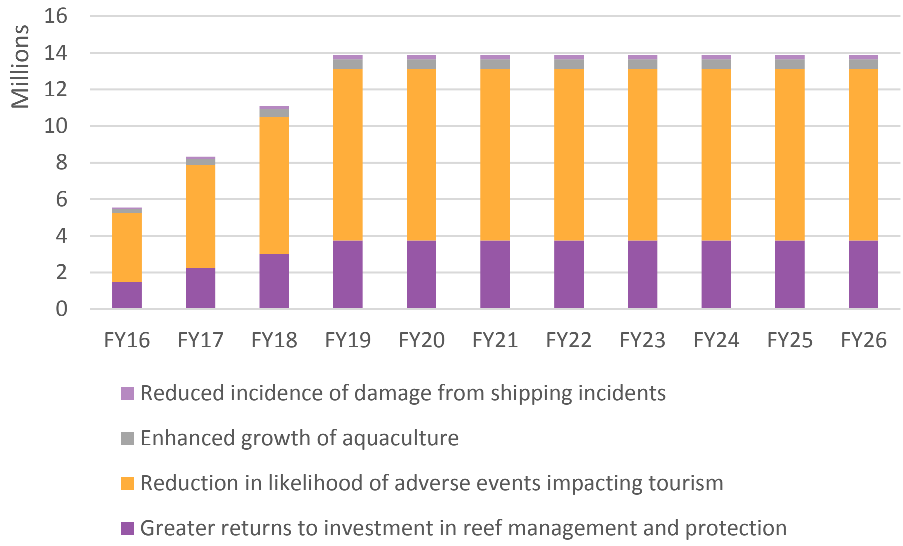
Taking into account the time lags associated with the diffusion of knowledge generated by the eReefs project, the total benefits of the project is expected to reach $18.5 million per year by 2018-19. Using the previously discussed attribution rate of 75 per cent, the annual benefit that can be attributed 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.