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CoastAdapt: an adaptation decision support framework for Australia's coastal managers

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Abstract Australia's coastline is exposed to climate change and sea-level rise impacts from erosion, inundation, and changes to storm tracks and intensity. It accommodates about 80% of the population. Around 250 local councils are responsible for coastal management, with very different capacities to undertake adaptation. A decision support framework was developed to support coastal managers seeking to understand present-day and future climate change, its impacts and possible response options. Extensive engagement was undertaken with practitioners before commencing the design and at all stages of the build, in order to ensure usefulness and usability. The resulting framework, CoastAdapt (coastadapt.com.au), provides comprehensive guidance and support, including understanding of climate change science, expected impacts, and adaptation options. It contains datasets on historical flooding; present-day coastal sensitivity to erosion; and future climate extremes, sea-level rise, and inundation for each coastal council. A risk management framework supports users through the six stages of adaptation from identifying the challenges through to monitoring and evaluation. The performance of CoastAdapt has been evaluated through 11 6-week test cases with coastal managers in the public and private sectors. In future, if CoastAdapt is to remain a useful resource, it must be seen by practitioners as dynamic, relevant, and current, and on-going resources will be needed to achieve this.

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1 Introduction

Responsibility for carrying out practical projects to address climate change risks often falls to local councils (Stevens and Kiem 2014). In Australia, potential impacts include increased frequency and intensity of heatwaves, bushfire and rainfall extremes, and, in coastal areas, sea-level rise and associated erosion and inundation (Reisinger et al. 2014). Australia has close to 250 coastal councils, ranging in population from the very large (e.g. Brisbane City Council, population 1.2 million) to the very small (e.g. East Pilbara, population 6700 in an area of 372,571 km^2). Many smaller councils lack the financial and human resources to undertake adaptation projects (Measham et al. 2011). In addition, councils face legal risks from adaptation action (e.g. zoning land as unsuitable for development) or failure to act (e.g. damages sustained from inundation of at-risk housing) (Taylor et al. 2013; Verschuuren and McDonald 2012). Yet observed sea-level rise since 1993 is close to the global average at between 2.1 ± 0.2 mm $year^{-1}$ (from land-based tide gauges) and 3.1 ± 0.6 mm $year^{-1}$ (from satellite-based altimeters) (White et al. 2014; McInnes et al. 2016). Future sea-level rise is projected to reach close to 12 mm $year^{-1}$ by 2100 for RCP8.5 and 6 mm $year^{-1}$ for RCP4.5 (McInnes et al. 2015).

Against this background, the National Climate Change Adaptation Research Facility (NCCARF) was commissioned by the Australian Government Department of the Environment to 'produce a coastal climate risk management tool to … assist coastal decision makers understand future climate risks and provide practical guidance on how to manage the associated physical, social and economic risks' (taken from the Funding Agreement). There have been previous efforts in Australia to provide adaptation support. Aldum et al. (2014) identified 65 adaptation support tools in Australia. Many deal only with one stage of the adaptation process such as scenario development (CSIRO and Bureau of Meteorology 2015; Olson et al. 2016) or vulnerability assessment (Preston et al. 2008; Williams et al. 2008). Most are specific to individual states and their jurisdictional frameworks (LGASA 2012; LGAQ and DEHP 2016) or to local governments (HCCREMS 2012; Inglis et al. 2014). Reasons for this emphasis on regional and local scales are likely to include that planning and development controls are state-level responsibilities in Australia and, at local government level, the desire of adaptation 'trail blazers' to share more broadly any lessons learned. Australia-wide tools do exist for specific sectors, for example rangelands (Measham 2014) and natural resource management (Rissik et al. 2014). Aldum et al. (2014) found little evidence of uptake, apart from a guide for business and government developed by the Australian Greenhouse Office (AGO 2006).

Globally, a vast array of decision support tools exists. Webb et al. (2018) identify 300 adaptation support products, which they categorise into process (90), data (80), and knowledge products (130). In the USA, the Third National Climate Assessment (Moss et al. 2014) reviewed over 50 national decision support products. A very comprehensive approach is provided by the U.S. Climate Resilience Toolkit (Gardiner et al. submitted). In Europe, an early guide took practitioners step-by-step through the complete adaptation cycle (Willows and Connell 2003) and led in turn to the online Adaptation Wizard (UKCIP 2013). More recent approaches support a wide range of sectors and needs, including economic appraisal (Watkiss et al. 2015), urban planning (van de Ven et al. 2016), coastal zones (Torresan et al. 2016), and land-use planning (Andersson-Sköld et al. 2016). Thus, a wealth of experience exists but, as Harman et al. (2015) point out, adaptation options (and hence decision support frameworks) lack transferability between countries with different population distributions, histories, and governance arrangements.

These and other resources underpinned thinking about the design and implementation of NCCARF's adaptation framework for coastal managers. Principally, it should be comprehensive, covering all aspects of coastal adaptation from inception to implementation to evaluation. In addition, there are two other drivers: first, the requirements set out in the Funding Agreement and second, the over-arching need to produce a framework that would be both usable and useful (Prokopy et al. 2017). The Funding Agreement dictated that the framework should be national in scope, and should address the needs of coastal managers from the public and private sectors. There should be an emphasis on less well-resourced entities, especially local councils with small revenues and, to a lesser extent, small businesses operating in or dependent on the coastal zone. The Funding Agreement outlined governance arrangements that ensured, through three committees, that there was input from all levels of government, key potential users, such as the infrastructure and water resource sectors, and technical experts (Leitch et al. submitted).

To achieve usability and usefulness, it is necessary to take into account the particular characteristics of the target users. They are time-poor. Climate change impacts are not central to their day-to-day concerns although due diligence, legal risk and, for some, pressure from higher levels of government are highlighting their need to understand the risks and, where necessary, to act. Financial resources are constrained, and stakeholders may be sceptical or even hostile to any investment in adaptation. Against this background, we set out to understand the needs of our audience through in-depth engagement and consultation, as described below.

2 Participation and co-production

The involvement of potential users at all points in the design, build, and evaluation of the framework was seen as essential to ensure its sustained use (Lemos and Moorhouse 2005; Dilling and Lemos 2011; Romsdahl 2011; Lemos et al. 2012). Meadow et al. (2015) list the benefits of co-production as: transparency, legitimacy, delivery of knowledge at appropriate scales, ease of integration, and sense of ownership. A similar list from Prokopy et al. (2017) includes usability, legitimacy, buy-in/ownership, improved communication, creation of networks and communities of practice, capacity building, and long-term sustainability. Conversely, the 'loading dock approach' can lead to a lack of take-up (Cash et al. 2006; Kiem and Austin 2013; Kiem et al. 2014).

Through participation and co-production activities, NCCARF set out to build a framework which is accessible, authoritative, attractive, and comprehensive. It should engender a sense of ownership among users, build organisational and community capacity, and contribute towards building a community of adaptation practice. Early in the process, the framework came to be known as CoastAdapt (see coastadapt.com.au).

2.1 Initial consultation to scope content

The core target audience for CoastAdapt was identified as council officers working in coastal councils, particularly the less well-resourced councils with lower capacity (in financial and human resource terms) to adapt. These officers would work in environmental and planning departments, charged directly with managing the coast under climate change and sea-level rise. CoastAdapt should also address the needs of their stakeholders—line managers, senior management, and elected officials making decisions about the allocation of resources across whole of council business, as well as community members likely to experience impacts from adaptation activities (for example loss of amenity or property value).

We undertook a number of activities to understand what was wanted from CoastAdapt in terms of content and mode of delivery. These included a national meeting, 13 regional workshops in all state capitals and some large regional centres, and an online survey (Leitch et al. submitted; Palutikof et al. 2018). Letters were sent to all coastal local councils in Australia to inform them of opportunities to participate, and activities were publicised through the NCCARF website and newsletter. The survey was completed by 313 individuals. The workshops were attended by 330 people. There will be some crossover between the two categories.

2.2 User experience design and testing

Providing rich and appropriate content is important but should be complemented by well-organised design that is straightforward to navigate. Lack of care in design has the potential to create confusion and an overwhelming experience for users. Although primarily focussed on coastal managers, CoastAdapt has a role in capacity building for NGOs and community groups and education at secondary and tertiary levels. Climate change is unlikely to be a day-to-day central concern for such users, who are likely to be infrequent visitors to CoastAdapt and unable or unprepared to learn complicated navigation tasks. Without care and attention to design, the risk is that some of those who might benefit from CoastAdapt might never do so.

Following initial user consultation (Leitch et al. submitted; Palutikof et al. 2018), and at the point where we had a clear idea of the likely content to be carried in CoastAdapt and an outline structure of how this content might fit together, external consultants were hired to perform user experience design and testing of the website structure. NCCARF used external consultants because of a lack of in-house expertise in this specialised area.

The consultants worked in two phases. The first phase provided the information architecture for the site and wireframe mock-ups for the main pages. The consultants carried out interviews with relevant NCCARF staff, three small workshops and in-depth interviews with six potential users (three council officers, two coastal planning consultants, and one community member) and, on the basis of what they learned, created three 'personas' (Pruitt and Adlin 2010) defined as typical users of CoastAdapt: 'Joanna', a local council adaptation officer with day-to-day concerns about climate change impacts, 'Charles', a senior manager in a small local council juggling many different responsibilities with limited resources, and 'Thomas', a concerned community member who, in seeking to understand the possible impacts of adaptation planning on his environment and wellbeing, might turn to CoastAdapt for assistance. These personas were used to create user journeys through the outline structure, which in turn underpinned the design of the information architecture and the wireframe mock-ups.

Once a prototype with sufficient content and functionality was ready, the consultants returned for the second phase. The usability testing was carried out with six participants (five council officers and one leader of a regional grouping of councils). On the basis of the results, a number of changes were implemented, including upgrading the performance of the search function and dropping the requirement to register to use the site.

2.3 Participation and co-production during build and consultation

Early in the build, a need was identified for a representative user group that could be called upon to provide feedback on content throughout the process. To address this need, a Tool Development Partnership (TDP) was set up, consisting of individuals from eight local councils

across Australia, one regional grouping of councils (represented by a consultant) and one small business (providing services to horticulturalists). Council employees were drawn primarily from smaller councils (in revenue terms), with an average annual revenue of A$80 million (2016–17 financial year) and a range from A$10 million to A$255 million. They were generally mid-career and working in environmental services (although one was a senior engineer). More information on the role of the TDP is provided by Leitch et al. (submitted).

Partners were identified through an open call and provided with a small budget to facilitate participation. They reviewed content, contributed content (especially but not exclusively case studies) and introduced CoastAdapt to their networks.

Following the initial design and build stage, which lasted around 9 months, a beta version of CoastAdapt was released for a 4-month open review and consultation period. Various strategies were used to publicise the process, including advertising on the NCCARF website and in newsletters and making presentations at conferences. Seventeen workshops were held across Australia to introduce potential users to CoastAdapt. Comments were recorded on feedback forms accessible from every web page in CoastAdapt.

To test the usability and usefulness of CoastAdapt, five 6-week test cases were carried out during consultation. A call was made for organisations that could identify a well-constrained adaptation issue they wished to address. The intent was to explore in a range of contexts the extent to which CoastAdapt could support users to address real-world adaptation issues. Tasks carried out by test cases included a preliminary assessment of future sea-level rise risks to airport infrastructure, hiring a consultant to develop an adaptation plan for a local council and improving consideration of climate change-related issues in the Environmental Risk Statement of an aquaculture company. Test cases were asked to provide feedback on CoastAdapt performance.

Following consultation and review, feedback advice from the various sources was collated and assessed to identify changes to CoastAdapt that would enhance usefulness and usability, and were feasible to implement within the constraints of time and money. In total, around 1750 comments were received. A program of additions and changes to CoastAdapt was carried out. These include, for example, the addition of ‘Getting Started’ webpages, provision of temperature and rainfall extremes data for each coastal local council, addition of new checklists and templates and, following advice from the test cases, extensive revision of the templates helping councils to work with consultants. A revised version of CoastAdapt was released 5 months after the close of the review. Subsequently, a further six test cases have been carried out, together with a program of training workshops.

3 CoastAdapt content

Initial user consultation highlighted the very broad and diverse requirements of potential CoastAdapt users. At one extreme, there are managers with little knowledge of climate change but aware that they may need to take action. At the other, users may have extensive knowledge of climate change globally and of its possible impacts in their area, and be seeking support to undertake planning and implement action. All users may be attempting to manage sceptical stakeholders in their organisation and community. All seek opportunities to network with their peers and access expert knowledge (Romsdahl 2011). CoastAdapt is a public and free-to-use resource and, as such, users may come from the community, private, or public sectors. In addition to local council officers, they may be community members seeking to understand the

effects of coastal adaptation decisions, consultants preparing an adaptation plan for a local council, or a tourism business seeking to understand its exposure to sea-level rise. To address these complex needs, the structure and content shown in Fig. 1 were developed. Content delivery has three principal components: (i) information, including datasets, to underpin adaptation; (ii) a process for decision-making around risk management and adaptation in the coastal zone; and (iii) a mechanism for users to interact. As shown in Fig. 1, CoastAdapt seeks to provide comprehensive information and guidance to address all the needs of coastal managers seeking to adapt, ranging from the physical science of climate change through to cost-benefit analysis and non-monetary valuation, as well as how to build partnerships with stakeholders to facilitate adaptation action.

3.1 Information and guidance to underpin adaptation

The primary mode of delivery is through 84 webpages. Each contains three levels of information: described as 'skimmer', 'wader', and 'diver' (drawing an analogy with waterbirds). The 'skimmer' summary is a one-sentence description of the content on the page, helping the reader to decide whether to read further. The 'wader' summary is a paragraph or set of dot-points, at a level suitable for building a case with senior management and the community. The 'diver' information is a detailed technical description. Although written in straightforward and where possible non-technical language, it requires a time commitment from the reader, who is likely to be directly involved in adaptation activity.

In addition to webpages, a number of other formats for content delivery are used, including case studies, information manuals, and infographics, all delivered as downloadable PDFs (see Fig. 1). Each fulfils a particular purpose. The 80 case studies, drawn primarily from Australia but with some overseas examples, cover various stages of the adaptation process, industry, government, and community perspectives, and how different adaptation challenges have been met. Many were submitted by practitioners, and address the strongly held view, articulated during consultation, that shared peer-group experiences are as valuable, if not more so, than information delivered by experts. The majority deal with only one, often preliminary, stage in the adaptation process (e.g. initial communication engagement prior to writing an adaptation strategy), and there are few if any examples of comprehensive adaptation action, thus clearly demonstrating the barrier that exists in transitioning from adaptation planning to action (Barnett et al. 2015). The ten information manuals provide the technical underpinning for CoastAdapt. Whereas the principal goal was to deliver information written in accessible language that could be absorbed easily and quickly, it is necessary at the same time to demonstrate that CoastAdapt is authoritative and legitimate—evidence based and scientifically rigorous. To that end, all content in CoastAdapt was peer-reviewed, and the ten information manuals, covering key topics in adaptation from the science of sea-level rise through to the legal context of adaptation and community engagement, provide the technical detail needed by coastal managers serious about embarking on adaptation planning and implementation. The ten infographics provide attractive and easy to assimilate one-page summaries of key topics—suitable, for example, to help build community awareness of the need for adaptation.

A particular concern for coastal managers in local government is that they must adhere to the planning and regulatory frameworks of their next level of government—the state. Planning is handled at the state level in Australia, and each has its own set of laws, policies, and

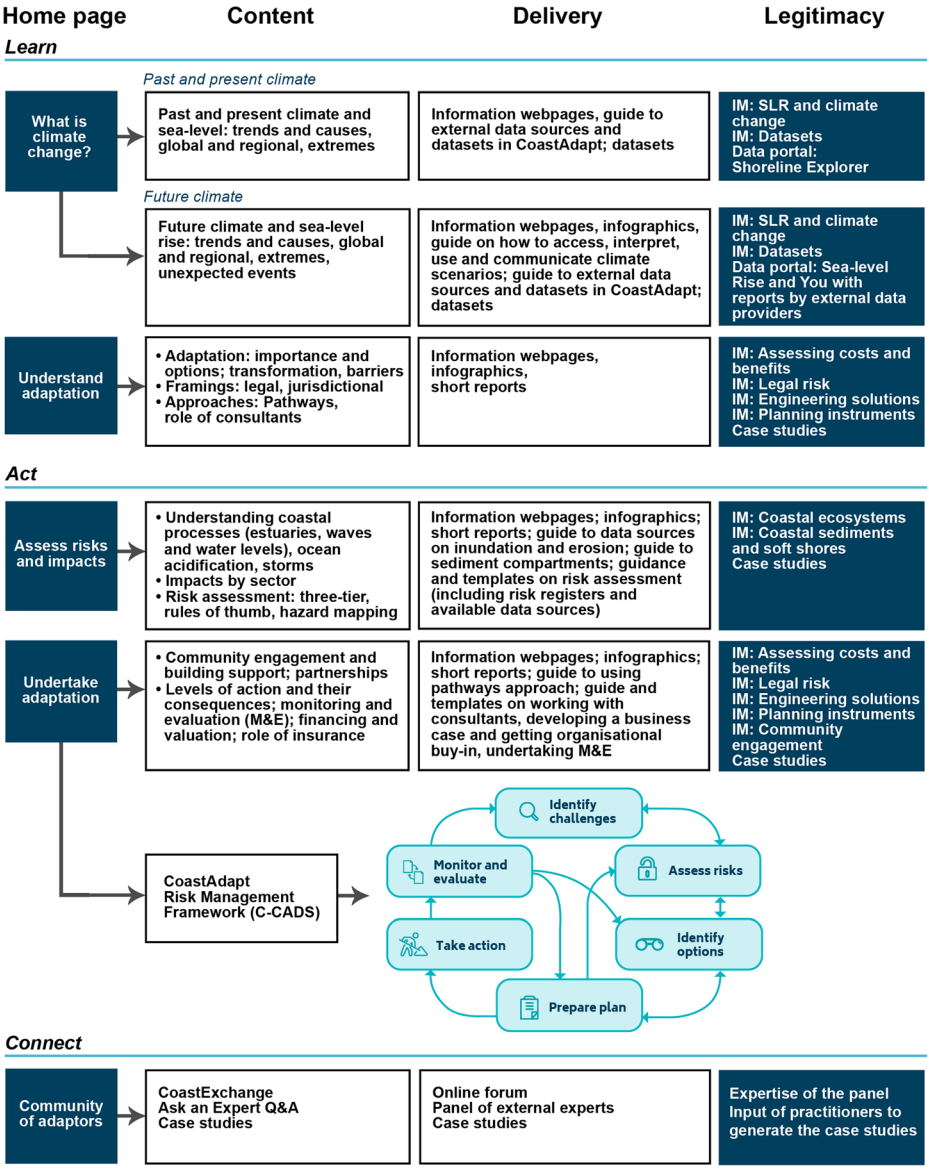

Fig. 1 CoastAdapt architecture, showing content under each home page heading, mode of delivery, and content items that provide legitimacy. *IM* Information Manual; *SLR* sea-level rise

regulations. Although the intention was always for CoastAdapt to be national in focus, failure to pay close attention to jurisdictional framings and differences would strongly erode user confidence in CoastAdapt. To address this, all states and the Northern Territory were asked to submit individual information webpages and provided with a template. These webpages are carried on CoastAdapt and are summarised into a single webpage on jurisdictional differences. This material has been updated twice (as at March 2018), and will be re-visited at 6-monthly intervals to ensure it remains accurate.

3.2 Datasets in CoastAdapt

Potential users of CoastAdapt seek to access local-scale datasets and visualisation products to help understand their climate change-related risks. In the scoping stage, it was envisaged that CoastAdapt would act as a portal to existing datasets relevant to adaptation planning. However, it became evident early on that these datasets were not readily accessible to CoastAdapt core users: issues included guidance material employing very technical language, websites difficult to navigate, and lack of appropriate data at the required resolutions. To address this problem, contracts were placed with the data-generating organisations to process data into formats appropriate for and useful to coastal managers. As a result, CoastAdapt delivers its own data products in most cases, tailored to user needs and accompanied by guidance material written in clear non-technical language. These data products are summarised in Table 1.

3.3 A process for decision-making

CoastAdapt provides a risk-based decision support process that steps users through the process of developing and implementing an adaptation plan (see Fig. 1 and Tonmoy et al. submitted). The Coastal Climate Adaptation Decision Support framework (C-CADS) takes users through a series of iterative steps from identifying climate change challenges and impacts through to implementing adaptation solutions, monitoring and evaluating their effects, and making necessary adjustments. It includes a progress checklist and measures of success against which users can benchmark their project.

The narrative at each step of C-CADS provides a unifying framework for CoastAdapt by comprehensively referencing its datasets, case studies, checklists etc. C-CADS' iterative structure, advice on exploring system sensitivities to a range of climate change scenarios, information on trigger and threshold identification, and guidance on monitoring and evaluation provide the basis for users to take a staged approach to adaptation (i.e. to develop adaptation pathways) (Wise et al. 2014; Fazey et al. 2016). By taking such a staged approach, C-CADS encourages users to incorporate considerations of uncertainty into their adaptation planning and action.

C-CADS is designed to support users just beginning to plan adaptation as well as those that have already developed plans or are some way through the planning process (in the latter case, by enabling self-evaluation and integration of existing business plans). To enable this broad approach, it calls upon a number of tools. CoastAdapt contains a risk assessment framework that takes users through the three stages of risk assessment, together with templates and checklists to mark their progress (Tonmoy et al. submitted). There are also templates, for example, to help decision makers engage, manage, and evaluate consultants undertaking adaptation projects and build a business case for adaptation.

3.4 Opportunity for users to interact

Adaptation practitioners often work in isolation in their organisations and are poorly networked. Opportunities to connect were identified as a need during initial consultation, and this was addressed in two ways. First, an online forum (CoastExchange) was established to allow members to post questions and information and join discussions. Effort was taken to ensure that news and anecdotes of interesting climate change adaptation activities were posted regularly in order to stimulate discussion. Second, a process was created that allowed the

Table 1 Datasets in CoastAdapt

Type of content	Purpose	Dataset	Display type/resolution	Suppliers	Reference
Shoreline Explorer (datasets are searchable by local council name)					
Geomorphology, ocean currents	To explore present-day and future sensitivity and vulnerability to inundation, erosion, and sea-level rise	Sediment compartments: categorisation of the coast into broadly homogeneous (in terms of sediment distribution and processes acting) compartments, together with descriptions of sensitivity to climate change in each compartment	Secondary sediment compartments	Geoscience Australia plus interpretation by expert panel	Thom et al. 2018
Coastal landform type	To explore present-day and future sensitivity and vulnerability to inundation, erosion, and sea-level rise	Smartline: a nationally consistent geomorphic and landform stability mapping of the Australian coast; available in basic and advanced forms	A coloured line around the Australian coast; colours represent the type of coastal landform (cliff, sandy shore, etc.)	Geoscience Australia	Sharples et al. 2009
Water Observations from Space	To help understanding of the present-day vulnerability of the land surface to flooding	Satellite data (Landsat 5 and Landsat 7) showing frequency and distribution of lying water (i.e. flooding), 1987 to present	25 m × 25 m	Geoscience Australia	http://www.ga.gov.au/scientific-topics/hazards/flood/wofs
Sea-level Rise and You (data are available for each coastal local council)					
Historic sea level	To understand historical fluctuations/trends in sea level	Satellite altimeter data 1993 to 2016	Monthly time series for each local council	CSIRO	Church et al. 2016
Future sea-level rise	To understand the scale of the risk from sea-level rise between now and 2100	Model data for the 4 RCPs from present-day to 2100	Time series for each local council (one value per year, which is a 21-year average centred on that year) with confidence intervals	CSIRO CSIRO	Church et al. 2016

Table 1 (continued)

Type of content	Purpose	Dataset	Display type/resolution	Suppliers	Reference
Future allowances: the vertical distance an asset needs to be raised under sea-level rise so that the present likelihood of flooding does not increase	To understand the scale of the risk from sea-level rise and storm surge between now and 2100	Calculated from model data for the 4 RCPs from present-day to 2100	Time series for each local council (one value per year, which is a 21-year average centred on that year)		Church et al. 2016; Buchanan et al. 2016
Inundation mapping	To understand future flood risk (indicative only given limitations of bathtub modelling)	Inundation mapping for 2050 (for RCP8.5) and 2100 (for RCP4.5 and RCP8.5), based on bathtub modelling and where LiDAR mapping has been performed	Three maps for each coastal council with LiDAR information	Cooperative Research Centre for Spatial Information	NCCARF 2017
Temperature extremes	To understand how temperature extremes may evolve into the future	Model data for the present-day and four time points to 2100 for RCP4.5 and RCP8.5 (means and confidence limits)	Time series graphs for: •Days/year with maximum temperature > 30 °C •Nights/year with minimum temperature > 25 °C •Longest run of days/year with maximum temperature > 30 °C (heatwave)	CSIRO	Clarke et al. 2017
Rainfall extremes	To understand how rainfall extremes may evolve into the future	Model data for the present-day and four time points to 2100 for RCP4.5 and RCP8.5 (means and confidence limits)	•Days/year when rainfall > historic 99.9th percentile •Mean annual (May–Apr) number of months when total rainfall < historic 10th percentile (drought)	CSIRO	Clarke et al. 2017

adaptation community to ask questions of a panel of experts, recruited from across Australia. This 'Ask an Expert' forum operated within CoastExchange, and took questions and provided responses on a monthly basis. This has built a database of questions and answers on adaptation topics that is included in CoastAdapt.

4 Use of CoastAdapt

We tracked usage of CoastAdapt to understand how our initial thinking around content and design has performed. Bearing in mind that the holiday months in Australia are December and January, numbers have held up well over time, despite concerns that, following initial interest, visits would gradually decline. This suggests that CoastAdapt offers real and recognised value to its users. Nevertheless, Fig. 2 clearly demonstrates the value of promotional activities—the peak in May–June coincides with a CoastAdapt training program.

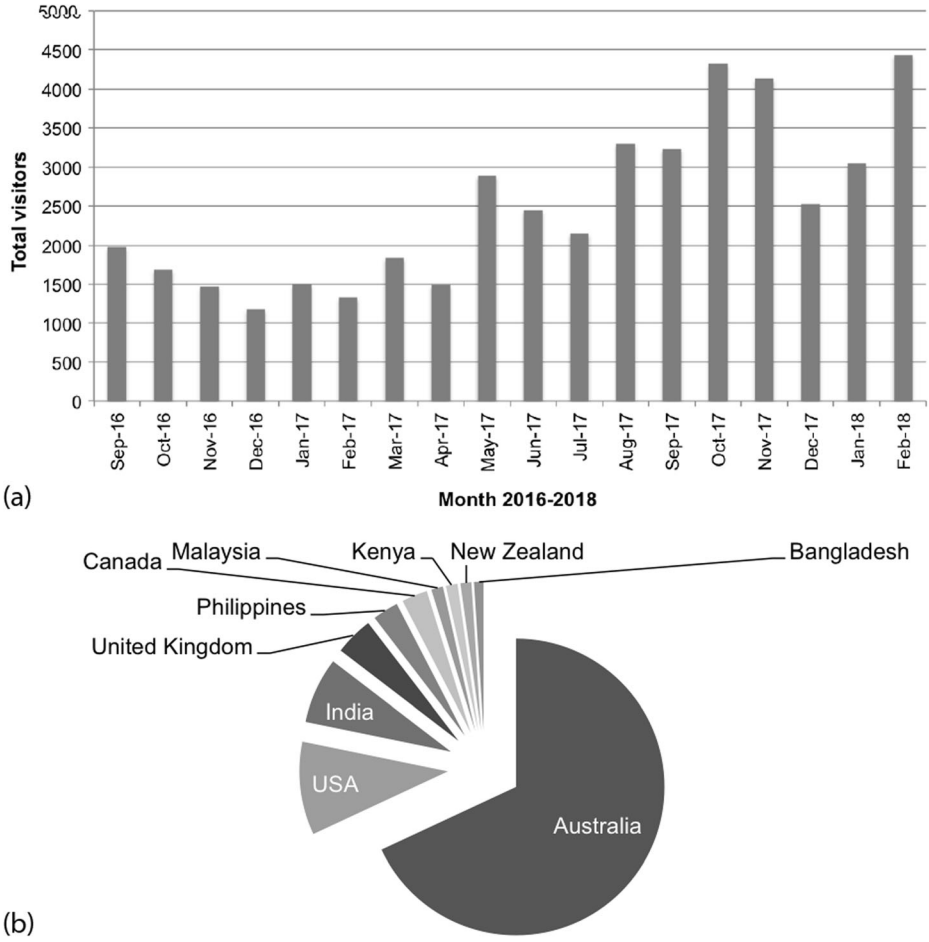

Fig. 2 Visitors to CoastAdapt between September 2016 and February 2018. **a** Total visitors per month. **b** Country of origin of visitors over the whole period. Source: Google Analytics

The most frequently accessed areas of CoastAdapt are the datasets. The inundation maps received around 6000 page views over a 10-month period (6% of the total of 102,493 page views). Altogether, Sea-level Rise and You (which includes the inundation mapping) and Shoreline Explorer (see Table 1) accounted for 14% of all page views.

Monitoring usage of information manuals, which represent the detailed and authoritative knowledge underpinning CoastAdapt, provides insight into who users are and their adaptation needs. The two manuals of greatest interest are, first, on sea-level rise and climate change science and second, on available datasets for hazard assessment (together, 30% of manual page views). These, together with the manual on coastal sediments and geomorphology, represent 42% of page views. This suggests that, overall, users are at an early stage in thinking about climate change risks. Manuals more oriented towards planning and action received less attention: only the 'Assessing costs and benefits' manual had more than the 'expected' 10% of page views.

For case studies—which cover a broad range of topics and geographic distribution—there is no distinct pattern of viewing frequency. It is sometimes possible to link increased page views to specific events. For example, the most popular case study, on floods in Mackay, had a peak in popularity in mid-March 2017, when Cyclone Debbie was tracking close to the town. The least viewed are those drawn from outside Australia. The international case studies were selected to demonstrate aspects of adaptation that are generally not present in Australia, such as strategies to provide flood insurance to at-risk properties in the UK and USA, and coastal realignment projects from the UK. Over time, as adaptation becomes more widespread in Australia, it may be possible to replace the overseas case studies with local examples.

5 Discussion

Building a decision support system for adaptation takes time, in our case close to 2 years to produce the beta version, and yet the contexts for adaptation in Australia are shifting very rapidly. Most state governments now provide some level of support for their coastal councils, for example by financing adaptation planning (LGAQ and DEHP 2016) or through regulatory requirement (NSW DPE 2016). Local councils themselves have made progress, with many moving at least to the adaptation planning stage. This speaks to the need for flexibility in the design and build of decision support systems. The target audience may change or broaden. For example, as local councils seek to build buy-in for their adaptation plans, CoastAdapt has assumed an educational role, helping communities to understand why adaptation is necessary and to meaningfully contribute to the debate on appropriate actions and their timing. At the same time, it maintains its role of supporting local councils to take action, through information provision, guidance, and support for risk assessment.

The apparent progress of local councils in adaptation may be somewhat illusory. Many councils lack in-house capacity and expertise and so employ consultants to write their adaptation plans. This has two negative results. First, councils fail to build institutional knowledge and experience in adaptation. Second, because they lack adaptation knowledge and experience, councils may struggle to achieve their goals in their dealings with consultants at all points, from writing the request for tenders through to evaluating the adequacy of the final reporting. It is often the case that councils work hand-in-hand with consultants and will, for example, co-sponsor and co-organise community consultation workshops. CoastAdapt

provides substantial guidance to help councils manage their interactions with consultants, including how to evaluate their work from the initial bid to final reporting.

The initial criteria for CoastAdapt were that it should be accessible, authoritative, attractive, and comprehensive. To ensure *accessibility*, we designed CoastAdapt with different entry points, intended for users across the spectrum of knowledge, roles, and needs. Thus, the 'Getting started' webpages provide role-specific suggestions for users ranging from community groups to elected council officers. Web pages are stratified into 'skimmer', 'wader', and 'diver' information of increasing detail and complexity. All content was reviewed by coastal managers and modified where it was judged to be unnecessarily complex or long, or lacking relevance. Users must perceive CoastAdapt as *authoritative* if sustained use is to be assured. All content is peer-reviewed. The information manuals and content on jurisdictional differences provide authority, but will need to be regularly inspected to ensure they reflect the latest science and policy framings. If content is judged to be out of date, users will seek alternative resources. CoastAdapt is designed to be *attractive*, and this includes ease of navigation. By using drop-down menus, most content is reached directly from the home page. We have found that where this is not the case, and users must navigate through an intermediate webpage, content can become lost to users. For example, the guidance on 'Climate change adaptation and your council: where to start', which was judged to be very useful by user reviewers, received only 16 visits from September 2016 to May 2017, compared to 204 visits to its host webpage (and there are plans to re-structure in order to give this content greater visibility). Nevertheless, where users are drawn to information, especially information that has clear relevance to their location or experience, they will overcome any complexities of navigation. Thus, the case studies and datasets, which are accessed from the home page through landing pages, and in the case of the datasets require thought to navigate, are some of the most heavily visited areas of CoastAdapt. Finally, intense engagement prior to embarking on the design of CoastAdapt systematically identified the knowledge needs of coastal managers, ensuring that the final product is *comprehensive*. Writing for a broad audience has ensured a flexible product which is sustainable in the long-term against a background of fluctuating policy settings and evolving skills, knowledge, and needs of potential users.

Nevertheless, there are areas of CoastAdapt that did not function as expected. Most notable is the online forum, CoastExchange, set up in response to strong demand expressed during consultation for a forum to exchange information, experiences, and advice. A substantial effort was made by NCCARF to ensure that new content was added (with one goal being to provoke discussion), and that users had the opportunity to ask questions of experts (a need identified as important by potential users). There was considerable use of CoastExchange (for example, 6000 sessions and 27,000 page views over the 15 months of operation). However, it never really operated as a discussion forum, and we regard the low number of contributors and threads as a failure. CoastExchange has now been discontinued, at least for the moment.

6 Conclusions

A persistent question from potential users of CoastAdapt concerns its longevity, and in particular how funding will be sustained over time to ensure it remains current and authoritative. Ideally, decision support frameworks for adaptation should be seen as operational tools, managed for the long term by operational bodies in meteorology or, in this case, for coastal protection. NCCARF is receiving Australian Government support to explore sustainable

funding strategies for CoastAdapt, and is currently working to identify, evaluate, and implement potential funding mechanisms.

A founding principle of CoastAdapt is that whole of life engagement and co-production with the user community are essential components of success. Yet the time, effort, and financial resource requirement can be heavy, on both sides. The benefits may be clear to the project team, but the same is not necessarily true for users. Why should time-poor local council or small business employees devote time to attending a workshop to discuss CoastAdapt, and why should their managers support their attendance? In recognition of this, NCCARF elected to work with a self-nominated group of users, the TDP, to steer and support development of CoastAdapt. This led to an emphasis on council officers working in roles related to environmental management. If there had been involvement by a wider diversity of potential users, including finance and planning officers, it is possible that the emphases in CoastAdapt would have been different, for example with more content on valuation and costing. However, for NCCARF, the benefits of working with a group committed to the success of CoastAdapt were a paramount consideration.

It is important to provide incentives to ensure that employees at the right level in the organisation participate and are engaged (Leitch et al. submitted). TDP members were under contract and paid to work with NCCARF on development of CoastAdapt, as incentivisation and also as a means to legitimise their participation with their organisations and line managers. For shorter-term engagement (e.g. single workshops), networking opportunities can be a powerful motivation to attend.

If CoastAdapt is to remain useful and usable into the future, it needs to be seen as dynamic, relevant, and current. A minimum commitment involves regular (say, 6-monthly) checking for broken links and biannual review of state government webpages to ensure the accuracy and currency of content on planning legislation, regulatory frameworks, and available datasets. Equally necessary is the review and update of climate change science content, as new research emerges. For example, the growing literature (DeConto and Pollard 2016; Mengel et al. 2016) suggesting that sea-level rise may exceed projections in the Fifth Assessment of the Intergovernmental Panel on Climate Change (Church et al. 2013) is of great interest to coastal managers. A website summarising that literature and being clear about the uncertainties involved would be welcomed.

Updating and 'housekeeping' are a bare minimum. As adaptation progresses in Australia, the types of adaptation practitioner, as well as their needs, will evolve. With appropriate resourcing, CoastAdapt can meet these changing needs in three ways. First, the regular addition of new content to meet the needs of coastal managers, especially (given the interests of users) case studies and new datasets as these become available, would help to ensure the longevity of the framework. Second, the capacity to continue to engage with practitioners through workshops, training sessions, and test cases would greatly enhance the likelihood that CoastAdapt will continue to provide legitimate, relevant, and trustworthy information. Finally, although CoastAdapt content is focussed on Australian coastal managers, the architecture and some of the content are transferable to other locations and sectors within Australia and, with greater expenditure of effort, overseas. Considerable thought and effort have gone into the design of CoastAdapt, to ensure its appearance is attractive and its architecture straightforward to navigate, thus making it a strong analogue for the future construction of decision support frameworks.

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