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Modelling a Tourism Response to Climate Change Using a Four Stage Problem Definition and Response Framework

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Climate change has become a hot topic for research, but the response of national governments has been relatively cool, particularly in their support for effective mitigation measures to combat the problem. A review of the scientific literature (Intergovernmental Panel on Climate Change [IPCC]. (2007). Summary for policy makers. In S. Solomon, M. Qin, Z. Manning, M. Chen, K. Marquia, M. Averyt, M. Tignor, & H. Miller (Eds.), Climate change 2007: the physical science basis. Contribution of working group 1 to the fourth assessment report of the Intergovernmental Panel on Climate Change. *Cambridge, United Kingdom and New York: Cambridge University Press) paints a generally grim view of where the Earth is heading for by the end of the century if effective mitigation strategies are not implemented in the next few years. Mitigation measures of the type required to prevent major environmental damage in the future can only be effective if a global political approach based on agreed levels of climate change gas reduction is implemented. For its part the tourism industry is caught in a trap, unable to adopt meaningful mitigation strategies because of reluctance by consumers to bear the cost of changes that will be required but having to meet the cost of climate change mitigation and adaptation strategies when they are introduced in the future. This article proposes a four stage problem definition and response framework with associated models that can be used by the industry to plan for and adapt to climate change both prior to and after the introduction of legislation and policies to combat climate change at the national and international levels.*

Key words: climate change, mitigation, adaptation, frameworks, models, Great Barrier Reef

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Introduction

While the issue of climate change is attracting growing interest in the tourism literature, many aspects are not well understood by academics, the public or industry (McKercher & Prideaux, 2011). The scientific evidence that the global climate is changing and that human action is a key driver is now accepted by almost all members of the scientific community, but many governments and large sections of the general public have yet to accept this proposition. Readers are referred to the paper by Pang, McKercher, and Prideaux in this special issue for a summary of research undertaken to date on the issue of tourism and climate change. Given its importance and the potential for future disruption of tourism flows, there is a need to develop new tools, models and frameworks that can be used by tourism planners, practitioners and academics to deal with climate change and its possible impacts. This article proposes a framework and associated models to assist the tourism industry to respond to climate change in the future. The framework is tested to some extent by using IPCC (2007) climate projections and an analysis of adaption options available to coral reef dependent destinations. The following discussion commences with a review of how climates have changed in the past, followed by identification of gaps in understanding. The article then outlines a four state problem definition and response framework.

Background

Before examining current trends in global warming that have led to the current concern, it is worth briefly reviewing how climates have changed in the past and the impacts that this caused. This background provides a useful framework against which to assess potential impacts. Rapid changes in global temperatures have occurred in the past, though from natural processes and not from human causes as is the present case. Examples of abrupt climate change include the Carboniferous Rainforest Collapse, the Paleocene–Eocene Thermal Maximum (PETM), Dansgaard–Oeschger events and the more recent Younger Dryas event. The PETM event occurred at the temporal boundary between the Paleocene and Eocene epochs about 55.8 million years ago, and over a period of approximately 20,000 years global temperatures rose by approximately 6°C (Katz, Pak, Dickens, & Miller, 1999). There is evidence of almost complete melting of polar ice caps, almost complete dissolution of deep water carbonates, high levels of ocean acidification, increased extinction rates of terrestrial biota and an increase in mammalian abundance. Possible causes of the PETM include increased volcanic activity and an increase in deep ocean methane release (Norris & Röhl, 1999).

In the recent past, there have been significant changes in global temperatures during periods of glaciation, the most recent being the current Pliocene–Quaternary glaciations which commenced about 2.58 million years ago. The Earth is currently in an interglacial stage with the last glacial period ending about 10,000 years ago after peaking at the Last Glacial Maximum approximately 20,000 years ago. Since that peak, the Earth has gradually warmed and sea levels have risen by approximately 120 metres.

There is ample geological evidence of rapid change in global temperatures during the most recent glacial period with the latest being the Younger Dryas event when there was a sudden interruption of global warming towards the end of the last ice age (Berger, 1990). Gradual warming ceased when temperatures fell by up to 8°C and there was a return to a cold global climate for about 1300 years (1300 ± 70 years) during the period 12,000 to 11,500 years ago (12.9–11.5ka BP calibrated) (Alley, 2000). This period was followed by a 40–50-year period when temperatures rose approximately by 8°C over three discrete steps, each lasting about five years (Alley, 2000) taking temperature to the level they are today. Estimations of temperature changes of this nature are based on proxy factors such as pollen evidence of changes in vegetation, ice cores and marine sediments. Rapid temperature changes of the nature experienced during the Younger Dryas event indicate that global temperatures are not stable over the long run, although in the past the triggers for these events have been natural rather than anthropogenic. Factors that have contributed to past climate change include variations in the Earth's orbit around the sun, continental drift, changes in solar output, cosmic collisions and volcanism (Pittock, 2005).

Figure 1 illustrates the flow of carbon between various reservoirs in the atmosphere, on the land and in the oceans. In understanding how these flows affect temperature, it is important to consider the effect of delayed climate responses, tipping points, trigger mechanisms and the effect of feedback mechanisms. A tipping point occurs when global climates move from one state of stability to another state of stability. One possible tipping point is the melting of arctic permafrost, leading to the release of large quantities of methane (Zimov, Schuur, & Chapin, 2006). Trigger mechanisms describe factors that cause significant change such as a global scale period of volcanic eruptions. Positive feedback (see Figure 1) amplifies change, while negative feedback describes the process of mitigation leading to a return to normal conditions. For example, the build-up of atmospheric CO_2 from the burning of fossil fuels and deforestation (positive feedback) may take centuries to be reabsorbed (negative feedback) via CO_2 exchange into the deep oceans, in marine organisms such as microscopic plankton and algae and through wide-scale re-afforestation. For this reason, it is reasonable to apply the precautionary principle to the current trend of high greenhouse emissions. The precautionary principle was included in the 1992 Rio Declaration

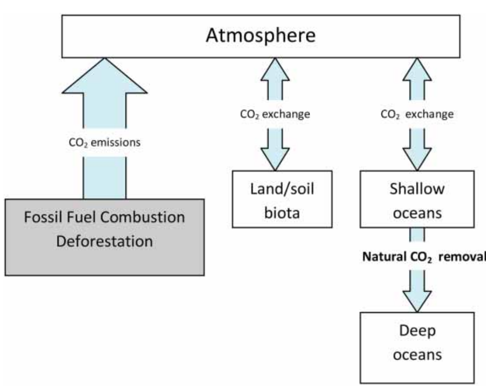

Figure 1 CO_2 Flows between Carbon Reserves in the Atmosphere, Land and Soil Biota and Shallow Oceans and Eventual Removal into the Deep Ocean.
Source: Pittock (2005, p. 13).

(UNEP, 1992) and states "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". To date this principle is only just beginning to be applied on a global scale to combat climate change.

The scientific community is generally united in its view that climate change is the result of anthropogenic influences (Anderegg, Prall, Harold, & Schneider, 2010; United States National Academy of Sciences, 2008) and unless mitigation is able to successfully arrest the rise in global temperatures in the near future there will be significant economic and ecological costs for future generations (IPCC, 2007; Stern, 2006). However, it is not the role of the scientific community to institute policies and legislation to deal with this issue. Action of this nature requires global cooperation from all nations. Unfortunately, achieving global cooperation has been difficult for a range of reasons, including national self interest, lobbying by major industrial stakeholders likely to be affected by mitigation policies, concerns about the cost of mitigation and lack of public support. Public support is an essential requirement for a meaningful political response, but in many nations public support is at best lukewarm as demonstrated by the difficulty the Australian Government experienced over the introduction of a carbon tax in 2011. It appears that the public remains unconvinced of the need for immediate action particularly where it has a direct and personal monetary cost.

In part because of cost and in part because of the doubts raised by a small group of scientists (for example see Gladstones, 2011; Plimer, 2009; Scafetta, 2010) who either are sceptical about anthropogenic causes for climatic change and view increase in CO_2 as a component of climate variability (Singer and Avery, 2005) or have concerns about the validity of temperature data used to measure climatic change, there is a widespread view by the public and many policy makers that climate change is unproven or the result of natural forces over which humanity has no control. Sceptics generally base their concerns on the methodology (Plimer, 2009) used to measure temperature, citing problems in the measurement of temperate variations in cities which in effect are heat sinks, poor data and data selection bias.

Temperature data used to estimate the rate of climate change is collected from a global network of weather stations, with the earliest data recorded in the mid-nineteenth century. Three independent research groups, NASA's Goddard Institute for Space Studies (GISS), a collaboration between the British Metrological Office and the Climate Research Group of the University of East Anglia and the US National Oceanic and Atmospheric Administration (NOAA), assess this data. An independent reassessment of global temperature records by the Berkeley Earth Surface Temperature Group found that the concerns about temperature findings released by the University of East Anglia, NOAA and NASA's GISS were not valid and that over the last 50 years the global land surface had warmed by 0.911°C (Science Daily, 2011; Tollefson, 2011).

The views of sceptics and other critics have had a significant impact on the debate in much the same way as sceptics influenced the initial course of public debate over the impact of smoking or on the long-term effect of depletion of ozone (Jacques, 2009). For these reasons it has been difficult to reach a global consensus on the need for coordinated international efforts to reduce greenhouse gas emissions. The first attempt, the Kyoto Protocol signed in 1997, resulted in a number of nations and the EU agreeing to reduce emissions, but the failure of the USA to sign the protocol and the exclusion of developing nations including China and India meant that overall global emissions have not fallen. However, by the late 2000s there was a growing realisation that climate change is a major issue and in 2009 United Nations Climate Change Conference, generally referred to as the Copenhagen Conference, produced the non-binding "Copenhagen Accord" that called for action to keep the temperature increase below 2°C. The more recent 17th session of the Conference of the Parties to the United National Framework Convention on Climate Change (UNFCCC) held in Durban, South Africa, in late 2011 produced a consensus that a legally binding deal (the Durban Platform) comprising all countries be prepared by 2015 to take effect from 2020 (Black, 2011).

Currently, the annual level of emissions is accelerating, driven both by continued global economic growth and the failure of the global community to implement policies to limit future emissions. The most recent evidence indicates that in 2010 overall atmospheric concentrations of CO_2 increased by 5.9% and is now at its highest level for 800,000 years (Peters et al., 2011). A recent modelling also suggests that humankind has already reached the halfway point to the total level of CO_2 emissions required to increase global temperatures by 2°C (Friedlingstein et al., 2011).

Any action by the tourism industry or specific elements of the industry to unilaterally attempt to combat climate change is unlikely to be supported either by the industry or by consumers unless there is a significant degree of legislative compulsion. The aviation industry, for example, has forecast a significant increase in demand for air travel in coming decades, with Boeing predicting that the number of airliners in service will rise from 19,410 in 2010 to 39,530 in 2030 (Boeing, 2011). While aircraft manufacturers are actively seeking ways to reduce fuel burn with new generations of aircraft such as the Boeing 787 and Airbus 350, they do not appear to be concerned that future mitigation strategies may impact on the demand for long haul travel.

Tourism is estimated to generate 5% of all anthropogenic emissions of CO_2 (Scott et al., 2008). In the tourism sector, transport is the largest generator of CO_2 (with air transport contributing 75% of that figure) followed by accommodation (21%). The actual contribution of a holiday trip to CO_2 can vary widely. Scott et al. (2008) estimated that the globally, the average tourist trip lasted 4.15 days and generated an average emission of 0.25 t of CO_2 per person trip. The actual contribution per trip may however vary widely. According to Lamars and Amelung (2007), a 14-day holiday by a European travelling to Thailand will produce 2.4 t of CO_2 per person. Although air-related travel generates only 17% of all trips, it generated about 40% of all tourism-related CO_2 (Hall, 2011). Scott et al. (2008) estimated that long haul aviation tourism from Europe accounts for 17% of global tourism emission but only 2.7% of all tourist trips. As a point of comparison, the average per capita emissions of CO_2 globally in 2010 was 4.7 t, the EU had a per capita emission of 8.4 t per capita, the USA had 17.5 t per person, while China, now the world's largest emitter of CO_2 by volume, had a per capita emission of 6.7 t (United Nations Statistical Division, 2011).

Where does the current global situation in relation to mitigation and adaptation leave the tourism industry? Until legislation is introduced to force consumers and the industry to reduce their greenhouse gas emissions, there is little incentive for proactive mitigation across the sector. There is, however, an opportunity to support proactive adaption, primarily for tourism-related infrastructure that have a long life span such as airports and transport networks and are located either in areas likely to be affected by climate change or in coastal areas. There is also a need to look for opportunities to influence policy, but for this to occur the tourism industry must first agree that climate change is a significant issue and then learn how to work within legislative frameworks to reduce the impact of climate change. To date and with a few exceptions, the tourism industry has not begun to seriously debate this issue or consider the type of actions it should support.

As the following discussion indicates, consideration of the impact of climate change on the tourism industry has generally been restricted to specific industry sectors and on time scales that are generally short term. This article advocates the need to take a long-term view on a scale that is industry wide and for this reason suggests a multi element framework that can be used to aid the industry to develop a response to public sector policies that will need to be introduced in the future to combat climate change grows.

Gaps in Understanding

The following review briefly explores the major themes that have emerged in the tourism literature. However, before undertaking this review it is worth reviewing the most influential publications on climate change from a scientific as well as an economic perspective.

The IPCC reports (1990, 1995, 2001, 2007 with the fifth report due in 2014) synthesise the scientific and related literature to bring together in one publication a balanced view of the current state of knowledge about climatic change (IPCC, 2007). The fourth report (2007) cited over 6000 peer-reviewed publications and was itself reviewed by 625 expert reviewers (IPCC, 2011 [accessed 16 November 2011]). Much of the current research into aspects of climate change uses the IPCC reports as either a source of scientific data or a core reference. The scientific literature represents a range of views from reporting of impacts without views about the consequences for human society to discussion on likely impacts. One example of the latter is the reports by coral scientists that raise alarm about climate-change-induced coral bleaching (Hoegh-Guldberg, Stout, Cesar, & Timmerman, 2000). The 2006 Stern Report commissioned by the UK Government identified the economic cost of climate change and has been another influential publication.

An analysis of the tourism literature reveals a number of gaps and shortcomings. Specific areas where there has been little research include: the links between scientific and tourism research; broad or macro views of how the industry may respond to climate change in the future; a lack of broad-scale models and frameworks that are able to facilitate assessment of how government policy will affect the tourism sector; and the impact that climatic change will have on the future global and regional consumption of tourism experiences. Conversely, the literature is particularly strong at exploring how firms and destination may respond to the problem at the micro level.

Major problems that will be encountered when responding to gaps in the literature include:

- A clear understanding of the rate at which global temperature will rise in the future given that at this point of time it is not possible to predict if and when a binding global mitigation accord will be agreed to and implemented. Without knowledge of this specific nature it is not possible to predict the ultimate impact of climate change.

- Difficulty in predicting how society will respond to mitigation policies particularly where the personal and national costs are high. For example, will there be a move to discourage long haul travel in favour of short haul travel, possibly reinforced by taxes and charges of the nature recently imposed by the UK (Air Passenger Duty Tax) and the additional costs imposed by the EU's Emissions' Trading Scheme on long haul air travel travel?
- Lack of clarity in the science on some of the possible impacts of rising temperatures including issues such as the potential for CO_2 currently trapped in permafrost to escape into the atmosphere (Zimov et al., 2006), the tipping point for a runaway melting of the ice sheets of the Arctic and Antarctic and the ultimate level of global temperature increase.
- Lack of understanding of the science behind climate change by many social science researchers.

While there is an obvious need for tourism researchers to consider these issues, there are limitations with the current suite of tourism-related models, frameworks and tools and as a consequence there is a need for look for new models and tools or adapt existing ones. Some of the issues that tools, models and frameworks of this nature must respond to are apparent from the previous review of the literature.

Issues identified in the literature that seem particularly important in determining how the tourism industry may have to respond to climate change in the future include:

- Measuring how biological and physical systems will change as a consequence of climate change and how the tourism sector will respond to these changes. One area of likely change is the species mix of protected areas as species move, adapt or become extinct.
- Will the tourism industry respond voluntarily or be forced by government policy or consumer demand to make change in the manner and location of the provision of tourism services as the impact of climate change becomes more apparent?
- How will consumers respond to the biological and physical aspects of these changes and how will they call for and subsequently respond to policy changes to mitigate and adapt to the changes in their physical, social and economic environments?
- What will consumers' response be to new policies that may affect their ability to continue to participate in tourism experiences of the nature currently offered? One example of experiences that may be affected is long haul air travel unless new green house friendly fuels are developed.
- Building new models and frameworks as well as adapting existing models and frameworks to assist policy makers, investors and destinations to plan for changes that will occur as a result of climate change.

Many of these issues also affect industries other than tourism. For this reason, it is beyond the scope of this article to examine each of these issues in detail, although each issue does require a detailed analysis. Given the constraints of space necessarily imposed by the journal format, this article will specifically examine the first and the last issues while recognising the need for further analysis of the remaining issues.

Building a Problem Definition and Assessment Framework

The objective of this article is to suggest a tourism-specific approach to dealing with climate change in the long term, based on a framework and associated models that can be used for adaption as well as providing guidance for responding to legislative changes. The issues identified in this article call for an approach that moves beyond the usual positivist framework of data collection and analysis. For example, standard forecasting analysis based on manipulation and extrapolation of existing data to develop forecasts of the future is unlikely to be useful, given the paucity of knowledge in areas such as the future intent of policy makers, deficiencies in current scientific knowledge that effect accurate prediction and a clear understanding of how tourists will react to specific types of change in the future. The issues identified in the earlier discussion call for a different approach to examining the future by construction of methodological tools that are able to deal with relatively messy and ill-defined issues where data sets are unlikely to be helpful at least until a platform has been built that facilitates the incorporation of quantitative data.

This article suggests a four stage process based on problem solving using linked models (see Figure 2) to develop a framework that can be used to investigate this issue. A sequenced approach is used, commencing with the need for problem conceptualisation. This is followed by problem specification, problem analysis and finally tourism responses. In the manner used here, the sequence enables a messy and ill-defined problem to be identified, defined and analysed in four stages.

The main limitation encountered in developing the framework and associated models is the difficulty of extending the following discussion to include a data-rich detailed application of the framework in a specific location. Space limitations preclude application of this nature in the current article although a limited application is undertaken

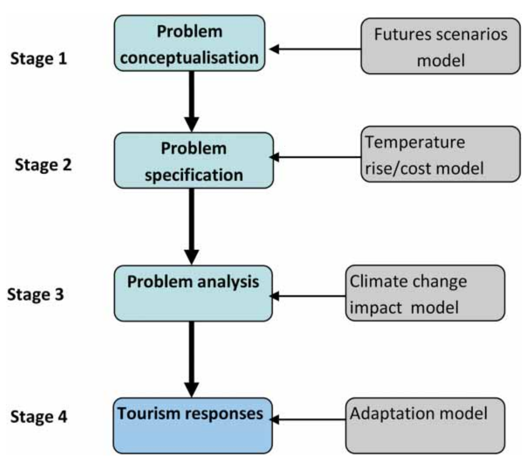

Figure 2 Four Stage Problem Definition and Response Framework.

based on the Great Barrier Reef (GBR) in Australia. For this reason detailed application and testing of the framework is deferred to a later article.

The first element of the framework requires the problem to be conceptualised in a manner that allows key relationships to be identified, how those relationships may change over time and what broad implications these changes may have. As the literature has pointed out, the impact of climate change at any given point in time will be determined by the interaction of a complex set of relationships governed by:

- the cumulative volume of green house gasses produced in the past,
- the rate at which production of green house gasses is occurring in the contemporary time period,
- the impact that various triggers, tipping points, lags and positive and negative feedback mechanisms will have on temperature in the near, medium and long term,
- various time lags that exist between emission and impact,
- the impact that green house production will have on key environmental indicators, some of which are still not fully understood by the scientific community,
- the point at which mitigation will be able to arrest continuing increases in green house gas production,
- the point at which total levels of green house gas production on an annual basis will fall, and finally
- how far below current emission levels future emission will fall.

A key point in the preceding discussion is the willingness of policy makers, on a global basis, firstly to accept the reality of climate change and secondly to develop coordinated responses that through mitigation will contain the problem at some point in time and at some yet to be determined magnitude of damage. The first issue is difficult to predict because of the complex intersection of personal, industry and public sector views on the validity of scientific claims on the magnitude and even causes of climate change, self interest that may be on a scale ranging from personal to national and finally willingness to accept the costs of action. The second issue is almost as difficult given that responses of this nature require coordinated action between all nations. There are precedents for international cooperation to resolve global environmental issues with action to rectify the problem of atmospheric ozone depletion (UNEP accessed 16 November 2011) being the most successful to date. In the case of climate change, however, the high cost, willingness to pay and agreement on who will be forced to pay have been major hurdles in reaching an agreement.

A number of authors (Godet, 2000; van der Heijden, 1996) have suggested scenario-based models as an approach that enables problems of this nature to be contextualised into a form that illustrates both the complexity of the issues involved and the costs and benefits of action and/or no action. In this case, a modified future scenario based on a recent work by Prideaux (2009) is suggested as a suitable vehicle for conceptualising the issues and relationships involved.

Major parameters that will determine the extent to which climate change will affect global society in the future include the rate that temperatures rise, the time this increase occurs over, the impact of temperature increases, the role of change and how change is responded through policy and the resulting futures that may emerge. Figure 3 illustrates how various combinations of these parameters

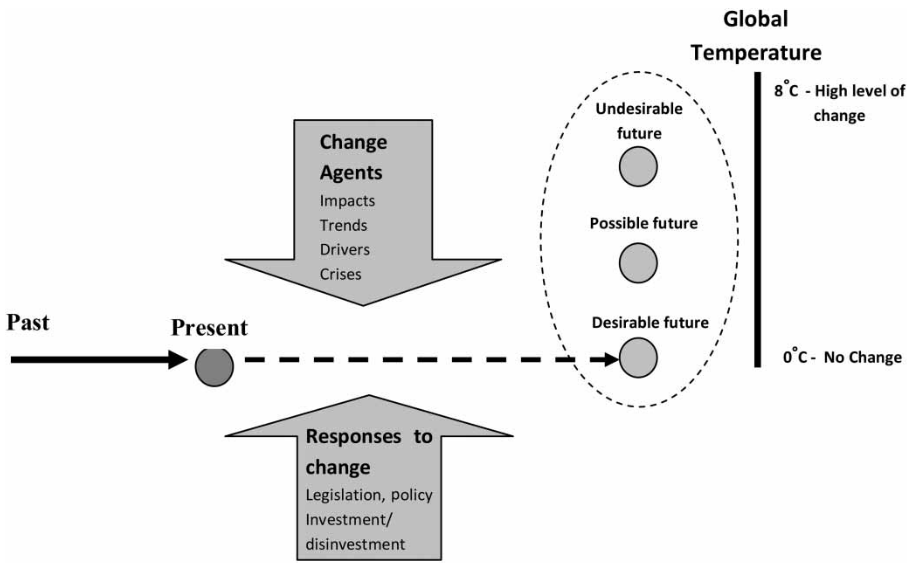

Figure 3 Futures Scenarios Showing the Effect of Impacts (Trend, Random Events, Crises, Drivers and Inhibitors) and Responses (Policies, Investment and Marketing).
Source: Adapted from Prideaux (2009).

create alternative futures. In this way, the model is able to contextualise the problem in a relatively simple manner by combinations of these parameters that are shown as three versions of the future: a desirable future, a possible future and an undesirable future. While three futures are shown here, many additional versions are possible. Which future is ultimately achieved will be determined by the choices that global stakeholders make in the near future. Each future can be described in detail based on the scientific evidence currently available. Moreover, each possible future is in part determined by the global temperature prevalent in that future. The temperature level will be determined by the manner in which policy makers and the public respond to increasing global temperature caused by change agents, here represented as trends, drivers, crises and impacts. In the following discussion likely impacts are based on data published in the 2007 IPCC Report.

In the best case scenario represented by desirable future, loosely based on the IPCC Summary for Policy Makers (2007) B1 Global environmental sustainability model (with temperature rises of 1.1–2.9°C), global policy responses are sufficient to prevent additional climate warming and there are no long-term adverse impacts from climate change. This scenario does not appear to be realistic given that global action to keep temperature increase to >2°C may not occur until 2020. In the possible future, policy makers are unsuccessful in achieving a global response and temperature change exceeds the 2°C rise advocated by the Copenhagen Accord of 2009 and has significant impacts on the environment. This scenario is loosely based on the IPCC B2 Local environmental sustainability (1.4–3.8°C increase in global temperature) scenario. In the worst case scenario described as undesirable future (loosely based on the IPCC A1F1 rapid economic growth scenario with a rise between

1.4°C and 6.4°C), global temperatures continue to rise causing a range of problems including significant melting of ice caps leading to significant sea level rises, significant changes in global weather patterns, large-scale loss of biodiversity and so forth. Obviously there are many more scenarios of the future than illustrated in Figure 3 and these generally lie at some point between the desirable and undesirable futures.

The key element of Figure 3 is determining which future is most likely. If the introduction of policies to halt emissions is delayed, temperatures will continue to rise. Three significant factors appear to determine the level at which temperatures will ultimately rise: time elapsed between the present and when global temperature increase stabilises; the process of change; and responses to change agents (crises, trends, drivers, impacts). Change is defined (Prideaux, 2009, p. 259) as a " a fundamental long term shift and is a key force in the continuing process of reshaping and reordering global society". Responding to change agents includes the responses by the private and public sectors to mitigate adverse change. These factors collectively describe a process where change occurs over time and is responded to by global society. Each player in this process, in this case national governments, business and citizens, will seek to shape their response to climate change in a manner that best benefits their self interest or in many cases the interests of the powerful lobby groups that have captured the attention of the public and governments. Currently, national self interest continues to impede the introduction of an effective global mitigation strategy.

Until an international strategy is introduced, global temperatures will continue to increase driven by a series of both human and natural drivers. Principal human drivers include increasing consumption of fossil fuels, a reluctance to switch to clean energy sources, continuing deforestation, growing global population, increased consumption and reluctance to introduce energy saving on a national scale. Natural drivers may include the release of vast quantities of methane gas currently trapped in the deep oceans and the release of gas as the northern tundra regions begin to warm (Oechel et al., 1993).

The second stage of the problem definition and response framework (Figure 2) is illustrated in Figure 4 and outlines a conceptual model that facilitates problem specification based on identifying relationships between a range of complex relations including time, temperature increase, predicted impacts at various temperature levels and the monetary and biological impacts that temperature increase will have on the economy. This model allows the choices illustrated in Figure 3 to be quantified in monetary and ecological impact terms. The model was designed to show relationships between the key factors identified earlier. In the model, the positive element of the *Y*-axis measures increase in global average temperature, while the negative element of the *Y*-axis measures the increasing cost to society of each degree rise in temperature. The *X*-axis represents time and the impact on the economy. In this simple version of the model, data for measuring possible impacts at least in biophysical terms is drawn from the 2007 IPCC Report. As the intensity of research into this issue gathers pace, the accuracy of biophysical impacts will be enhanced.

In the model, *T* represents time, *C* represents the cost of dealing with climate change and *I* represents impacts. The scenarios outlined in Figure 4 parallel those introduced in Figure 3. Under the desirable scenario, temperature increases of <2°C have a relatively low impact, causing only minor long-term damage to the ecosystem. Thus a rise in temperature

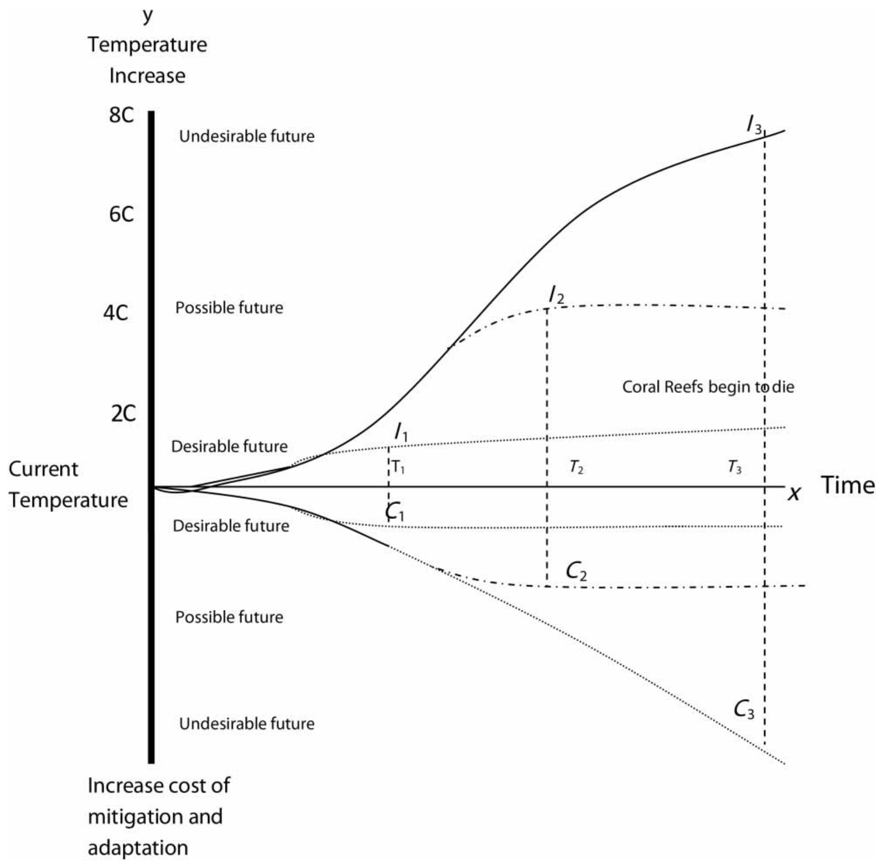

Figure 4 Temperature Cost Model.

below 2°C by time T_1 is shown to have an impact measured as I_1 and a cost of C_1. In the possible future scenario, global policies are not able to halt temperature increases at 2°C and they increase by up to 4°C by T_2. At I_2 the economic cost will rise to C_2 by T_2. In this scenario, coral reefs suffer massive bleaching and die out. If global temperature increases up to 8°C (undesirable future), the economic cost will rise to C_3 by T_3. As a policy tool the model is able to identify the relationship between temperature increase, impacts and economic cost. Used in this way, the model gives users the ability to compare the cost of impacts in monetary and ecological terms based on specific levels of temperature increase. As it is outlined in this article, the model is largely conceptual; however, a later article is planned to quantify the model.

The third stage of the problem definition framework is problem analysis. It is apparent that for problem analysis to be effective the output of scientific research needs to be built into scenarios. This knowledge can be used to determine the likely impact on tourism. In this article, problem analysis is focused on a specific ecosystem rather than a country. Figure 5, originally developed to examine the impact of climate change on rainforest tourism (Prideaux, Coghlan, & McNamara, 2010), illustrates a conceptual model for integrating scientific data with tourism research findings to identify

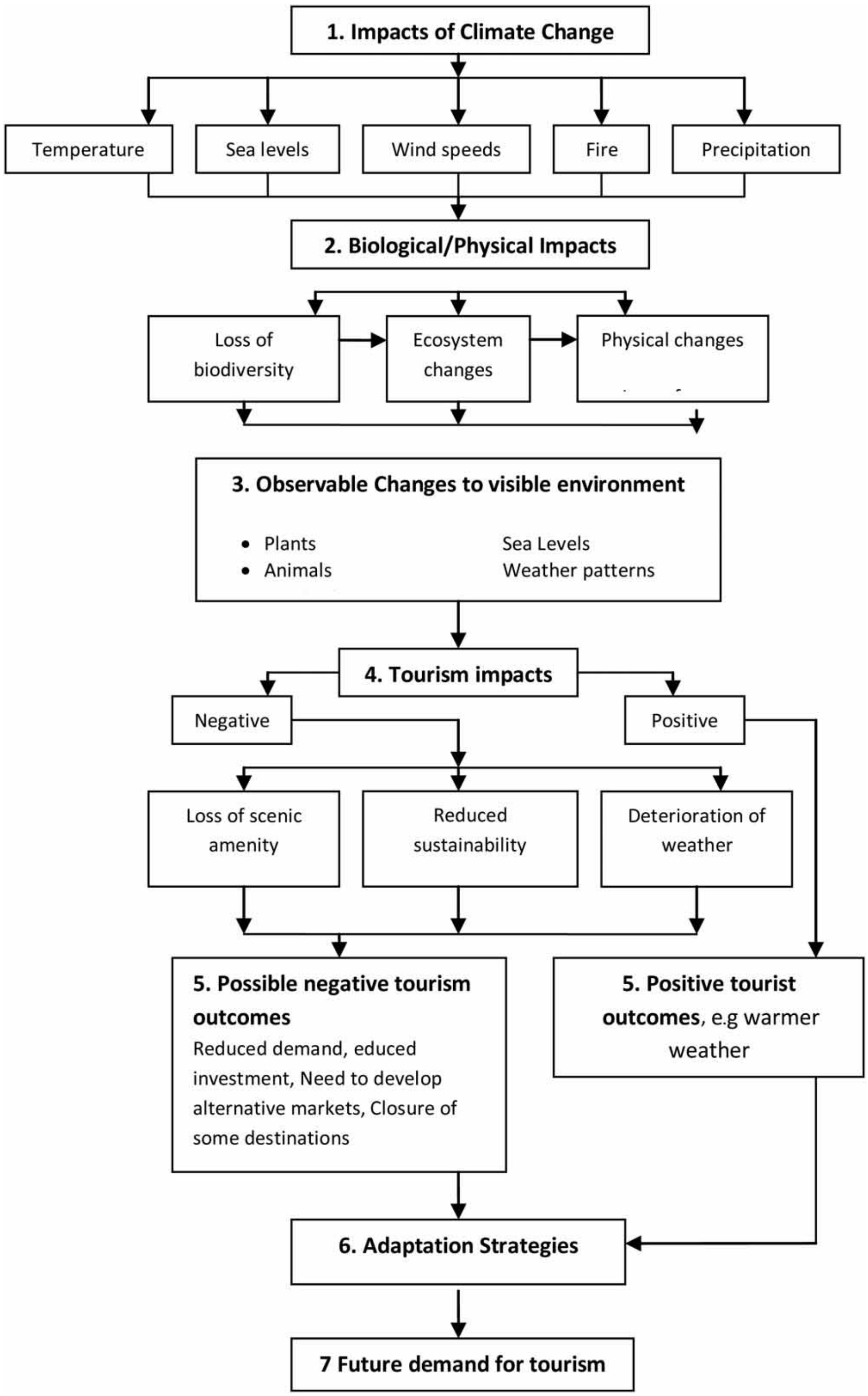

Figure 5 The Climate Change Impact Model. Adapted from Prideaux et al. (2010).

the possible impacts that climate change will have on a specific ecosystem setting, in this case the GBR in Australia. In its current form, the model illustrates a range of climate-driven linkages but has not been developed to the extent where these impacts are quantified in specific terms such as visitor numbers or tourism revenue. The original Climate Change Impact model has been modified and extended from a six step model to a seven step model by the inclusion of a seventh step that represents future demand.

In Figure 5, step 1 is based on assessing the impact of climate change in a specific locality based on changes that will occur to temperature, sea levels, wind speeds, fire regimes and precipitation. These impacts can be readily estimated for each degree increase in temperature based on past meteorological records. Collectively, these factors will have both biological and physical impacts (step 2) that include loss of biodiversity, ecosystem changes, physical changes and reduction in sustainability. Step 3 measures how these impacts will result in observable changes in a specific environment. For example, a 2°C or more increase in temperature will result in many coral reefs experiencing coral bleaching which describes the process where coral reefs begin to die (Hoegh-Gulberg, 2007). Once observable changes for each degree change have been established, it is possible to estimate the impact on tourism demand. In some cases, the impact may be positive as may be the case in cold areas where the temperature rises will create more pleasant conditions for vacationing (Scott, Jones, & Konopek, 2007). In many cases, however, the impacts are likely to be negative and lead to loss of scenic amenity, deterioration in weather and reduced sustainability. Once an estimate for the possible impact on demand has been calculated, adaption strategies (step 6) can be developed. The adoption of specific strategies in step 6 will be influenced by the impact of international mitigation strategies and national responses on the tourism sector. Depending on the effectiveness of these strategies, it may be possible to reverse the early estimates of change in demand identified in step 5 to create a new level of demand outlined as step 7, future demand.

The fourth stage of the problem definition and response framework is the development of adaption strategies. In the Climate Change Impact model outlined above, the location of adaption strategies is suggested as step 6 and follows an assessment of likely impacts from both a scientific perspective (steps 1–3) and a tourism perspective (steps 4–7). Step 6 is best illustrated in an accompanying model illustrated in Figure 6. Based on a model suggested by Pittock (2005), adaption options can be based on four strategies ranging from maintaining the current activity to disinvestment. These broadly follow the adaptation types suggested by Scott, de Freitas, & Matzarakis (2006): technical adaptation, business management adaptation and behavioural adaptation together with a new adaptation type based on public sector policy response. The strategy possibilities commence with a search for methods of retaining the current resource but in a modified form. Moving from left to right, other strategy options are considered including subsidies, alternative resources that may be developed as a tourism attraction and finally disinvestment. The version of the model illustrated in Figure 6 looks at strategies related to adaption by destinations that currently have significant coral reef attractions and that wish to develop adaption strategies of the possible scenario outlined in Figure 3. The model is also able to be used for larger-scale adaption strategies at regional or national level but with considerable expansion of steps and com-

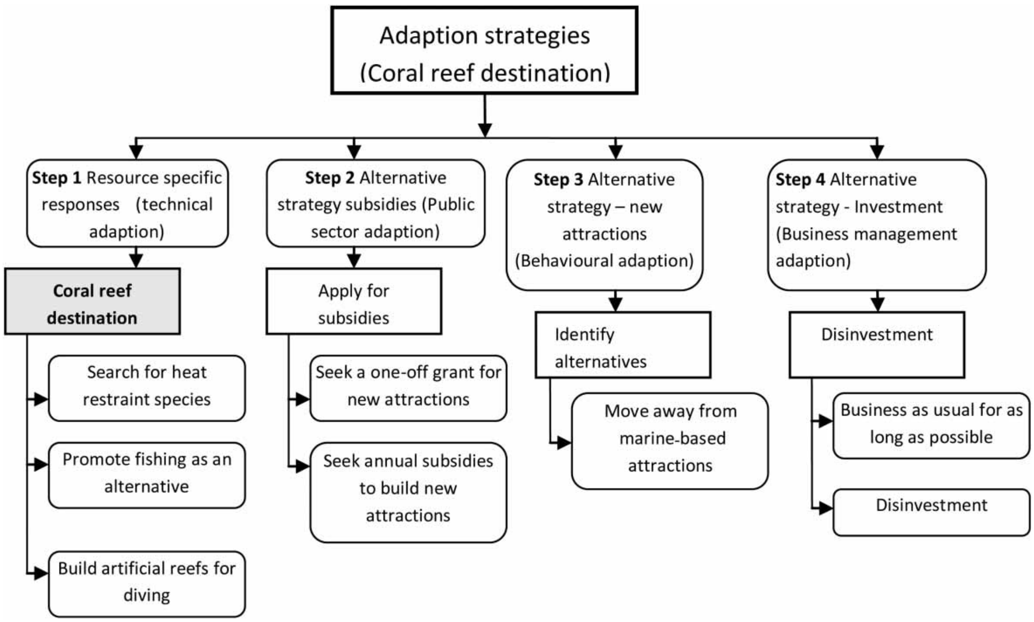

Figure 6 Adaption Strategy Options Model (Small Scale Version). Adapted from Pittock 2005.

plexity of factors included in the analysis. Other regional adaption models may also be used in step 4 of the problem definition and response framework such as Regional Tourism Adaptation Framework (RTAF) model (Jopp, DeLacy, & Mair, 2010).

In the following discussion, the (GBR) in Australia is used as a proxy to demonstrate how the Climate Change Impact model (Figure 5) model can be employed in a specific ecosystem setting. In the case of the GBR the impact on tourism is expected to be significant. The GBR extends for a distance of 2600 kilometres along the Queensland coast and attracts about 1.8 million visits per year. Tourism associated with the reef generates an estimated 66,000 fulltime equivalent jobs (Fenton, Kelly, Vella, & Innes, 2007). Research by Coghlan and Prideaux (2009) has shown that the desire to visit the GBR is the most important motivation for visiting major tourism-dependent cities in the region.

The actual impact of climate change on large systems such as the GBR continues to be researched. For example, some species of corals found in reefs that straddle the equator have a higher upper temperature heat tolerance than corals found below the Tropic of Capricorn and successful southward and northward migration of species from the equator may increase reef resilience, although compressed timeframes may be a major inhibitor. There is, for example, research by Hughes et al. (2003) that indicates that the GBR may not disappear entirely and that parts will be successful in adapting to higher temperatures. There are other dangers for the reef (made up of coral polyp secreted calcium) including the danger posed by increasing acidity of the oceans as they absorb additional carbon (Orr, Fabry, Aumont and Bopp, 2006). While research by Ramis and Prideaux (in press) found that demand for reef experiences can be sustained for some time under conditions of a slow decline in coral cover and species richness, there will be a point reached when the reef will lose its attractiveness. At that point tourism-dependent destinations including those on the GBR will need to either find a substitute attraction or suffer a decline in visitor numbers. If efforts to protect the reef are unsuccessful (step 1 Figure 6), the reef-dependent destination has a series of adaption strategies it may explore. In step 1, for example, the destination could continue with its current support for coral-reef-related activities and using a technical adaptation approach (utilising technology and science to adjust to climate change) support a search for heat resistant species, promote fishing or build artificial reefs based on the aquarium model. As outlined in step 2, the destination also has the option of a public sector policy driven adaption based on seeking subsidies either on a one-off basis or ongoing to cushion the decline in coral reef tourism. There is also an option for looking at alternative tourism resources (step 3) such as events tourism using a behavioural adaptation. Finally, destinations have the option (step 4) of disinvesting in coral reef tourism using a business management adaption approach and either relying on new tourism resources (step 3) or seeking new non-tourism industries.

The framework outlined in Figure 2 commenced with the need for problem conceptualisation. The fourth stage of the framework considers tourism responses. Stage 7 of the Climate Change Impact model indicates that it is possible to estimate future demand based on an assessment of how tourists will respond to future changes. As research by Ramis and Prideaux (in press) on changes in demand for reef experiences and by Prideaux, Coghlan and Falco-Mammone (2007) on changes in demand for a climate-change-modified rainforest indicate, climate-modified ecosystems will continue to be of interest to tourists in the future. It is of course difficult to predict future demand based on current demand patterns.

Conclusion

The aim of this article was to propose a framework and associated models to assist the tourism industry to respond to climate change in the future. A four stage framework with associated models was outlined. While largely theoretical, the ability of the model to be used in specific destinations, in this case in a destination reliant on coral reef tourism, has been in part demonstrated.

It is apparent that as concern over climate change grows and citizens begin to demand that their governments introduce strategies to both mitigate and adapt to the changes that global warming will cause, the global tourism industry will come under increased scrutiny and possibly have to accept controls on the number of visitors. At the time of writing, it was not possible to forecast the level that global temperatures will rise to or the time periods that will be involved. It is apparent, however, that rising global temperatures will have an adverse impact on the environment and on tourism. Adoption of the proposed framework will assist destinations to become informed about the range of consequences, the cost and strategies for adaptation.

In developing responses to climate change, it is important that destinations, planners, protected area managers and tourism enterprises take into account the possibility that consumer tastes and opinions will change over time. Future generations of visitors will assess destinations and experiences within their own (future) framework of experiences and expectations, and what to contemporary tourists might seem poor may be seen in an entirely different light in the future (Prideaux, in press). It is important to consider this observation when developing adaption strategies that forecast future demand profiles.

The next step in the process outlined in this article is to apply the framework in more detail to a specific destination or perhaps protected area. An important element of any research of this nature is access to detailed scientific evaluation of how the ecosystem will respond to changes in climate. To some extent, this has been demonstrated in the brief demonstration of how the framework can be applied to the GBR in Australia.

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