facilitate two-way dialogue based on a demand and supply approach where science is 'supplied' when published through these channels, and scientists provide a service of scientific expertise on which the media can draw to align with their often reactive approach to communication and public engagement. However, press officers often act as gatekeepers — a role that is necessary at times, but which does little to encourage trust and open dialogue. The most desirable situation is one in which scientists are equipped with the skills, the contacts and the desire to initiate communication in the same way as any other citizen.

Direct personal experience of climate change increases engagement on the issue, whereas future projections increase its psychological distance[18]. We propose that this local salience can be built on to create constructive dialogue between the public and climate scientists in their area if they are willing to engage via local media and other local channels of communication. This would enable local publics to use their engagement with local scientists to 'visualize' climate change in a way that resonates and is relevant to them, enabling them to make informed decisions about how they choose to engage on the issue and to critically examine climate policies for their national and local implications.

The benefits of increased local engagement would be plentiful. Locally, it would lead to increased salience of the issue, increased science literacy, reduced misperceptions of the science, enlightenment of what research the public helps to fund, better incorporation of local concerns and understanding in decision-making and increased understanding of the scientific process. For climate scientists and local media this would lead to a better understanding of each other's culture, improved science communication skills, clearer understanding of the impact and value of research locally, increased understanding of the context within which science is understood and applied, and trusted relationships between journalists and scientists, where each feels comfortable in dealing with the other. ❐

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COMMENTARY:

Securing the future of the Great Barrier Reef

Terry P. Hughes, Jon C. Day and Jon Brodie

The decline of the Great Barrier Reef can be reversed by improvements to governance and management: current policies that promote fossil fuels and economic development of the Reef region need to be reformed to prioritize long-term protection from climate change and other stressors.

The Great Barrier Reef (GBR), the world's largest coral reef system, has lost half of its coral cover over the past 40 years[1–3]. The latest five-yearly analysis of the condition of the GBR, released in August 2014, concluded that its condition is poor and deteriorating, and that reductions in all stressors are required to improve its state[3]. The Australian government has correctly identified climate change as the greatest threat to the GBR, although ironically Australia is the world's largest exporter of seaborne fossil fuels, and also has the world's highest per capita emissions of greenhouse gases. So far, global warming has triggered two major bouts of coral bleaching on the GBR, in 1998 and 2002, causing extensive and widespread loss of corals[4], and there is growing concern for the future impacts of inevitable ocean acidification, extreme weather events and rising sea levels[3]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has expressed concern over the decline of the outstanding universal value of the GBR World Heritage Area (WHA), particularly from the rapid industrialization of the Queensland coastline and the development of ports for export of unprecedented amounts of fossil fuels. The World Heritage Committee is threatening to place the GBR on the World Heritage 'In Danger' list in 2015[5]. Here we briefly outline why the GBR is in decline and provide recommendations for securing its future in the face of rapid climate change that are broadly applicable to coral reefs and many natural WHAs worldwide.

Drivers of change and responses

The GBR's diverse array of ecosystems is being affected by the cumulative impacts of multiple human drivers: unsustainable fishing, agricultural runoff, coastal development, rapid climate change and a burgeoning fossil-fuel industry. Broadly, these represent a historical sequence of compounding pressures that are steadily escalating, and set to grow rapidly in the future under current policies (Fig. 1). Importantly, the capacity of the GBR to cope with future climate change will depend on all of these drivers being addressed[3].

The catchment area of the state of Queensland that adjoins the GBR has been transformed by land clearing for agricultural crops and cattle grazing since European settlement in the nineteenth century, resulting in a three- to fourfold increase in the amount of sediment and nutrients delivered by rivers to the GBR lagoon[6]. The population of Queensland is also growing rapidly, particularly along the coast, and is expected to more than double from 4.5 million today to 10 million by 2050[7]. Currently, there are more than 250,000 recreational boat licences in Queensland, one for every 19 residents, and the number of recreational fishers is likely to double within the next 30 years as the population continues to grow (Fig. 1). Already, the biomass of targeted fish is suppressed by approximately 80% in areas of the GBR open to recreational and commercial fishing compared with no-fishing zones, and poaching within no-fishing areas is widespread and increasing[3].

The fossil-fuel industry has grown rapidly in Queensland since the 1970s (Fig. 1), resulting in an unprecedented amount of mining, greenhouse-gas emissions, shipping, port development and dredging[3]. In the past 10 years, more than 25 million cubic metres of dredge spoil from ports has been dumped at sea within the GBR WHA (Fig. 2), an amount that roughly equals the total volume of sediment historically delivered from all 35 rivers draining into the GBR each decade, prior to land clearing[8]. Australia is now the world's biggest shipper of coal and will soon be the world's second-largest supplier of liquefied natural gas. In July 2014, the Commonwealth government approved a new 200-km^2 coal mine development in outback Queensland. If it proceeds, the mine will produce up to 60 million tonnes of thermal coal annually for more than 60 years, and it would account for 4% or more of the world's total emissions by mid-century, depending on the reduction in global emissions. The

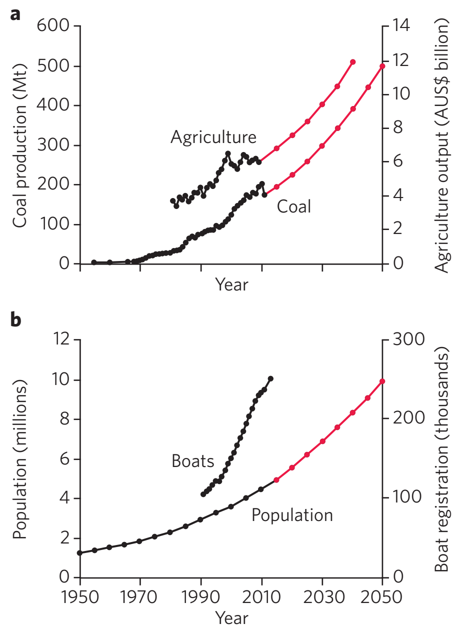

Figure 1 | Long term changes in drivers or stressors affecting the Great Barrier Reef. Observed (black) and projected (red) driver, under current policy settings, are shown from 1950–2050. **a**, Growth in agricultural output and coal production in Queensland. **b**, Growth in registered recreational boats and population in Queensland. The temporary drop in coal production in 2011 was caused by floods. Data from refs 3,7,19,20.

additional coal will be shipped across the GBR, requiring much more dredging, with approximately 60 million cubic meters of dredging in the GBR WHA currently planned over the next decade[8].

Because of the cumulative impacts of these escalating drivers (Fig. 1), 25 out of 42 metrics or values that collectively comprise the outstanding universal value of the GBR WHA have deteriorated since its inscription in 1981[9]. Of the 25 diminished attributes, 10 are currently 'poor' rather than 'good' or 'very good' (Table 1). For example, four of the key elements of outstanding universal value are geomorphological features, ecological processes, and the number of dugongs and turtles. Recent research indicates that reef calcification, growth of massive corals and survival of corals in the GBR are already being compromised by climate change[3,10,11]. Similarly, there is clear evidence for widespread regional-scale declines in ecological processes such as recruitment, herbivory and predation[3], and most species of iconic megafauna are severely depleted. For example, the dugong population has declined by more than 95% in the central and southern two-thirds of the GBR (Fig. 2a,b) due to the combined impact of hunting, drowning in nets, collisions with vessels, physiological stress and reduction of seagrass habitats (caused by sediment influx from soil erosion during floods, coastal development and dredging)[3]. Grazing of seagrass beds by dugongs, which plays a critical ecological role in maintaining plant diversity (Fig. 2a,c), has all but disappeared as an ecological process in most areas of the WHA[12]. Similarly, depleted populations of turtles face a range of new threats from climate change, including shifting sex ratios of hatchlings due to global warming, and inundation of nests from sea-level rise[13].

The intensity and diversity of drivers or stressors affecting the GBR continue to grow strongly (Fig. 1). Even at present levels, pollution, overfishing and climate change exceed the capacity of the Reef to absorb their impacts, and the ecological condition and outstanding universal value of the GBR is increasingly compromised. Clearly, the long-term solution will require a reduction in the strength and impact of these drivers.

Successes and failures of governance

The establishment of the GBR Marine Park in 1975, then by far the largest in the world, was an outstanding and novel achievement resulting from widespread public concern that the Reef was being threatened by plans for oil drilling and limestone mining. The enabling legislation, the Great Barrier Reef Marine Park Act 1975, explicitly prioritizes protection and conservation as the overriding objective[14], which, until recently, has been the fundamental tenet of its governance. The Marine Park Authority was placed in charge of virtually all activities within its bounds, except for shipping and fisheries management. In 2004, the marine park was rezoned to increase no-fishing zones from 5% to 33% of the total area. Although the rezoning provides some fisheries benefits[15], it affords little or no protection from the impacts of most other escalating drivers, including climate change.

Today, the policy emphasis is less on protection and conservation, and more about generating sustainable wealth from the region[16]. In response to UNESCO's concerns, the Australian and Queensland governments drafted the *Reef 2050 Long-term Sustainability Plan*[17] and released it for public comments. The plan emphasizes 'multiple use' of the region and its catchment, and although it contains many positive elements, its underlying economic objective is the creation of the world's largest export industry for coal and coal seam gas[14]. The Australian Academy of Science concluded that the draft plan was inadequate to achieve the goal of restoring or even maintaining the diminished outstanding universal value of the GBR[18]. Unfortunately, the final Plan, released in March 2015, remains short-sighted, given its aspiration to provide an overarching framework for the next 35 years. Critically, the revised plan lacks any action on climate change, identified by scientists and the government[3] as the key threat to the GBR owing to the impact of global warming and ocean acidification.

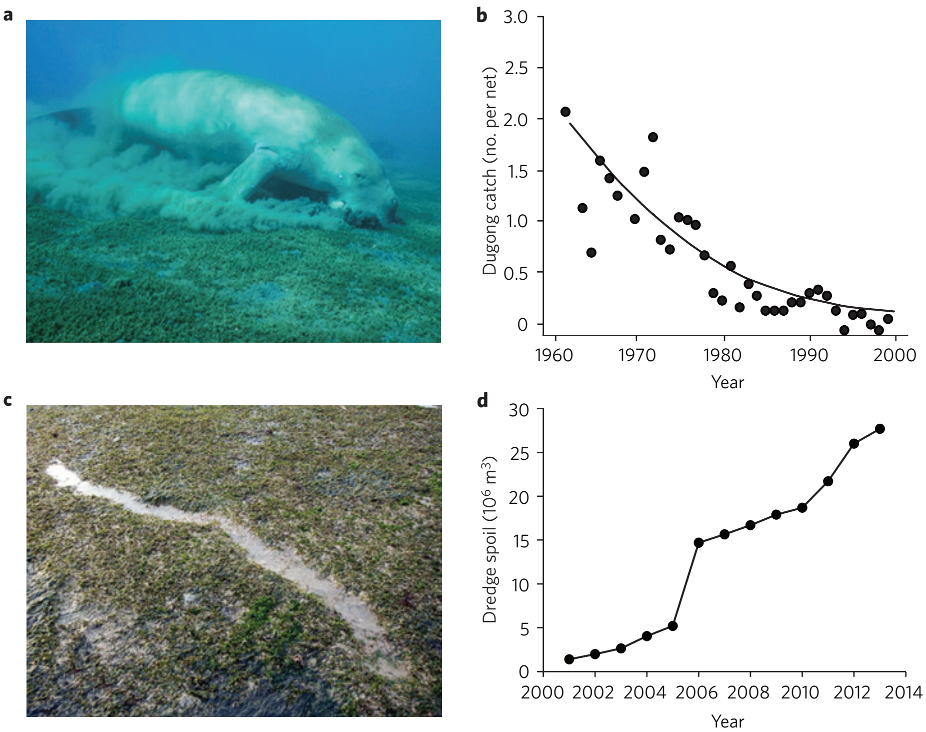

Figure 2 | The GBR contains a globally significant population of dugong, which is a key element of its outstanding universal value. **a**, Dugong feeding on sea grass. **b**, Number of dugong caught in shark control nets (catch per net) on the central and southern GBR between 1963 and 1999, suggesting a 9% annual decline in numbers. **c**, Dugong feeding trail in seagrass. **d**, Cumulative amounts of dredge material disposed in the GBR WHA onto seagrass and coastal habitats (2001–2013). Data from ref. 3.

A six-point plan for restoring the GBR

Here we propose an action plan to restore the outstanding universal value of the GBR to its condition at the time of inscription as a WHA in 1981. First, the former emphasis on conservation and protection must be reinstated, recognizing that it will not be possible to develop and operate the largest coal ports in the world along the edge of the GBR WHA over the next 60 years without causing permanent damage to the region. Second, Australia should play a more active role in transitioning away from fossil fuels to renewable energy, and rejoin the global community in tackling dangerous climate change. The era of thermal coal is coming to an end and efforts to prolong it by opening new coal mines are too risky for the GBR and for climate-sensitive ecosystems elsewhere. Third, we encourage a permanent legislative ban of sea dumping of dredge spoil, both capital and maintenance, within the WHA. Fourth, the environmental impact assessment processes for new developments should be reformulated to ensure that all options to avoid impacts are comprehensively and transparently evaluated and independently assessed, and that offsets are used only as a last resort. Fifth, the GBR Marine Park Authority needs to be reinstated as the lead agency responsible for all aspects of the GBR, including fishing and port activities. The GBR Marine Park should be expanded to include ports, as a new type of zone, thereby providing more effective and integrated management over areas currently adjoining the marine park and fulfilling the mandate of the Great Barrier Reef Marine Park Act 1975 for sustainable management of the Great Barrier Reef Region. Finally, we suggest there is an urgent need to develop and adequately fund a 50-year plan for use of the catchment, designed to reduce greenhouse-gas emissions and agricultural runoff.

The future of the GBR depends on the Australian and Queensland governments taking their responsibilities more seriously than recent decisions, such as the relaxation of tree-clearing laws in Queensland, the weakening of renewable energy targets, subsidizing the extraction of fossil fuels and scrapping a price on carbon emissions. The Australian public and the global community need to make it clear that they want policy actions to ensure the outstanding universal value of the GBR is restored for future generations. ❒

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Table 1 | The current condition and ongoing trend of components of the outstanding universal value of the GBR WHA and its integrity, benchmarked against their condition when the GBR was inscribed by UNESCO in 1981.

	Condition			Trend
Components of outstanding universal value (number of metrics)	**Very good (%)**	**Good (%)**	**Poor (%)**	**Values deteriorating (%)**
Natural beauty and superlative phenomena (13)	38	31v	31	46
Earth's evolutionary history (6)	50	50	0	50
Ecological and biological processes (8)	12.5	75	12.5	75
Habitats for conserving biodiversity (11)	9	55	36	73
Integrity (3)	67	0	33	66

Data from ref. 9.

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Correction

In the Commentary 'Influence of internal variability on Arctic sea-ice trends' (*Nature Clim. Change* **5,** 86–89; 2015), in Fig. 3c, the *x*-axis label for pause length of 20 years was incorrectly repeated. Corrected after print 16 April 2015.