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Technical Report

Drivers of change in the Torres Strait region: status and trends

Butler, J.R.A., Bohensky, E., Skewes, T., Maru, Y., Busilacchi, S., Rochester, W., Katzfey, J. and Wise, R.M.

Australian Government
Department of the Environment

Reef & Rainforest RESEARCH CENTRE

Drivers of change in the Torres Strait region: status and trends

Project 11.1 Building Resilient Communities for Torres Strait Futures

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http://www.nerptropical.edu.au/research

Contents

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John Rainbird	TSRA Land and Sea Management Unit
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Executive summary

The Torres Strait is a region of rich natural and cultural values, with tight linkages between its environmental assets and the livelihoods of local communities. The Torres Strait Treaty between Australia and Papua New Guinea (PNG) explicitly aims to protect these communities' livelihoods, and improve them through sustainable economic development. As Australia's northern border with Asia, however, the region is undergoing unprecendented change. Because of a rapid and increasing rate of regional development and global uncertainty, it is important to make predictions of potential changes and plan proactively rather than respond reactively. This requires the design of 'no regrets' strategies which bring benefits under any future conditions of change, and which are flexible and therefore less likely to be 'mal-adaptive'.

Through participatory scenario planning with Torres Strait communities and regional stakeholders, informed by integrated ecosystem services, climate and resilience modeling, this project explored potential future scenarios for the region, identified 'no regrets' strategies to protect livelihoods and achieve sustainable economic development. In July 2010-December 2014 the project aimed to:

1. Provide information to communities and regional stakeholders to advise strategic decision-making, including the Torres Strait Treaty
2. Identify 'no regrets' adaptation strategies
3. Increase the capacity for communities and stakeholders to avoid mal-adaptive strategies
4. Support the development of TSRA community-based adaptation planning

This report summarises the secondary data collated on drivers of change for the Torres Strait region, defined as '*any natural or human-induced factor that directly or indirectly causes a change in the system of interest, plus institutional and governance issues that mediate livelihood outcomes*'. This information was summarized and presented to workshop participants as scientific and expert knowledge, and subsequently integrated with workshop participants' own perceptions of important drivers of change. The conceptual role of drivers of change in the Torres Strait social-ecological system, and the project's participatory process, is shown in the figure below.

The identification of drivers began with a workshop held by the research team and the Steering Committee in May 2012. Each participant was asked to identify the three most important drivers for the Torres Strait. The three highest ranked drivers were, in descending order: climate change, economic development and population change. The project team then collated secondary information and projections for these domains. Where information was missing, we undertook our own analyses to fill gaps based on existing data, including: downscaled climate projections, Human Development Index for the Torres Strait, population projections for Western Province PNG, and island population densities.

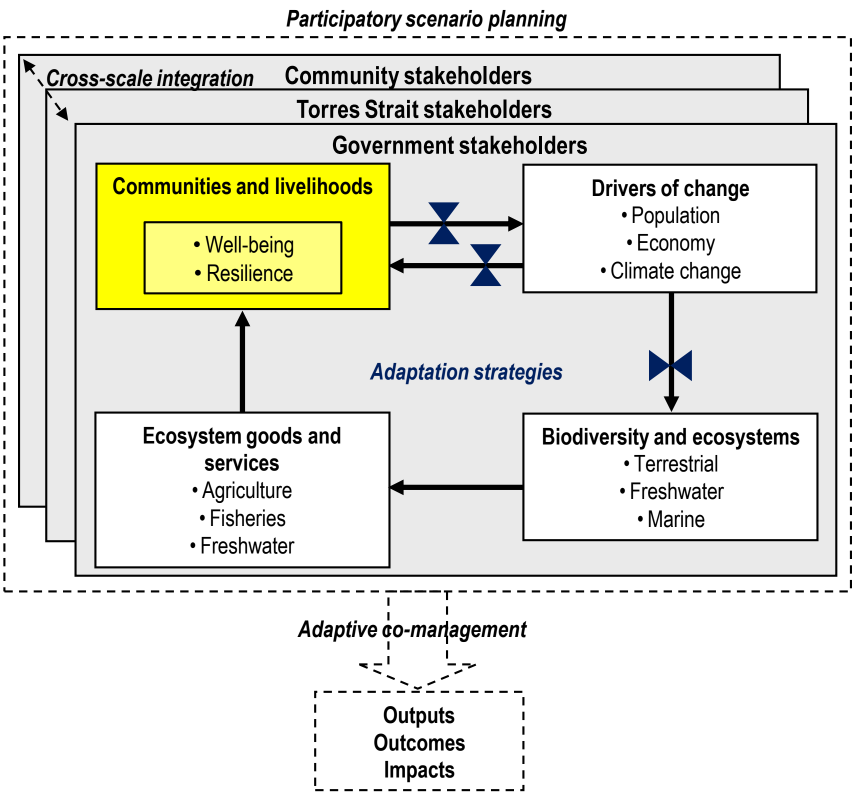
Data presented in this report are as follows:

- Climate change:
  - Downscaled climate projections under the Business as Usual SRES A2 global emissions scenario for the Torres Strait and Fly River catchment
  - Sea level rise projections

- Economic and social development:
  - Torres Strait employment, education and housing trends
  - PNG Treaty Village housing, electrification and water supply trends
  - Human Development Index estimates for the Torres Strait and Western Province, PNG
  - Current and planned resource exploitation in Western Province

- Shipping traffic trends and projections

- Population change:
  - Torres Strait regional trends and projections
  - Western Province trends and projections
  - PNG Treaty Village trends and projections
  - Island population densities



Conceptual diagram of the role of drivers of change, and their influence on the Torres Strait social-ecological system. The system dynamics and adaptation strategies were analysed at different stakeholder levels. The research process is indicated by dashed lines

These data were synthesised in terms of projected trends for the Torres Strait island communities, and the neighbouring PNG Treaty Villages and Western Province (see table below). Exogenous drivers affect the whole region, namely climate change and shipping. Endogenous drivers show some differences between the Australian Torres Strait Islands and the Western Province region and PNG Treaty Villages. Employment, education and health are improving in the Torres Strait, and this is reflected in a relatively high Human Development Index (HDI) of 0.736, which is also likely to be increasing. In Western Province and the PNG Treaty Villages these indicators are declining, and the very low HDI of 0.260 is unlikely to be improving, as indicated by the chronic occurrence of drug-resistant tuberculosis and cholera. Natural resource extraction is also escalating in Western Province, and related infrastructure. Population growth is occurring on both sides of the border, but is approximately double in Western Province and the PNG Treaty Villages (1.5% per annum) compared to the Torres Strait Islands (0.91%). Island population densities are increasing in most cases, but this is of greater concern for the PNG islands of Daru and Parama where infrastructure and services are poor and declining, and carrying capacities may already have been exceeded.

Synthesis of trends in drivers of change for the Torres Strait region (⇧ increasing trend; ⇧⇧ rapidly increasing trend; ⇩ decreasing trend; ⇔ no change; NA not applicable).

Driver of change	Indicator	Regional trend	Torres Strait Islands trend	Western Province PNG trend
Climate change	Annual surface temperature	⇧		
	Annual rainfall	⇔		
	Sea level rise	⇧		
Economic and social development	Employment, education, health		⇧	⇩
	Human Development Index		⇧	⇔
	Oil, gas and mining		NA	⇧⇧
	Logging and infrastructure		NA	⇧⇧
	Shipping	⇧		
Population change	Population		⇧	⇧⇧
	Island population densities		⇧	⇧⇧

1. Introduction

The Torres Strait (Fig. 1) is a region of rich natural and cultural values, with tight linkages between its environmental assets, ecosystem services and the livelihoods of communities. The Torres Strait Treaty between Australia and Papua New Guinea (PNG) explicitly aims to protect these communities' livelihoods, and improve them through sustainable economic development. As Australia's northern border with Asia, however, the region is undergoing unprecendented change. Because of a rapid and increasing rate of regional development and global uncertainty, it is important to make predictions of potential changes and plan proactively rather than respond reactively. This requires the design of 'no regrets' strategies which bring benefits under any future conditions of change, and which are flexible and therefore less likely to be 'mal-adaptive'.

Through participatory scenario planning and resilience analysis with Torres Strait communities and stakeholders, informed by integrated ecosystem service and climate modeling, this project explored potential future scenarios for the region, identified 'no regrets' strategies to protect livelihoods and achieve sustainable economic development. This responded in part to the 2010 Senate Foreign Affairs, Defence and Trade Committee Inquiry, which recommended an analysis of the vulnerability of the Torres Strait to climate change and other future pressures (Commonwealth of Australia 2010). The project outputs have supported the delivery of ongoing Torres Strait Regional Authority (TSRA), Department of Foreign Affairs and Trade (DFAT) and Queensland Government initiatives promoting climate adaptation, alternative livelihoods, food security and sustainable economic development in the region.

In July 2010-December 2014 the project has:

1. Provided information to communities and regional stakeholders to advise strategic decision-making, including the Torres Strait Treaty
2. Identified 'no regrets' adaptation strategies
3. Increased the capacity for communities and stakeholders to avoid mal-adaptive strategies
4. Supported the development of TSRA community-based adaptation planning

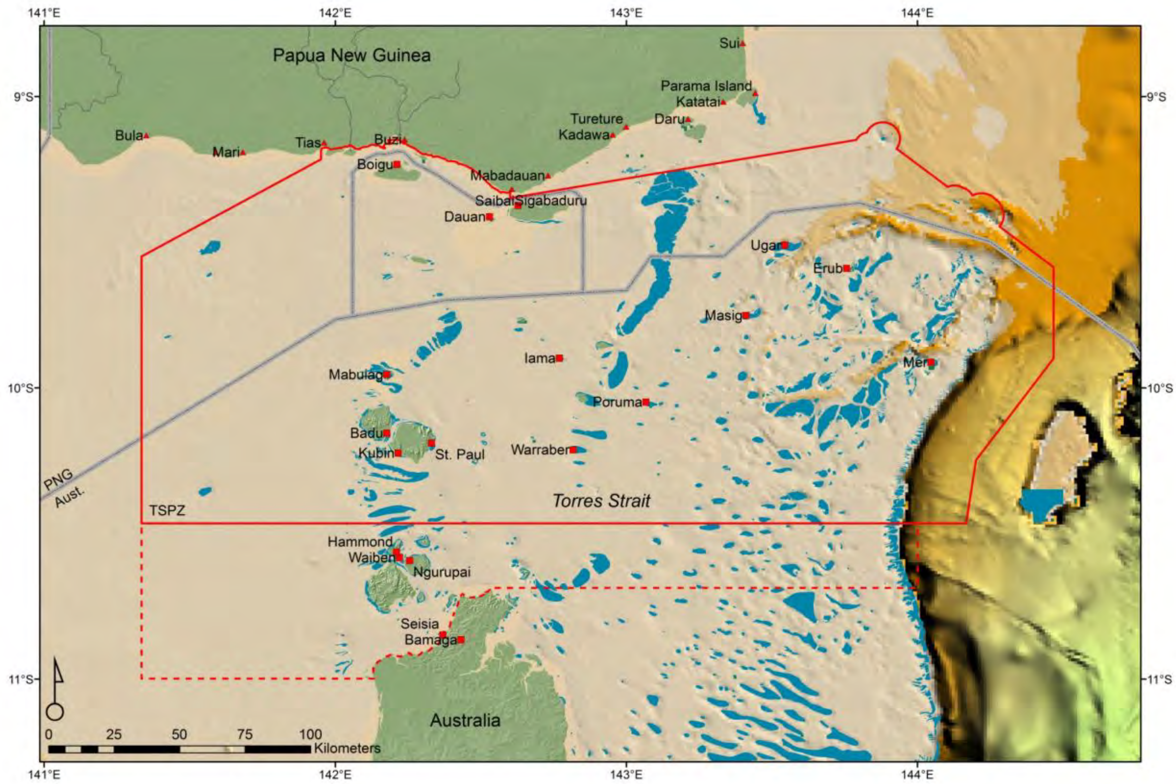


Figure 1. The Torres Strait region, showing reefs, international boundaries, the Torres Strait Protected Zone and Australian and PNG communities.

2. Methodology

2.1 Project design

There are many stakeholders from different sectors involved in the planning and improvement of livelihoods, including communities themselves. They may have similar aims, but different roles and perceptions of how to achieve sustainable development. To be more effective, these stakeholders' efforts need to be coordinated, and their knowledge combined to tackle development challenges. By exploring and visualising potential future development trajectories, scenario planning can challenge values and assumptions, bridge stakeholders' world views, generate innovation and create an anticipatory 'adaptation window' (Gidley et al. 2009; Ravera et al. 2011). The method is also effective for integrating scientific information with traditional or local knowledge (Enfors et al. 2008), which is both an opportunity and challenge in the Torres Strait (Butler et al. 2012a).

This project applied an integrated top-down and bottom-up participatory planning approach with government and community stakeholders to enable them to express their different perceptions of livelihoods, the system dynamics determining their characteristics and possible development trajectories (Butler et al. in press). Workshops held at the regional and community level identified adaptation strategies which stakeholders believed would reduce any perceived negative impacts of drivers of change on human well-being, reducing livelihoods' vulnerability and building communities' resilience to future uncertainty (Fig. 2). Subsequent workshops integrated the adaptation strategies identified by all stakeholders, allowing comparison between their perspectives, and an assessment of whether the strategies have been introduced by policies and programs. This social learning process encouraged 'adaptive co-management', whereby new knowledge, partnerships and adaptive capacity were generated amongst all stakeholders to improve livelihoods.

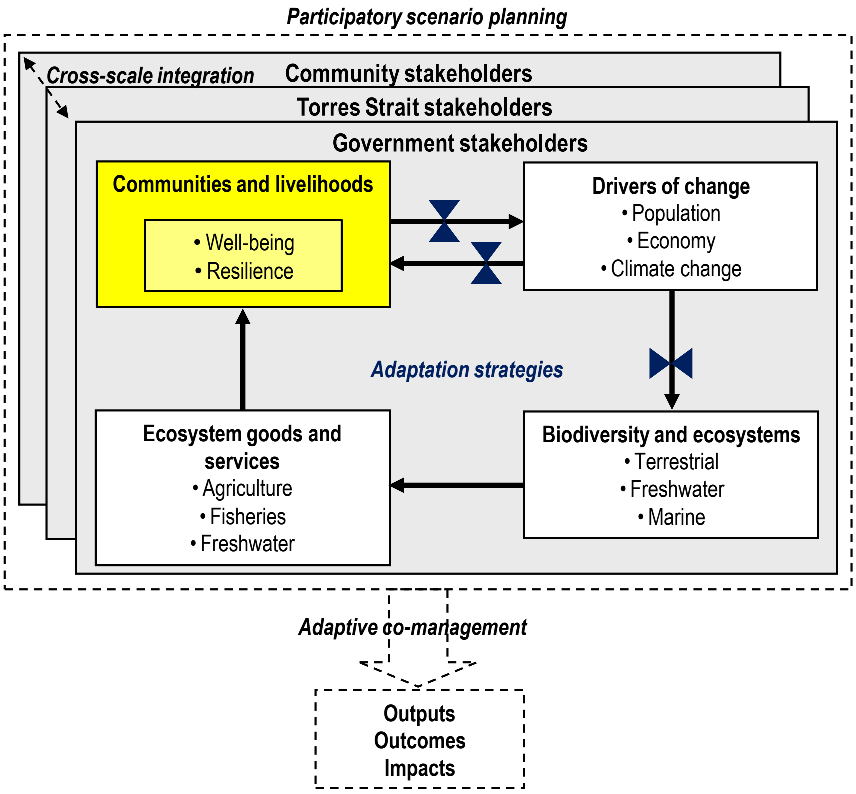


Figure 2. Conceptual diagram of the role of drivers of change, and their influence on the Torres Strait social-ecological system. The system dynamics and adaptation strategies were analysed at different stakeholder levels. The research process is indicated by dashed lines

In July 2011-December 2014 the project carried out a series of activities, linked by outputs (Fig. 3). This report describes the data that was collated in 2012 on drivers of change for the Torres Strait region, and their status and trends. This information was subsequently applied in the scenario planning workshops, where it was presented as scientific and expert-derived knowledge. For examples of workshops, and the application and integration of knowledge about drivers of change, see Butler et al. (2012b, 2013) and Bohensky et al. (2014a, 2014b).

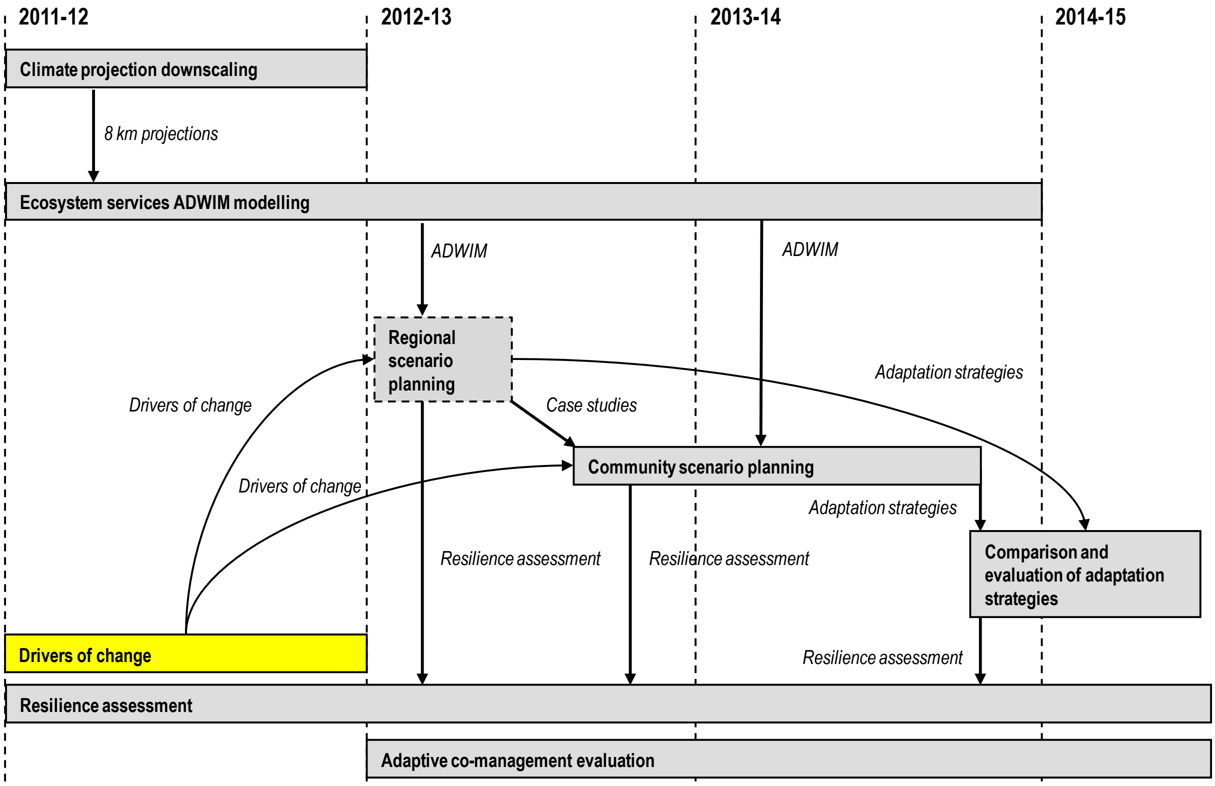


Figure 3. Timelines for project activities and outputs (in italics) linking activities in July 2011-December 2014. The activity reported here (drivers of change) is highlighted.

2.2 Drivers of change

Drivers of change are defined '*any natural or human-induced factor that directly or indirectly causes a change in the system of interest, plus institutional and governance issues that mediate livelihood outcomes*' (DfID 2004; Millennium Ecosystem Assessment 2005). Understanding drivers of change helps us to identify causes and mechanisms of change in variables of interest (Biggs et al. 2011; Fereira et al. 2011), anticipate and sometimes even predict future outcomes, and understand the context or 'backdrop' of past change. Drivers operate at multiple scales, from global to regional to local. They can also be internal ('endogenous') and therefore within the control of local managers, or external ('exogenous') to the system, and largely outwith their control (Millennium Ecosystem Assessment 2005).

The identification of drivers began with a workshop held by the research team and the Steering Committee in May 2012. Each participant was asked to identify the three most important drivers for the Torres Strait. The three highest ranked drivers were, in descending order: climate change, economic development, and population change (Fig. 4). The project team then collated secondary information and projections for these domains. Where key information was lacking, we calculated status and trends based on other available information, including: downscaled climate projections, Human Development Index for the Torres Strait, population projections for Western Province PNG, and island population densities. Data presented in this report are as follows:

- Climate change:
  - Downscaled climate projections under the Business as Usual SRES A2 global emissions scenario for the Torres Strait and Fly River catchment
  - Sea level rise projections

- Economic and social development:
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- Population change:
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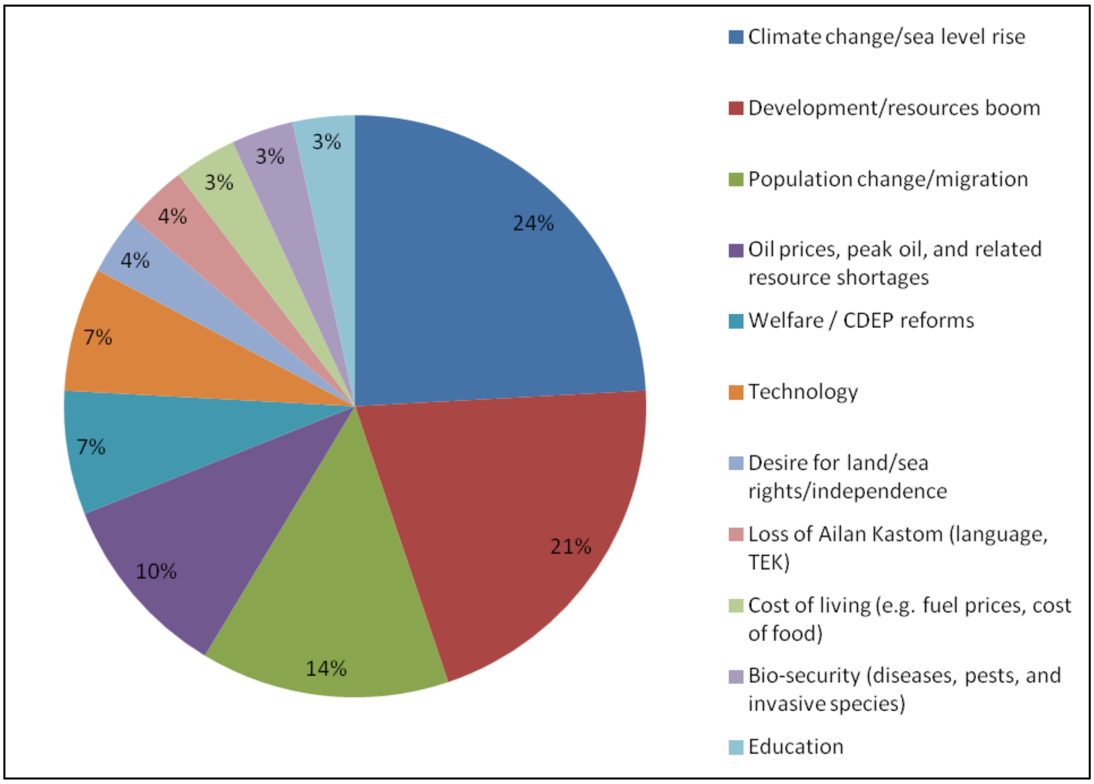

Figure 4. The frequency of the primary drivers of change identified by Steering Committee and project team members (n=12)

3. Climate change

3.1 Downscaled climate projection method

This section describes the process used to produce the downscaled results presented here. The dynamical downscaling conducted in the Pacific Climate Change Science Program (PCCSP) consisted of a primary set of simulations from which climate projections were derived, as well as a series of additional simulations designed to assess the uncertainty associated with those projections. All primary simulations were completed using CSIRO's global stretched-grid, Conformal Cubic Atmospheric Model (CCAM; McGregor and Dix 2008) run at 60 km grid spacing over the entire globe, while further downscaling to 8 km grid spacing was conducted for selected countries. The CCAM model was chosen for the downscaling because it is a global atmospheric model, so it was possible to bias-adjust the sea-surface temperature in order to improve upon large-scale circulation patterns. In addition, the use of a stretched grid eliminates the problems caused by lateral boundary conditions in limited-area models. The model has been well tested in various model inter-comparisons and in downscaling projects over the Australasian region (Corney et al. 2010).

CCAM 60 km global simulations were performed for six host global climate models (CSIRO-Mk3.5, ECHAM/MPI-OM, GFDL-CM2.0, GFDL-CM2.1, MIROC3.2 (medres) and UKMO-HadCM3) that were deemed to have acceptable skill in simulating the climate of the PCCSP region. For these simulations:

- The equivalent CO2, direct aerosol effect and ozone distribution for the SRES A2 (high) Business as Usual global emissions scenario were used (except in simulating the current climate, which used 20c3m equivalents)
- Monthly, bias-adjusted sea-surface temperature and sea-ice fraction output from the host global climate models was used. Bias adjustment refers to the removal of model errors in the present day, mean state climate. In this case, the sea-surface temperature bias adjustment was calculated by computing the monthly average biases of the global models for 1971-2000 relative to the observed climatology, based on the method of Reynolds (1988). These monthly biases were then subtracted from the global climate model monthly sea-surface temperature output throughout the simulation. This approach preserves the inter- and intra-annual variability and the climate change signal of the host global climate models.
- No atmospheric input from the global climate models was used, as the bias-adjusted sea-surface temperature is considered sufficient information to drive CCAM. In addition, the bias-adjustment makes the global climate model atmospheric fields incompatible with the sea-surface temperature distributions. It is assumed that the fixed, monthly adjustment is appropriate over the entire course of the simulation, which may be a disadvantage of the approach.
- The period 1961-2099 was simulated for the A2 (high) emissions scenario only.

Three global models (GFDL-CM2.1, UKMO-HadCM3 and ECHAM5 60 km CCAM global simulations) were selected for further downscaling to 8 km resolution. Of the six host models, these show a low, middle and high amount of global warming into the future, respectively. Due to the very high demand for computer resources when downscaling at 8 km resolution, the temporal and spatial extent of the simulations was limited. Only the 1980-1999, 2046-2065 and 2080-2099 time periods were simulated for seven 1000 km x 1000 km regions, including PNG, East Timor, Fiji, Solomon Islands, Vanuatu, Samoa and the Federated States of Micronesia. The results from the PNG simulation were used in this study because they also cover the Torres Strait region.

The topography of the Torres Strait and central PNG is shown in Fig. 5. Annual means of key variables are presented for 2055 and 2090 and summarized in Table 1. Monthly climatology for the Torres Strait and the Fly River catchment is also presented.

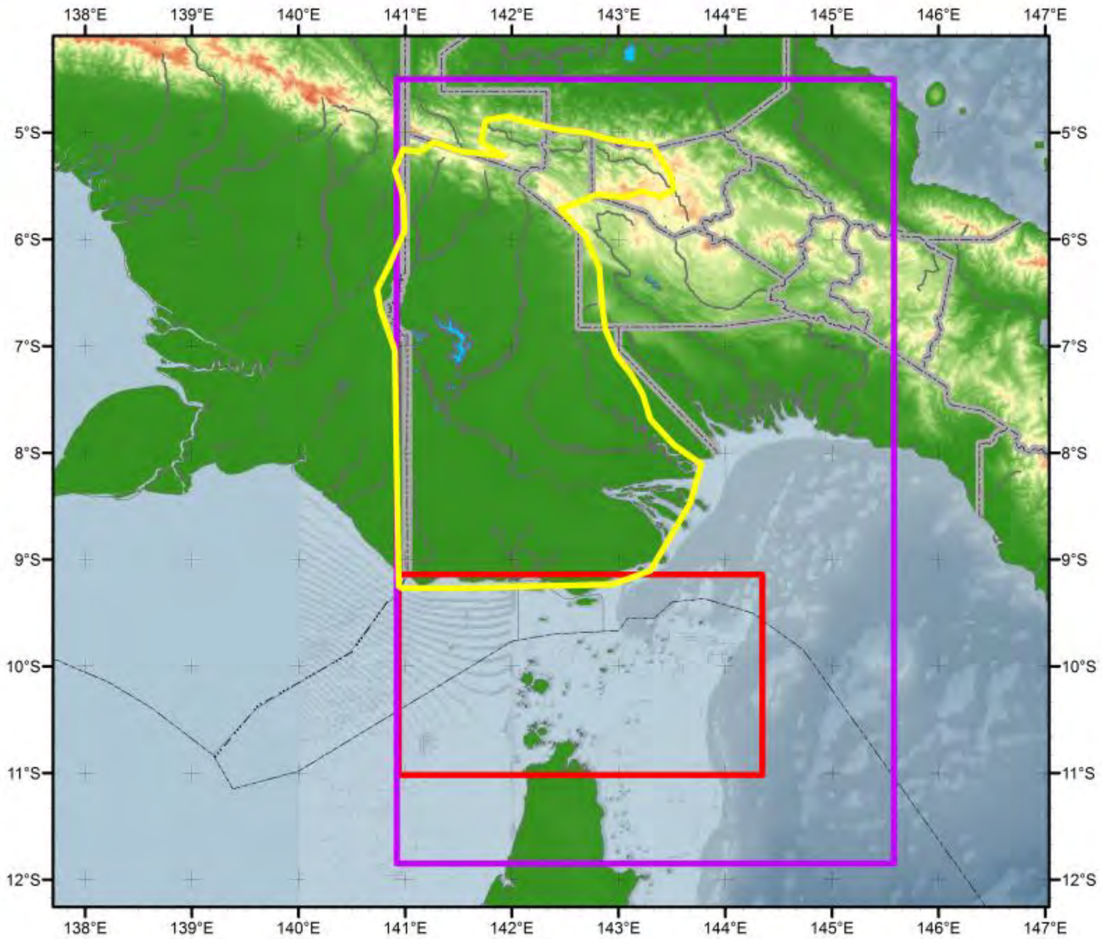

Figure 5. Topography of the Torres Strait region (red box) and Fly River catchment (yellow box)

Table 1. Summary of changes in climate parameters for the Torres Strait region from 1990 levels, averaged from downscaled CCAM data

A2 scenario	2055	2090
Temperature (°C)	+1.3	+2.5
Apparent temperature (°C)	+2.2	+4.8
Rainfall (%)	+3.4	-2.9
Relative humidity (% humidity)	+0.5	+0.6
Wind speed (%)	-2.2	-3.5

3.2 Annual surface temperature

The plots of annual mean surface temperature over central PNG and the Torres Strait region (Fig. 6) show the warmer values over the ocean and the coldest values over the higher mountains of PNG. The mean annual surface temperature increases nearly uniformly by 1-1.5^{0}C by 2055, with slightly lesser increases over the oceans relative to the land. By 2090, the increases over land are around 2.5^{0}C or greater, while over the ocean the increases are less than 2.5^{0}C. Slightly greater warming (nearly 4^{0}C) is evident over the Fly River catchment by 2090.

Comparison of these numbers with those produced by Suppiah et al. (2010; 2011) (hereafter called S10) based upon 24 global climate model (GCM) outputs shows broad similarity. However, by 2055, our warming is slightly higher than their median (50th percentile was 1.48^{0}C) and the range is much reduced due to downscaling only 3 GCMs versus the 24 GCMs used in S10. Similarly, for 2090 the S10 median was 2.07^{0}C versus the current study median of 2.5^{0}C.

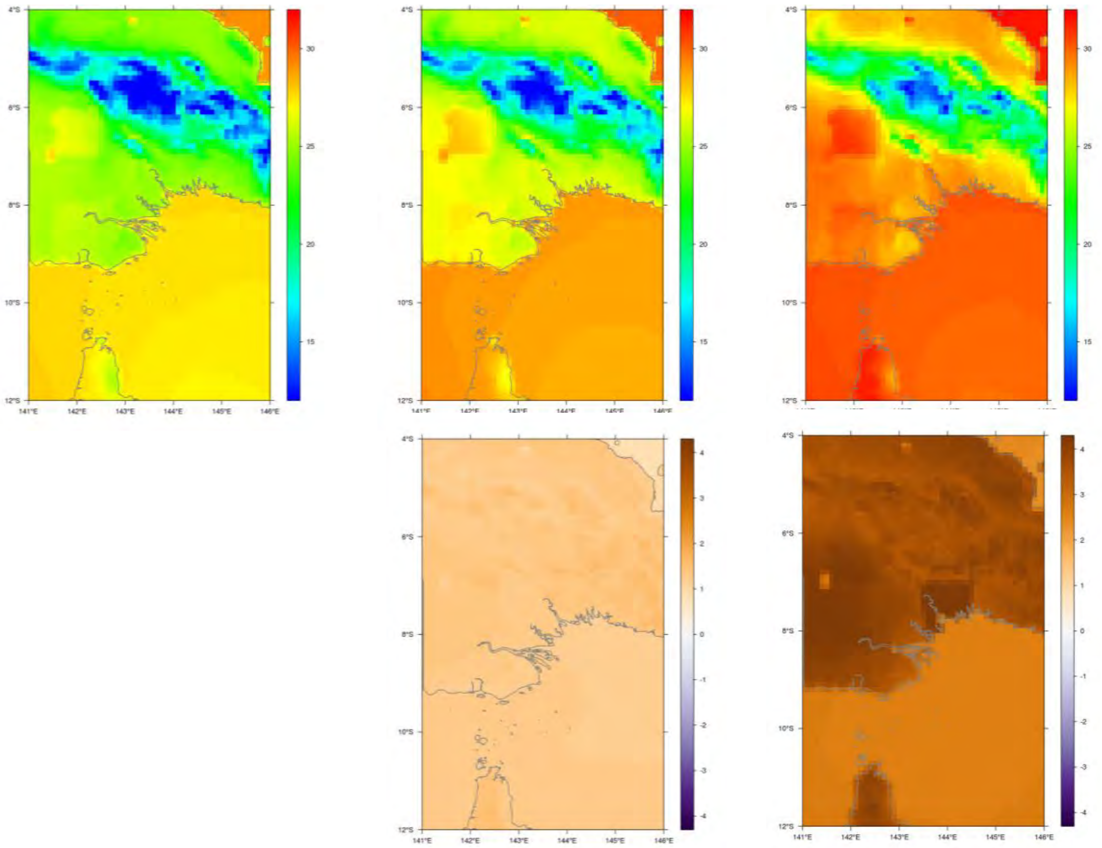

Figure 6. Annual mean surface temperature (^{0}C, top row) and changes relative to 1990 (bottom row). Left column is for 1990, middle column is for 2055 and right column is for 2090. All plots are for the 3-model mean from the CCAM 8 km simulations.

3.3 Annual rainfall

The distribution of the annual mean rainfall (Fig. 7) shows a complex pattern, with larger rainfall amounts over the slopes of the PNG mountains and along the coastal regions where trade winds flow onto land at certain times of the year, triggering rainfall. The veracity of this pattern of rainfall has been checked against the Tropical Rainfall Measuring Mission (not shown). The simulated rainfall pattern shows slightly more rainfall over the Torres Strait (around 6 mm d^{-1}) than to the east or west of the islands.

The change in annual rainfall also shows a complex pattern, with decreases in the southern portion of the domain and with large (+/- 15%) changes over the mountains of PNG. The changes over the Torres Strait by 2055 are generally small (less than 5%), with slight decreases to the south and slight increases in the northern part. By 2090, a large decrease in annual rainfall is evident (around -10%) over the region, with greater decreases over western regions (-15%) and further to the east (-15%). Increases of annual rainfall up to around 20% are evident along the northern shores of PNG as well as along some of the mountain slopes. For the Fly River catchment the annual rainfall changes are generally small.

The future rainfall changes over the Torres Strait presented here (little change by 2055 and decreases of -10% by 2090) are different than in S10, where they indicated increases of 2% by 2050 and 3.21% by 2070. It needs to be investigated whether this is a result of the downscaling or due to the small group of models selected.

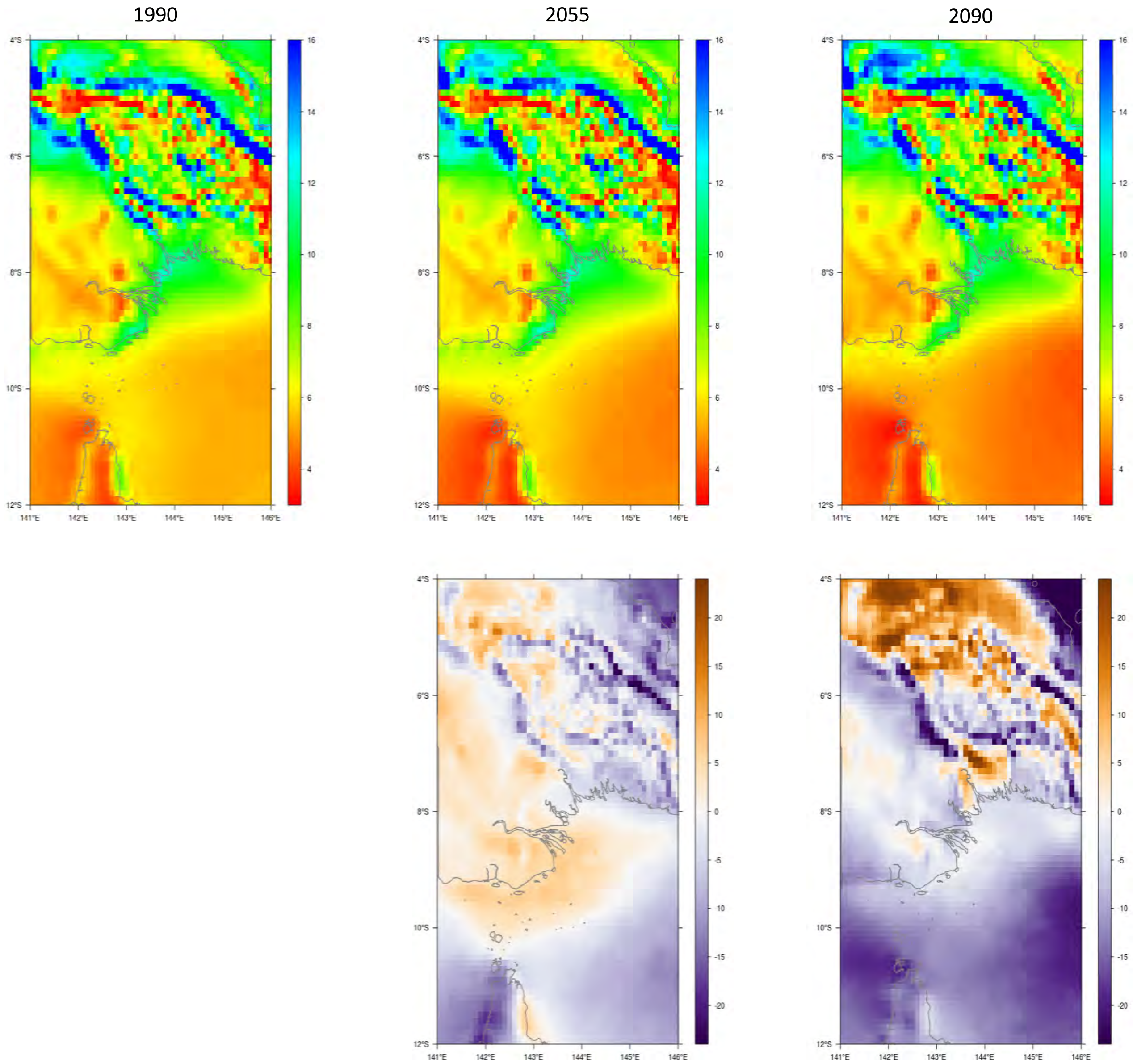

Figure 7. Annual mean rainfall rate (mm day^{-1}, top row) and changes relative to 1990 (bottom row). Left column is for 1990, middle column is for 2055 and right column is for 2090. All plots are for the 3-model mean from the CCAM 8 km simulations.

3.4 Monthly surface temperature

The seasonal cycle of surface air temperature (or screen temperature, which is the air temperature at 2 m above surface) for the Torres Strait is shown in Fig. 8. The seasonal cycle shows coolest temperatures in July and August and warmest temperatures in December through March. By 2055, there is a warming of 1.3^{0}C throughout the year, increasing to a warming of 2.6^{0}C by 2090. This uniform seasonal warming trend is similar to S10, though the values are about 0.5^{0}C greater.

The seasonal cycle of surface air temperature (or screen temperature) for the Fly River catchment is shown in Fig. 9. The seasonal cycle shows coolest temperatures (23.5°C) in June through August and warmest temperatures in November through April (24.8°C). By 2055, there is a warming of 1.3°C throughout the year, increasing to a warming of around 3°C by 2090.

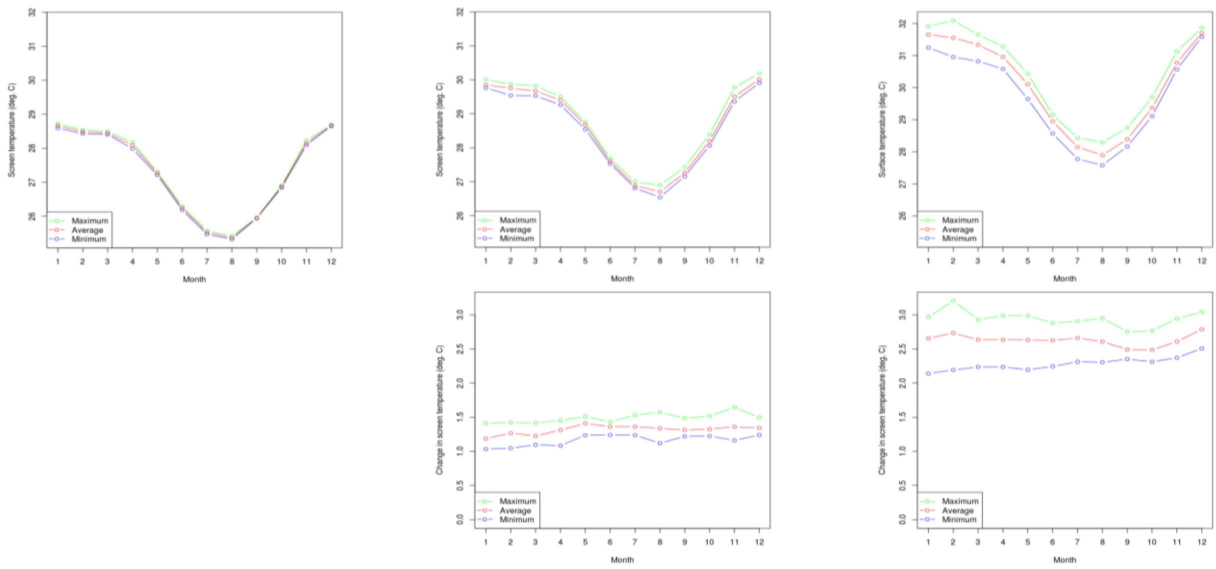

Figure 8. Torres Strait region climatology from CCAM 8 km multi-model mean for screen temperature (^{0}C) for 1990 (left), 2055 (centre) and 2090 (right). Bottom set of images are the changes from 1990.

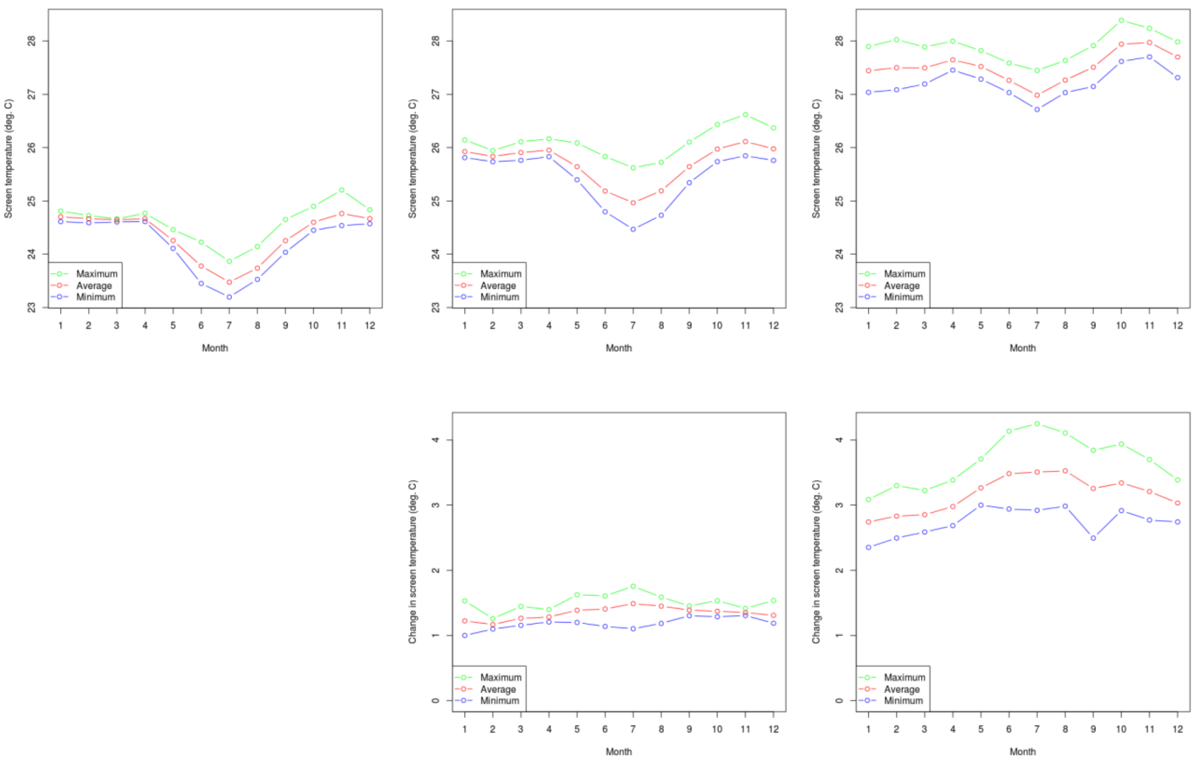

Figure 9. Fly River catchment climatology from CCAM 8 km multi-model mean for screen temperature (°C) for 1990 (left), 2055 (centre) and 2090 (right). Bottom set of images are the changes from1990.

3.5 Monthly rainfall

Monthly rainfall for the Torres Strait shows an annual cycle with peak values around 8-10 mm d^{-1} in January through April and minimum values of around 2 mm d^{-1} in August (Fig. 10). Under climate change, the rainfall for this region shows slight increases of around 5%, with greater increases in October of up to 20% by 2055. By 2090, the rainfall shows slight decreases in the first half of the year (around 5%), but with significant increases from June to October of up to 40%. The changes in rainfall indicated here are larger than those noted in S10. By 2050, S10 indicated a 0.5 to 2.7% increase, which though broadly similar, does not capture the larger increases indicated here, especially in October (nearly 20% increase). By 2090, the rainfall in S10 was projected to increase by around 3-4% except for JJA, where changes of less than 1 % were indicated. A much larger increase in rainfall is projected here.

For the Fly River catchment rainfall (Fig. 11) shows an annual cycle with peak values around 9-10 mm d^{-1} in January through April and minimum values of around 5 mm d^{-1} in June to August. With climate change, the rainfall for this region shows slight increases of around 5% by 2055 for most of the year, with lesser increases (near 0%) in July to September. By 2090, the rainfall increases by more than 5% in January and February and decreases by around 5% in May and from August to October

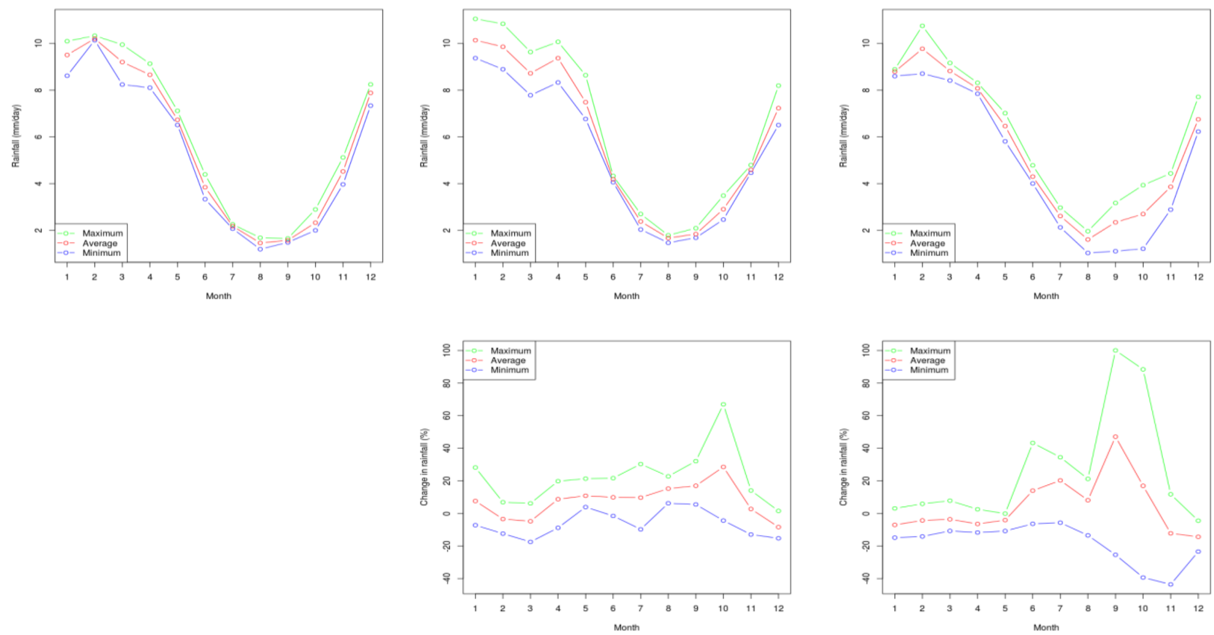

Figure 10. Torres Strait region climatology from CCAM 8 km multi-model mean for rainfall (mm day^{-1}) for 1990 (left), 2055 (centre) and 2090 (right). Bottom set of images are the percent changes from 1990.

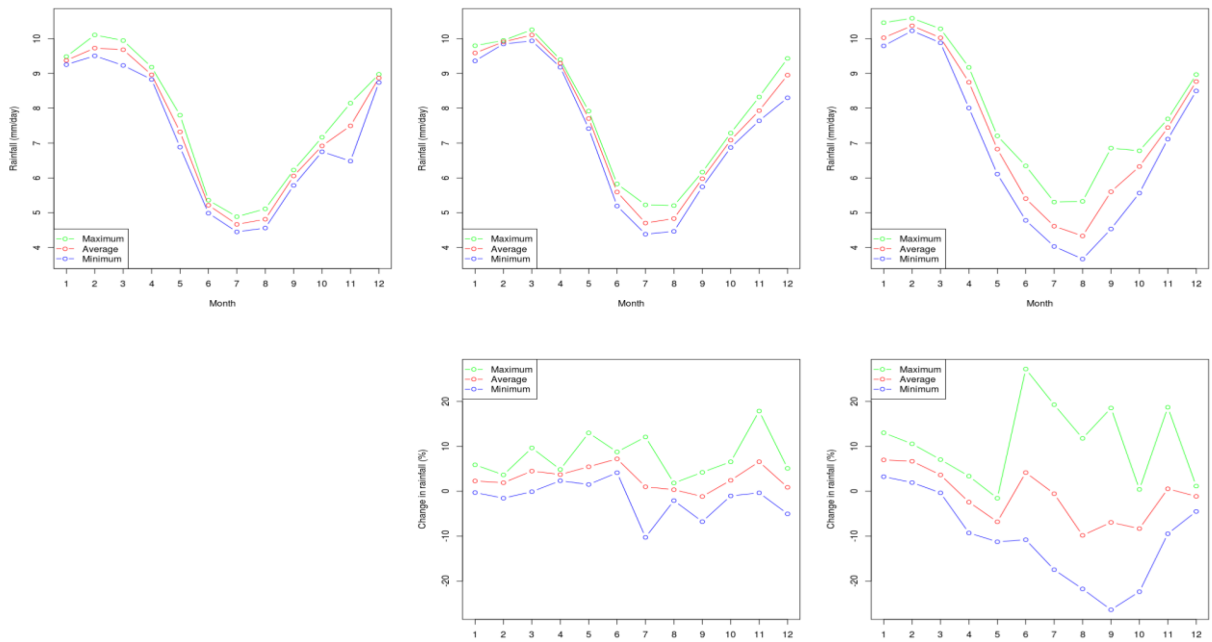

Figure 11. Fly River catchment climatology from CCAM 8 km multi-model mean for rainfall (mm day^{-1}) for 1990 (left), 2055 (centre) and 2090 (right). Bottom set of images are the percent changes from 1990.

3.6 Sea level rise

There is a wide range of potential global sea level rise projections, with up to 1 m being feasible by 2100. Accounting for these possibilities, detailed analyses of sea level rise impacts for the Torres Strait islands has been undertaken by Dr. Kevin Parnell (James Cook University), and the results have been incorporated into the TSRA's Land Use Plans. Low-lying coral atolls and mud islands in the central and northern area of the Torres Strait are most vulnerable. This information was collated and presented at each community-level workshop. As an example, the projections for Masig Island are shown here (Fig. 12).

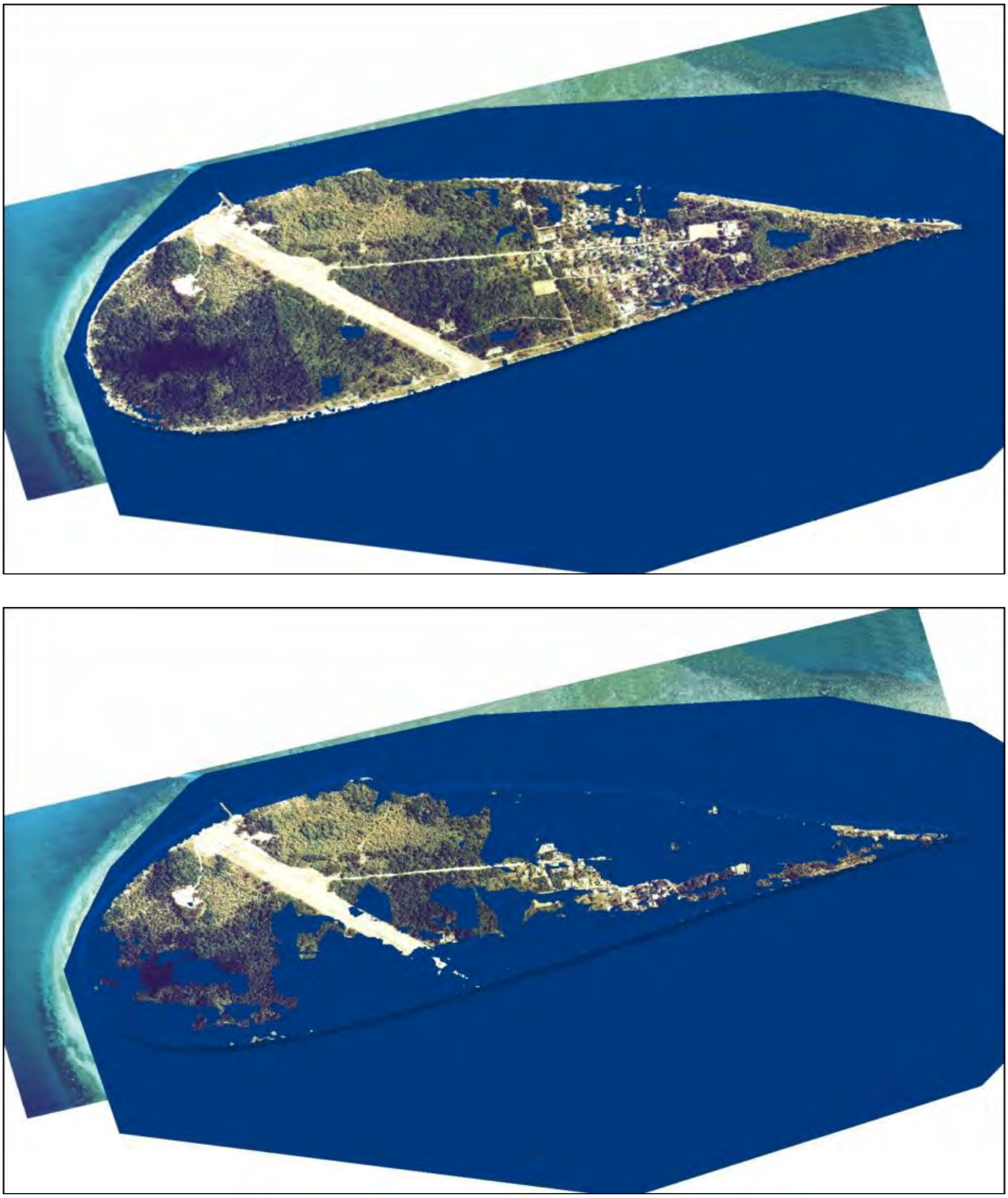

Figure 12. Inundation risk for Masig (Yorke) Island under current Highest Astronomical Tide (HAT) (top) and HAT plus 59 cm sea level rise (bottom). (Source: Kevin Parnell, James Cook University).

4. Economic and social development

4.1 Torres Strait employment, education and health

4.1.1 Employment and livelihoods

Employment statistics from the 2006 National Census are reported in Table 2 below. Note that for consistency, only values from the Australian Bureau of Statistics (ABS) online report 4713.0 (released 4/5/2010) are included. Although the data indicate higher employment of Torres Strait Islander people living in the Torres Strait Indigenous Region compared with elsewhere, 52% of the employed people were working in the Community Development Projects (CDEP) scheme.

Table 2. Employment status of Torres Strait Islander in 2006 (Source: ABS online report 4713.0, released 4/5/2010; www.abs.gov.au)

Employment 2006	Torres Strait Islander People			Indigenous	Non-Indigenous Australia
	Living in the Torres Strait Indigenous Region	Balance in Queensland	Balance or all Australia	All Australia	
% adults (15-64 years) employed	69	51	55	48	
% adults (15-64 years) unemployed			8	9	
% adults (15-64 years) not in labour force			37	43	
% of employed in CDEP	52				
Labour force participation rate	72		63	57	76
Unemployment rate	5		12		

In 2006, there were 2,723 employed Indigenous people in the region. The main sectors of employment were in government administration and defence (62%), health and community services (10%) and education (7%; Fig. 13). Only 1% of people stated they were employed in agriculture, forestry or fishing. The following sectors employed less than 0.5%: mining, manufacturing, communication services, wholesale trade, electricity, gas and water supply, finance and insurance, cultural and recreational services.

Income statistics from the 2006 Census are reported in Table 3. Note that for consistency, only values from the ABS online report 4713.0 (release 4/5/2010) are included. The proportion of households in the lowest two quintiles for gross weekly household income (79%) was higher for Torres Strait Islanders living in the Torres Strait Indigenous Region than for those in the rest of Queensland and Australia (65%), and also higher than for all Indigenous Australians (70%).

Table 3. Torres Strait Islander income statistics for 2006 (Source: ABS online report 4713.0, released 4/5/2010; www.abs.gov.au)

Income 2006	Torres Strait Islander People			Indigenous
	Living in the Torres Strait Indigenous Region	Balance in Queensland	Balance in Australia	All in Australia
Gross weekly household income up to $515 (lowest 2 quintiles)	79%	65%	65%	70%
Gross weekly household income at least $1,078 (highest quintile)	2%	6%	8%	

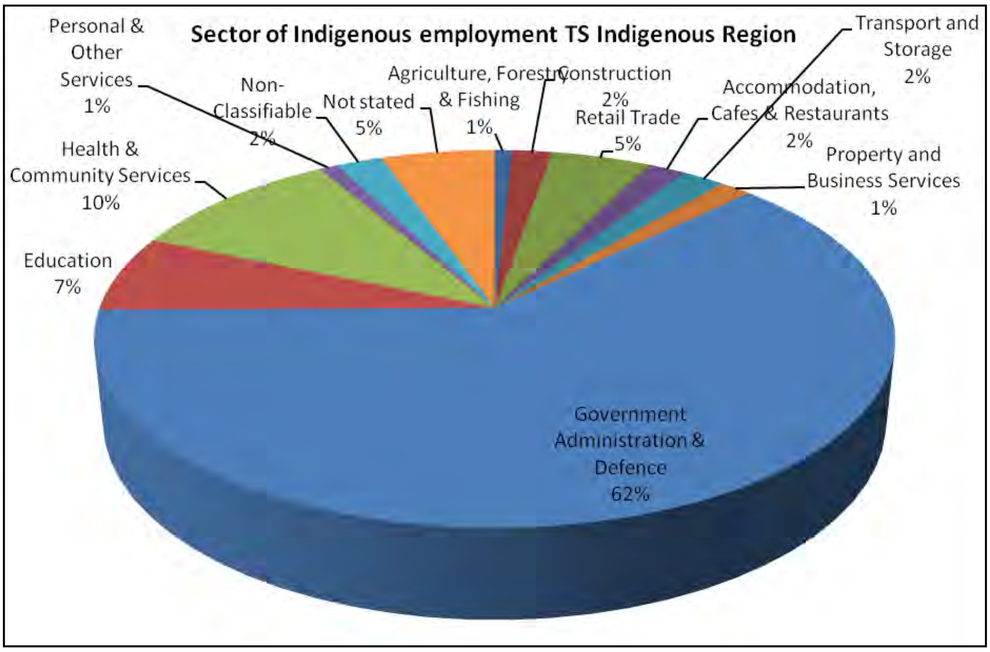

Figure 13. Indigenous employment in the Torres Strait Indigenous Region by sector in 2006 (Source: Table generated using ABS TableBuilder 2006).

4.1.2 Education

The proportion of Torres Strait Islander people living in the Torres Strait Indigenous Region who had completed Year 12 in 2006 was higher than for Torres Strait Islanders living in the rest of Queensland and other parts of Australia (Table 4). It was also higher than the proportion of all Indigenous people who had completed Year 12. However, the ABS (2010) notes that in 2008, there was no significant difference in Year 12 attainment rates between Torres Strait Islander people living in the Torres Strait Indigenous Region compared with those living elsewhere. Also, 49% of younger Torres Strait Islander adults aged 15-34 years completed Year 12 compared with 22% of those aged 35 years and over.

Table 4. Education characteristics of Torres Strait Islanders (Source: ABS 2006 and ABS 2010)

Education indicators		Torres Strait Islander People				Indigenous
	Year	Living in the Torres Strait Indigenous Region	Queensland	Australia	All Australia	All Australia
% adults (15 years and over) completed year 12	2006	38	35	25		22
% adults (15 years and over) completed year 12	2008				36	22
% adults (15 years and over) non-school qualification	2006	18	15	15	23	
% adults (25-64) non-school qualification	2002				33	
% adults (25-64) non-school qualification Cert III or higher	2002				19	
% adults (25-64) non-school qualification	2008				49	
% adults (25-64) non-school qualification Cert III or higher	2008				36	
% adults (15 years and over) highest- Bachelor degree	2006				3	

There was an increase in non-school qualifications for adults 25-64 years between 2001 (22%) and 2006 (29%), which according to ABS (2010) was due to more Torres Strait Islander people attaining a non-school qualification of Certificate III or higher (Table 5). Other statistics (not included in the table) reported were that in 2008, more Torres Strait Islander women (57%) than men (41%) had attained a non-school qualification. Also rates of attainment were similar for Torres Strait Islander people living in the Torres Strait Indigenous Region and those living elsewhere, and non-school qualification attainment rates for Torres Strait Islander people were similar to those for all Aboriginal and Torres Strait Islander people.

Table 5. Trends in education indicators between 2001 and 2006 for Torres Strait Islanders (Source: ABS 2006 and ABS 2010)

Education indicators	Year	
	2001	2006
Torres Strait adults (15 years old and over) who completed year 12 or equivalent (%)	27.4	32.2
Torres Strait aged 25-64 with a non-school qualification (%)	21.8	28.5
Torres Strait aged 25-64 with a bachelor degree or higher (%)	3.6	4.7

4.1.3 Health

The most recent report on health for Torres Strait Islander people in Australia indicates that in 2008, 47% aged 15 years and over had a disability or long-term health condition. Around 7% had a profound or severe core activity limitation. Data for age groups are shown in Table 6. The most common disability reported was physical restrictions (29%), sight, hearing or speech disabilities (18%) and psychological disabilities (11%).

Table 6. Disability status by age for Torres Strait Islander people in 2008 (Source: ABS 2010)

Disability or long-term health condition		
Age group (years)	Cases	Proportion (%)
15–24	3,367	32.9
25–34	3,615	44.0
35–44	2,839	41.4
45–54	2,508	64.2
55–64	1,656	69.7
65 and over	1,833	92.3

Data from the 2008 National Aboriginal and Torres Strait Islander Social Survey indicates that more than half of young Torres Strait Islander people think their health is excellent or very good, compared with 29% of people aged 35 years and older (Table 7).

Table 7. Self-assessed health for Torres Strait Islander people in 2008 (Source: ABS 2010, Table 7.1).

	Number			Proportion (%)		
Age group (years)	Excellent/ very good	Good	Fair/poor	Excellent/ very good	Good	Fair/poor
15–34 years	10,375	6,206	1,856	56.3	33.7	10.1
35 years and over	4,327	5,790	5,008	28.6	38.3	33.1
Total	14,702	11,997	6,864	43.8	35.7	20.5

Data from the 2008 Social Survey on neighbourhood and community problems indicates people in the Torres Strait Indigenous Region reported higher rates in each category, including alcohol and illegal drug use, theft, dangerous or noisy driving, and neighbourhood conflict. Data on well-being for the Torres Strait Indigenous Region indicates that residents living in the region are happier than in the rest of Australia (Table 8).

Table 8. Well-being status of Torres Strait Islander people aged 15 years and over in 2008 (Source: ABS 2010, Table 8.1).

	Proportion (%)	
	Torres Strait Indigenous Region	Balance of Australia
Happy all/most of the time	84.2	70.2
Full of life all/most of the time	75.6	55.6
Calm or peaceful all/most of the time	75.1	54.9
Had a lot of energy all/most of the time	62.3	49.2

4.2 Western Province human development

4.2.1 Education and health

Detailed data on human health, education and well-being is patchy or non-existent in Western Province. However, in 2008 the PNGSDP commissioned a report on health services, and this provided some evidence of the status of health indicators (Table 9). Life expectancy has been improving significantly, and the Infant Mortality Rate has been declining, both of which indicate improving human well-being. However, childhood malnutrition increased between 2001 and 2005, and was double the national rate in 2005. Incidence of malaria decreased in 2001-2005, but was higher than the national rate. Cases of pneumonia-related mortality in infants also declined. The levels of outreach clinic services were far lower than the national rate in 2005, and as a result the level of immunization of newborns was also far below the national level. The generally low levels of human development have been exemplified in recent years by outbreaks in Daru of cholera (DFAT 2010), and drug-resistant tuberculosis (DFAT 2014).

Table 9. Human health indicators for Western Province, trends and comparative data for PNG (source: PNGSDP 2008)

Indicator (unit)	1980	2000	2001	2005	Trend	PNG (2005)
Life expectancy (years)	46.2 (M) 49.5 (F)	54.0 (M) 54.7 (F)			⇧	
Fertility rate (births per female)		5.6				
Infant mortality rate (deaths per 1000 live births)	92 (M) 73 (F)	68 (M) 64 (F)			⇩	
Childhood malnutrition (% children < 5 years)			1.3	3.9	⇧	1.8
Malaria (% population treated)			47	36	⇩	28
Pneumonia (% deaths of children < 5 years)			4.8	2.0	⇩	
Outreach clinics (per 1,000 children < 5 years)				15.5		23.2
Triple Antigen Immunisation (% children < 1 year)				49		77

4.2.2 Housing, electrification and water

In 1995 CSIRO carried out a household survey of a PNG Treaty Village, Mabudauan, and the provincial capital, Daru (see Fig. 1), as part of the AusAID-funded *Western and Gulf Provinces Coastal Zone Management Plan*. This survey was repeated in 2012/13 by CSIRO as part of a project funded by the Australian Fisheries Management Authority and the PNG National Fisheries Authority, *Characterising the traditional fisheries of the PNG Treaty Villages*.

Results showed that in Daru the proportion of households with electricity (largely from generators) had increased to approximately 50%, but the prevalence of piped water and modern housing had declined. In Mabudauan the proportion of households with electricity had declined to less than 50%. Modern housing was already low in 1995, and had declined further, while piped water was absent in 1995 but had increased to 2% in 2012/13 (Fig. 14). Although the 1995 sample sizes are small, and only two settlements have been surveyed, these data suggest that in 2012/13 basic services enjoyed by households was low, and most indicators had declined or changed little since 1995.

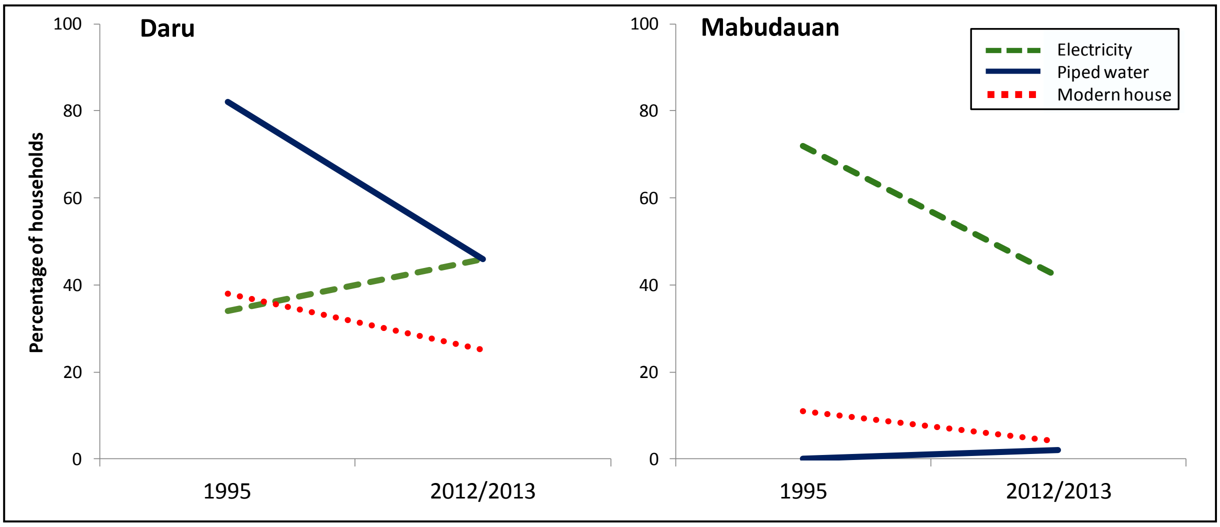

Figure 14. Trends in electricity, piped water and houses built with modern materials in Daru (left: 1995 n=29; 2012/13 n=319) and Mabudauan (right: 1995 n=18; 2012/13 n=127) (Source: Sara Busilacchi, unpublished data)

In 2012/13 the CSIRO survey also asked all households in the PNG Treaty Villages and Daru to estimate their level of well-being. In spite of indications of low and declining human development, the majority (54%) responded that their well-being was 'good' (Fig. 15). However, this contrasted with the Torres Strait where 84% were 'happy all/most of the time' (Table 9).

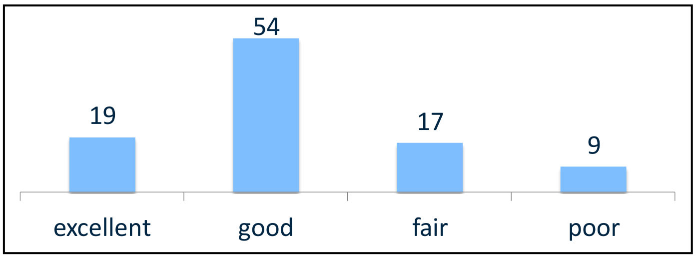

Figure 15. Household responses in the PNG Treaty Villages and Daru to the question "how would you rate your current well-being?" A total of 1,099 housholds were surveyed in 2012/13 (Source: Sara Busilacchi, unpublished data).

4.2.3 Environmental health impacts of Ok Tedi mine

Since the 1990s extensive environmental degradation has occurred along the Ok Tedi and Fly Rivers, and its negative effects are believed to have reached the estuaries of the delta in the south (Smith et al. 1990; Swales 2001). The primary visible impact is the effect of increased sedimentation due to mine waste and tailings. As a consequence extensive flooding has and will continue to occur, and it is estimated that 90% of the Middle Fly floodplain will be affected, resulting in an estimated 3,800 km2 of vegetation dieback for the next hundred years (Tingay 2006). Flooding has caused sediment to be carried over the banks of the river, producing extensive die-back in the forests along the lower Ok Tedi River. Since 1988, villages along the river have suffered absolute loss of tracts of land amounting to hundreds of hectares, including formerly valuable garden land in the river's floodplain. Riverine wildlife, including birds, fish, and turtles, have been adversely affected as well (Kirsch 1993). Fish populations have declined by 95% in the Ok Tedi, 85% in the upper Middle Fly and 60% in the lower Middle Fly (Tingay 2006).

Various studies have found elevated levels of mercury in human hair samples from people along the Fly River. This is due to due to bio-magnification through food chains from plankton to fish to humans. Tingay (2006) stresses that the effects on unborn children should be assessed as a priority.

At the same time there is also a process of Acid Rock Drainage (ARD) which is mainly sulfuric, from the mine tailings and sediment, which has and will continue to damage the environment. The total impact of the ARD along the rivers is unknown and scientists are yet to determine the full negative consequences on the environment, human health and nutrition. There will be chemical changes in the water, which will lead to the reduction of ecosystem function, reduction in food availability, reduction in food edibility, with resulting negative impacts on human health. A number of mitigation measures are being proposed by Ok Tedi mine such as removing wastes from the tailings, dredging and covering of stockpiles, re-vegetation on the stockpiles, and management of erosion and drainage. The idea of resettlement of the affected population is being discussed informally, but no plans have been developed. Many of the affected community members have emigrated to Daru and the PNG Treaty Villages.

4.3 Human Development Index

4.3.1 Torres Strait

The Human Development Index (HDI) is used by the United Nations Development Programme (UNDP) to rank countries according to key development indicators in the fields of life expectancy, adult literacy, school enrolments and per capita income. The HDI has also been modified for use in sub-populations such as Indigenous people.

When the HDI is calculated for countries, Gross Domestic Product per capita is included, but as this is not available for Australia by Indigenous status we used proxies developed by Yap and Biddle (2010). We did not consider gender differences. We used 2006 ABS Population and Housing Census for the Torres Strait Indigenous Region compared with all of Australia. The method used to calculate the HDI was:

1. Life Expectancy at Birth: Values used for this indicator were life expectancy for Australia for Indigenous and non-Indigenous people.
2. Education Index: Adult literacy (AL) is the proportion of the population at least 15 years old which has completed Year 10 or higher. Gross enrolment (GE) is the proportion of the population aged 15-24 years old which are attending an educational institution. To create the Education Index, AL was weighted by 2/3 and GE by 1/3.

3. Median gross weekly income for people aged 15 years and over was used as a proxy for the standard of living.
4. Each indicator was then scaled between 0 and 1. The HDI was calculated as the average of the three- dimensional indices. This value was then scaled so that the HDI for the Australian non-Indigenous population was equal to the value calculated by the UNDP for Australia (0.965 in 2006).

Fig. 16 illustrates the relative scores of the three indicators and the HDI results. The HDI for the Torres Strait Indigenous Region was 0.736, compared to 1.010 for non-Indigenous Australians in the region. The HDI for the Torres Strait Indigenous Region was very similar to that for Australian Indigenous people (0.735). Yap and Biddle (2010) calculated HDI for Indigenous Australians as 0.737, which is very close to our calculation of 0.736, providing credence to our results (see Table 10). The gap between Indigenous and non-Indigenous Australians is higher for the Torres Strait Indigenous Region (0.274) than for all of Australia (0.230).

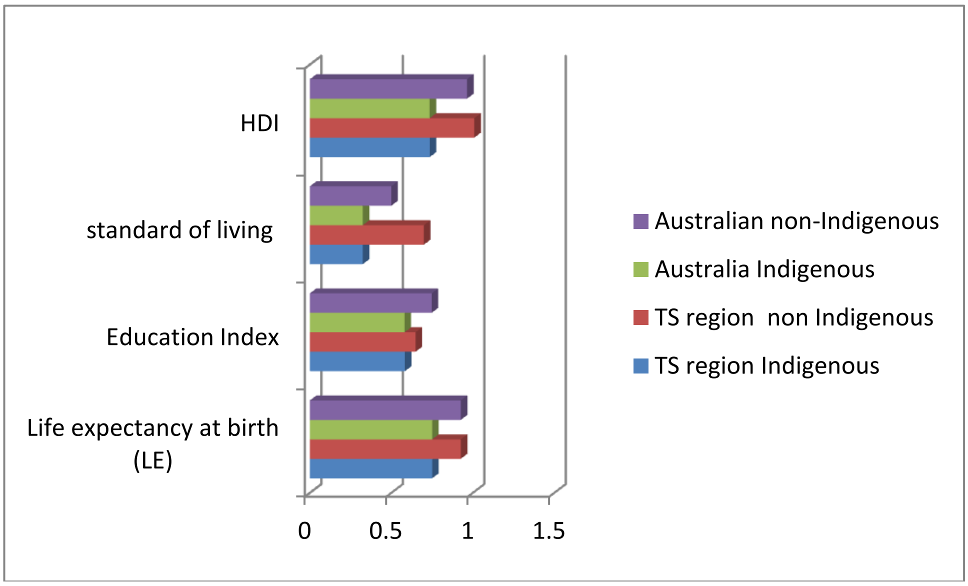

Figure 16. Human Development Index and component indices for the Torres Strait Indigenous Region and Australia, 2006.

Table 10. Human Development Index for the Torres Strait Indigenous Region and Australia in 2006 (Source: Calculations from ABS TableBuilder 2006).

	Indigenous	Non- Indigenous	
Area	HDI	HDI	Gap
Australia	0.735	0.965	0.230
Torres Strait Indigenous Region	0.736	1.010	0.274

4.3.2 Western Province

A recent report suggests that in 2007 Western Province's HDI was approximately 0.260. Relative to other national HDIs calaculated by the UNDP in 2007, Western Province ranks lower than Afghanistan and the Democratic Republic of Congo, and therefore it is one of the poorest regions in the world (McGillivray 2012). By comparison, PNG's national HDI was 0.466. When compared, there is therefore a difference of 0.476 in the HDI of communities living within 5 km of each other across the Torres Strait Protected Zone boundary (Fig. 17).

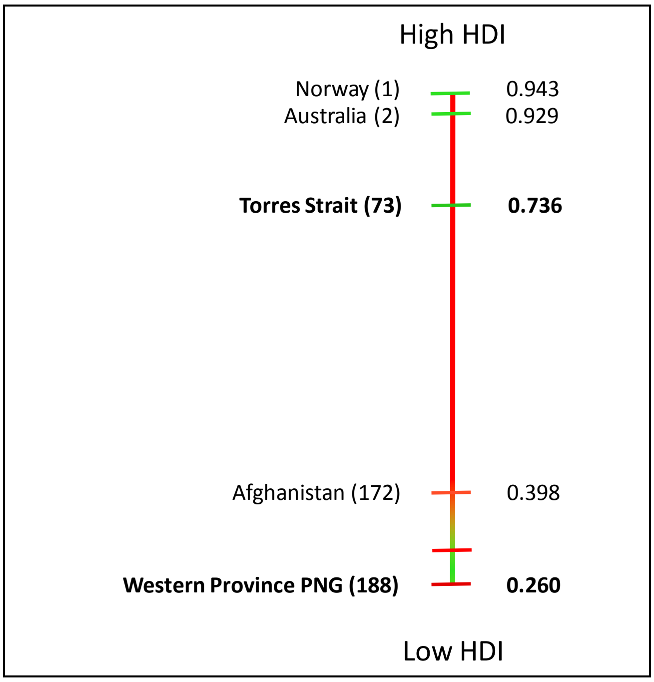

Figure 17. Comparisons between the Human Development Index (HDI) and world ranking in 2006/2007 for Australia, the Torres Strait Indigenous Region, and Western Province

4.4 Resource extraction in Western Province

4.4.1 Oil, gas and mining

There is a moratorium on mining and gas extraction in the Torres Strait Protected Zone, which was established by the Torres Strait Treaty. However, there are no similar restrictions outside this area. In 2012 a comprehensive search was made of available resource companies' annual reports, publicity announcements, websites and brochures for information on their current and planned portfolio of projects in south-western PNG, and Western Province in particular. Other sources included research and academic literature, media articles, NGOs, consumer watchdogs and the PNGSDP. The search identified three existing projects (Ok Tedi, Porgera and Kutubu/Gobe Moran oil); a further six projects are planned to start by 2015, including the development of a deep water port in Daru (Table 11). Fig. 18 illustrates these projects' locations relative to Western Province and the Torres Strait.

Table 11. Details of the three current and six proposed oil, gas, mineral or hydro developments in south-western PNG. See Fig. 18 for details

	Province	Development	Start	End	Shareholders	Infrastructure	References
Existing developments							
Ok Tedi	Western	Copper, gold	1984	2013 to 2022	Ok Tedi Mining PNG Government Inmet Ltd.		Swales 2001; Smith 1990
Porgera		Gold	1991	2015 to 2023	Barrick Gold		Jackson and Banks 2002; Gilberthorpe and Banks 2011
Kutubu/Gobe Moran		Oil	1992	-	Oil Search Ltd. ExxonMobile Merlin PNG Government BP, Chevron	Kumul export terminal Underground pipelines to Kumul	Owen and Latimore 1998
Planned developments							
LNG PNG	Southern Highlands; Western	LNG	2014	2042	ExxonMobile Oil Search Ltd. PNG Government Santos Ltd. Nippon Oil Exploration Petromin Mineral Resources Development Company	Gas conditioning plants Underground pipelines to the coast LNG facility near Port Moresby	Dixon et al. 2010; McIlraith 2011
Gulf LNG	Gulf	LNG	2014	-	InterOil Petromin	Underground pipelines to the coast Floating LNG facility LNG refinery near Port Moresby	Price 2012; InterOil Corporation 2010
LNG consortium	Western	LNG	2014	-	Horizon Oil Talisman Energy Eaglewood Energy	Underground pipelines to the coast Gas facility in Daru Deep water port in Daru Commercial centre in Oriomo Infrastructure corridor from Kiunga to Nomad and Balimo to the coast in Oriomo	Price 2012; PNGSDP 2009a, 2010
Mt Kare	Enga	Gold, silver	Feasibility study started 2011	-	Indochine Mining Ltd.	Due to its position close to the Porgera mine it can replace it in the economic and ecological scenario of local populations once its operations will end	Indochine 2012
Frieda River	Sepik	Gold, copper	Feasibility study started in 2010	-	Xstrata Highlands Pacific	Shareholders envisage replacing the Ok Tedi mine once its operation will end by providing economic benefits, infrastructures, and services to highland communities	Xstrata 2010
Purari River	Gulf	Hydro-electricity	MoC signed recently	-	PNG Energy Development Ltd. OriginEnergy Ltd.	Undersea transmission cable to Daru and then to North Queensland. The project is planned to provide electricity to the area around Daru.	OriginEnergy 2012

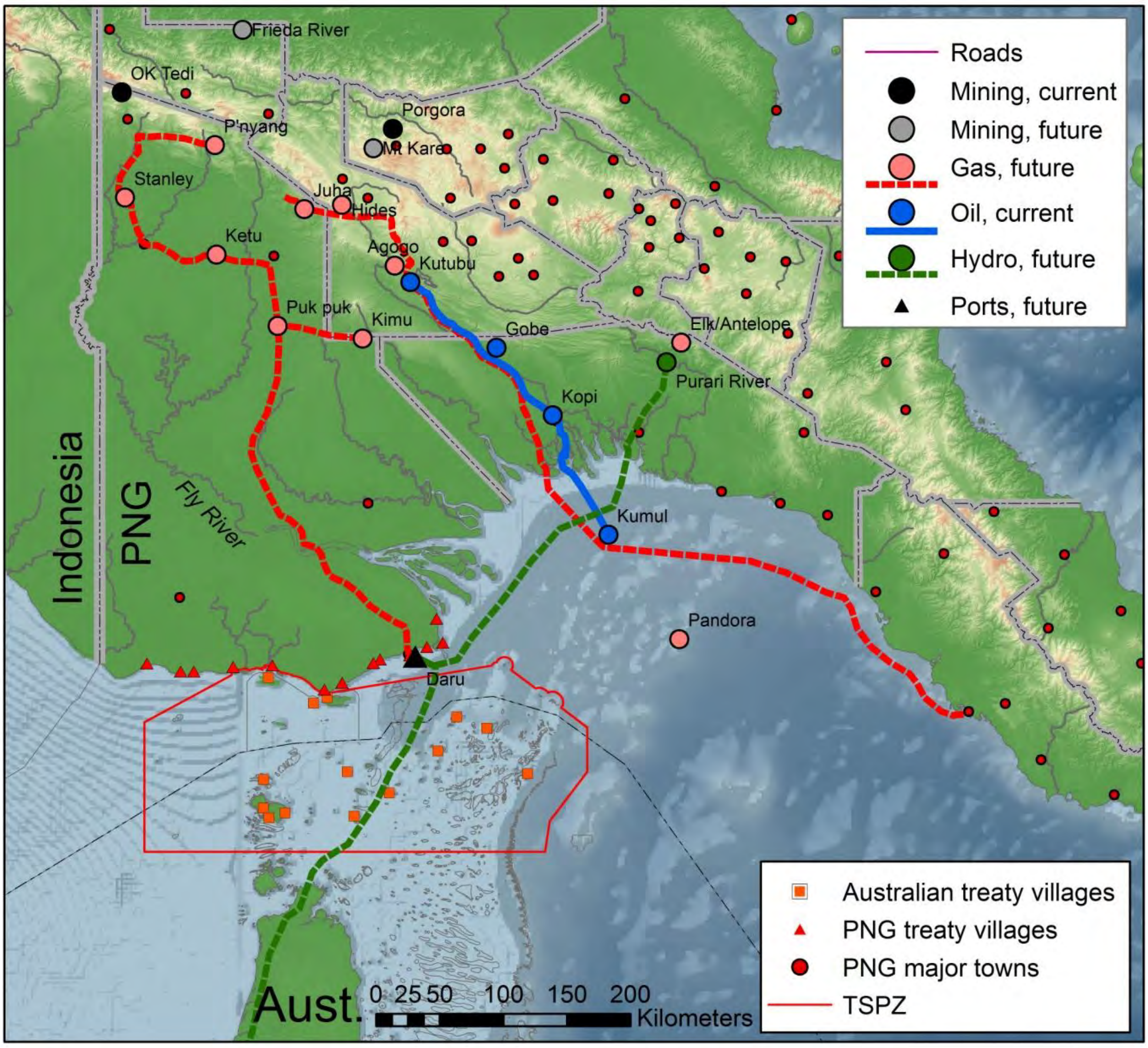

Figure 18. Locations of the three current and six proposed oil, gas, mineral or hydro-electricity developments in south-western PNG. See Table 11 for details.

4.4.2 Logging and infrastructure

A review of current and planned logging concessions identified eight existing projects in the region (Table 12), plus a further five planned (Table 13). Six are being run or proposed by Malaysian companies. Of the five proposed projects, one is located in Western Povince, plus a logging road from Kiunga to Nomad (Fig. 19). It is notable that in many cases there was evidence of illegal activity, or disputes with landowners. Consequently clear and transparent data is hard to source and verify (Filer 2012; Filer et al. 2012). In addition, infrastructure related to these and the oil, gas, mineral and hydro-electricity developments include a proposed Trans Papua road corridor from Kiunga to Daru, and expansion of the shipping routes to Daru linked to existing routes through the Torres Strait, Gulf of Papua and Great Barrier Reef (Fig. 19). It should be noted that this analysis did not examine similar mineral, oil, gas or logging developments in the adjacent Papua Province of Indonesia.

Table 12. Details of the eight current logging concessions in south-western PNG. See Fig. 19 for details. (FMA = Forest Management Agreement).

Province	Forest area	Concession size (ha)	Concession	Permit holder	Details	References
Western	Wipim Tapila	244,000	1996	Forest Management Services Ltd. (PNG)	WWF is planning to assist in the establishment of a Forest Stewardship Council certified forestry project	WWF 2008; Forest Trends 2006
Western	Kiunga to Aimbak	Not available	No proper FMA; the project was originally based on a Timber Permit for road construction. In 2003 the project was halted by courts	Concord Pacific (Samling)	Logging road with substantial log export. A review found that the project was in breach of both the National Forest Policy and the Forestry Act	Rogers 2008; Forest Trends 2006
Western	Wawoi Guavi	448,300	Timber Permit in 1992 with extension in 2002	Rimbunan Haijau (Malaysia)	A review found faults in the engagement process with landowners, in the application of legal requirements for sustainability, and in the application of a legal process	Rogers 2008; Forest Trends 2006
Western	Makapa	301,500	Timber Permit in 1991 and extended in 2003	Innovision		Forest Trends 2006
Western	East Awin	184,000	Timber Permit in 2003	CS Bos Ltd (Malaysia)	The permit was nullified by courts in 2004 but logging activities have continued	Forest Trends 2006
Western	Semabo	54,000			The project had not started by 2006	Forest Trends 2006
Gulf	Vailala Blocks 2/3	268,000	Timber Permit in 1992 with extension in 2002	Rimbunan Haijau (Malaysia)	Timber Permits were found to be unlawful but logging activities have continued	Forest Trends 2006
Gulf	Vailala Block 1	113,400	Timber Permit in 1991 with extension in 2003	Rimbunan Haijau (Malaysia)		Forest Trends 2006

Table 13. Details of the five proposed logging concessions and one logging road in south-western PNG. See Fig. 19 for details

Province	Forest area	Concession size (ha)	Concession	Permit holder	Details	References
Western	Kamula Doso	790,000	1998, declared invalid in 2010. The area is still to be given a concession. There is dispute between the aim for an agroforestry versus a conventional logging project. An earlier carbon trading scheme was ruled out.	Rimbunan Haijau (Malaysia) - proposed		Filer 2012; Filer et al. 2012; Forest Trends 2006
Southern Highlands	East Pangia	98,750	In 2001 a Timber Permit was ready to be signed by landowners			Rogers 2008
Western	Kiunga to Nomad				Logging road which would become part of the Trans Papua Road. This is being assessed by the PNG Department of Environment and Conservation	Rogers 2008
Southern Highlands	Hekiko	199,000	In 2001 a project agreement was nearing completion. The concession has passed from proposed to active.			Rogers 2008; Forest Trends 2006
Gulf	Hekiko	196,000	In 2001 a project agreement was concluded but has not progressed.	Yeung Group Ltd. - proposed		Rogers 2008; Forest Trends 2006
Gulf	Vailala (Meporo)	79,000	In 2000 the project was in its very early stages.	Rimbunan Haijau (Malaysia)		Forest Trends 2006

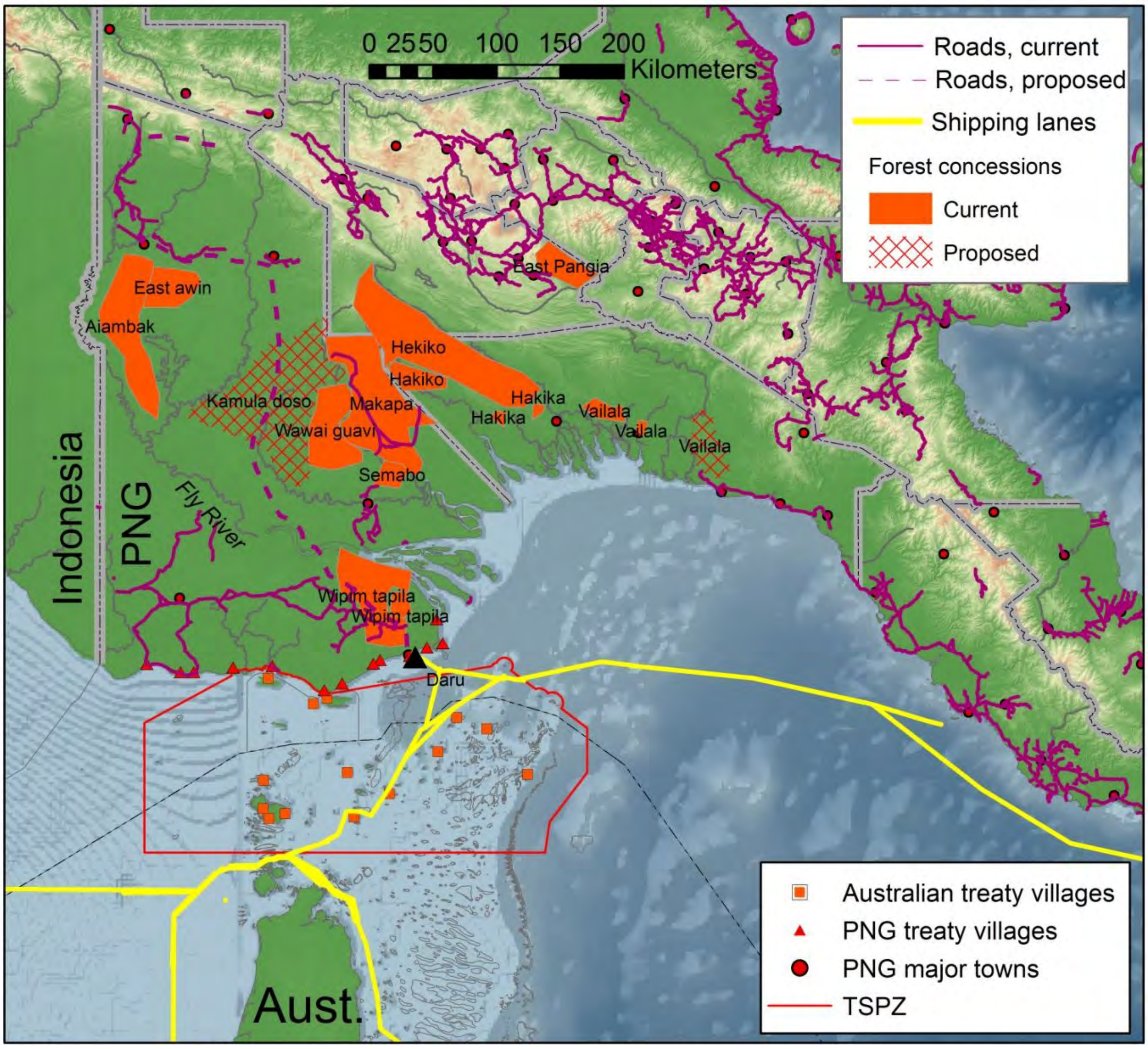

Figure 19. Current and proposed logging concessions, roads and shipping lanes in south-western PNG

4.5 Shipping

The Torres Strait is a primary shipping lane for international trade passing between the Pacific and Indian Ocean (Fig. 19). Locally, shipping lanes converge from the Gulf of Carpentaria in the west and Australia's eastern seaboard. With the proposed building of a deep water port in Daru, additional traffic is likely.

The total annual numbers of ships and voyages through the Torres Strait are recorded by the Australian Maritime Authority. Both have increased steadily during the period 1997-2009 (Fig. 20). The Prince of Wales and Great North East Channel has been identified as a high risk area for oil spills due to the concentration of shipping traffic. The channel has also been considered a grounding and collision area. A 2007 study by the Australian Navy found that the risk of powered grounding is the dominant contributor to the risk profile for the whole Great Barrier Reef on a per nautical mile basis, with a predicted frequency rate of 1-2 per year. The number of ships that pass through the Prince of Wales Channel in the Torres Strait has increased since that study, and consequently the risk of grounding, collision and oil spills has probably also increased.

A projection of an assumed trebling of shipping voyages in the region shows that some of the highest frequencies will occur in the Torres Strait (Fig. 21). This projection also provides a crude indication of the risk of shipping accidents and oil spillages.

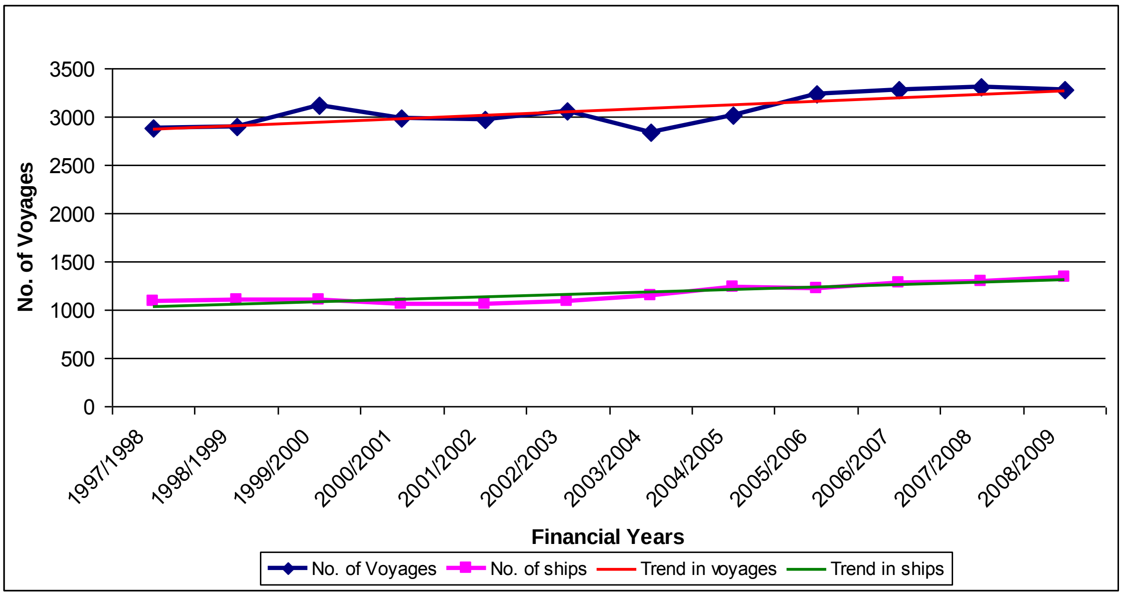

Figure 20. Shipping activity in the Torres Strait, 1997-2009 (Source: Australian Maritime Authority).

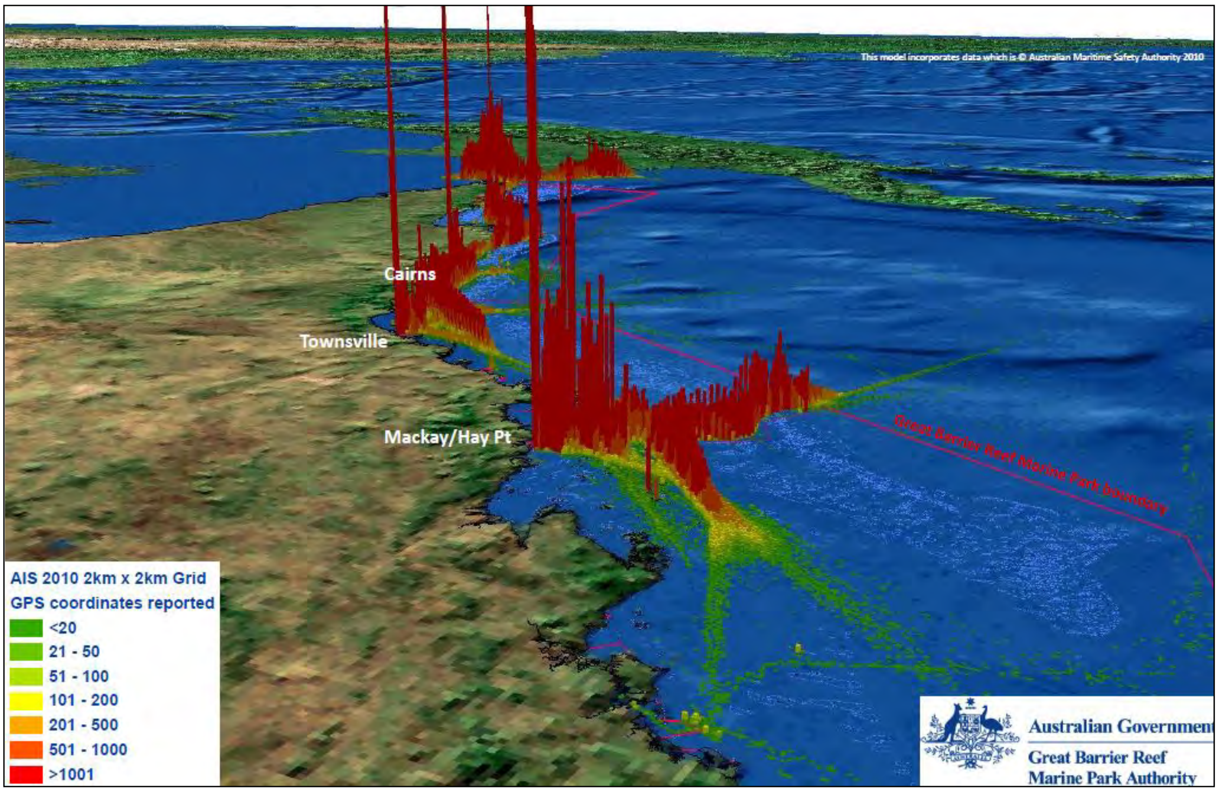

Figure 21. Projected shipping activity in the Great Barrier Reef and Torres Strait assuming a trebling of current voyages (Source: Great Barrier Reef Marine Park Authority).

5. Population change

5.1 Torres Strait population

5.1.1 Trends

Based on the 2006 Census the estimated Torres Strait Islander population was 53,000, comprising 10.3% of the Indigenous population of Australia, and 0.3% of the total Australian population. Among the Torres Strait Islander population 62% (33,300) were Torres Strait Islander origin only, and the reminder 38% (20,100) were both Aboriginal and Torres Strait Islander origin (ABS 2010).

In 2006 only 14% of the total Torres Strait Islander population were living in the Torres Strait Indigenous Region. There were more Torres Strait Islander people living in the remainder of Queensland (32,800: 47%) and New South Wales (8,500: 16%) (ABS 2010).

The population structure of Torres Strait Islander people is young with a median age of 21 years compared to 37 years for the non-Indigenous population of Australia (ABS 2006). The age distributions of Torres Strait Islanders and non-Indigenous people in Australia are shown in Fig. 22. In 2006, of the total Torres Strait Islander population, 38% were under 15 years of age, 71% were under 35 years of age and only 10% of the people were aged 55 years or over. For non-Indigenous Australians, 47% were under 35 years of age, 24% were aged 55 and over.

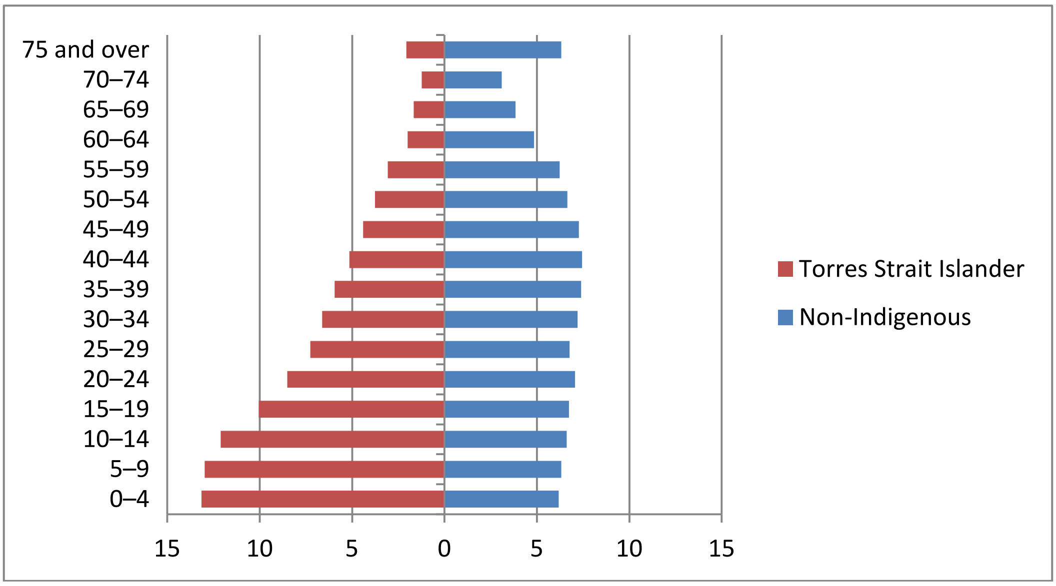

Figure 22. Demographic characteristics of the Torres Strait Islander and non-Indigenous Australians in 2006 (Source: www.abs.gov.au).

Statistics show that overall the population of the Torres Strait region has increased (Fig. 23) at an average rate of 0.9% per annum in 2001-2012. However, this pattern is not uniform, with some islands experiencing a net emigration of people (Fig. 24). For example, the Masig population has declined from 340 in 2001 to 290 in 2012 (Fig. 25).

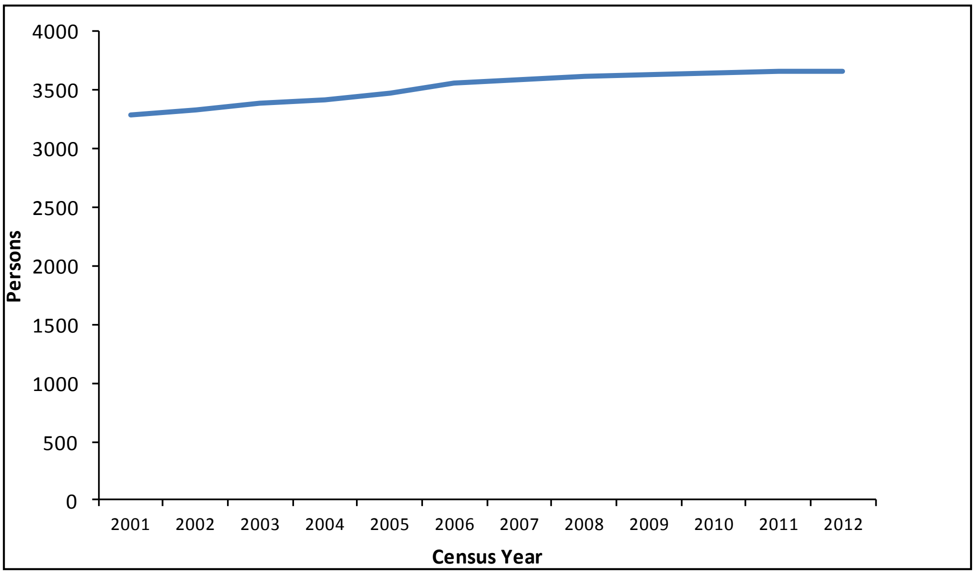

Figure 23. Trend in population of the outer Torres Strait islands (i.e. excluding Thursday Island and Horn Island), but including Hammond Island, in 2001-2012 (Source: www.abs.gov.au).

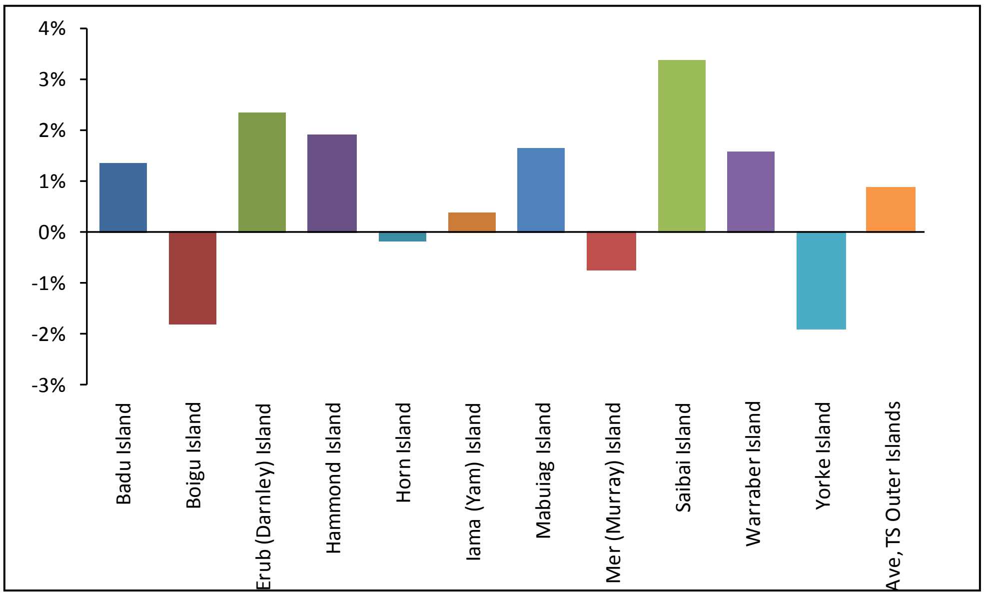

Figure 24. Average annual population growth rates for Torres Strait islands, 2001-2012 (Source: www.abs.gov.au).

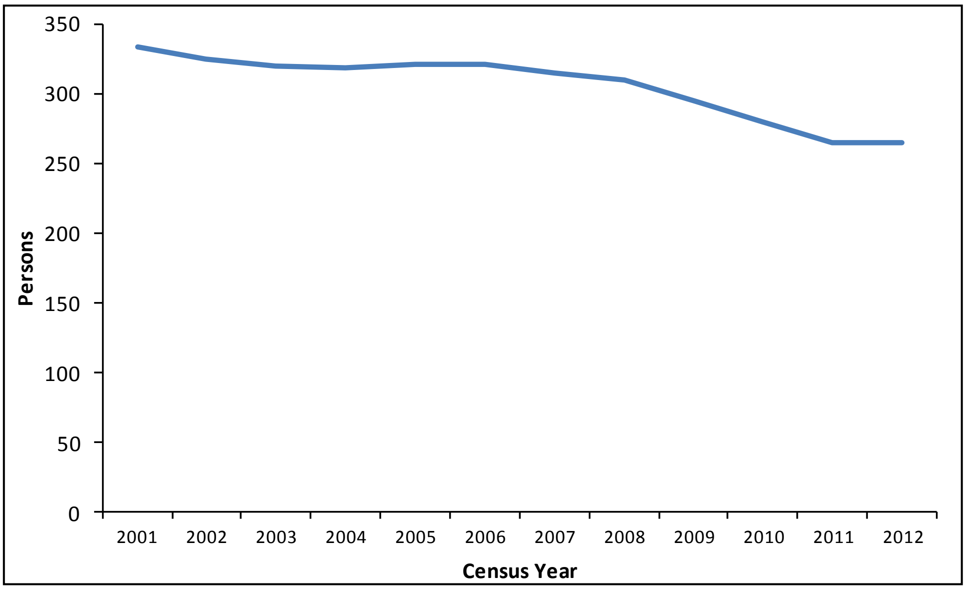

Figure 25. Trend in population of Masig (Yorke) Island, 2001-2012 (Source: www.abs.gov.au).

5.1.2 Projections

The Queensland Office of Economic and Statistical Research have developed population projections for Torres and Torres Strait Island Local Government Areas (LGA). Although not an exact fit, a combined population projection for both LGAs approximates the Torres Strait Indigenous Region. The projections are for residents (indigenous and non-indigenous) of the Torres Strait region and for years 2011 to 2031 under assumptions of low, medium and high growth rates. The population is projected to increase from around 8,800 in 2011 to between 9,749 (low series) and 12,037 people (high series) in 2031 with 10,667 as a medium series (Fig. 26). This is a projected average annual growth rate of 0.91%, which is much lower than the 2.2% projected for the Aboriginal and Torres Strait Islander population, and even lower than the 1.4% projected annual growth rate for the total Australian population (ABS 2010).

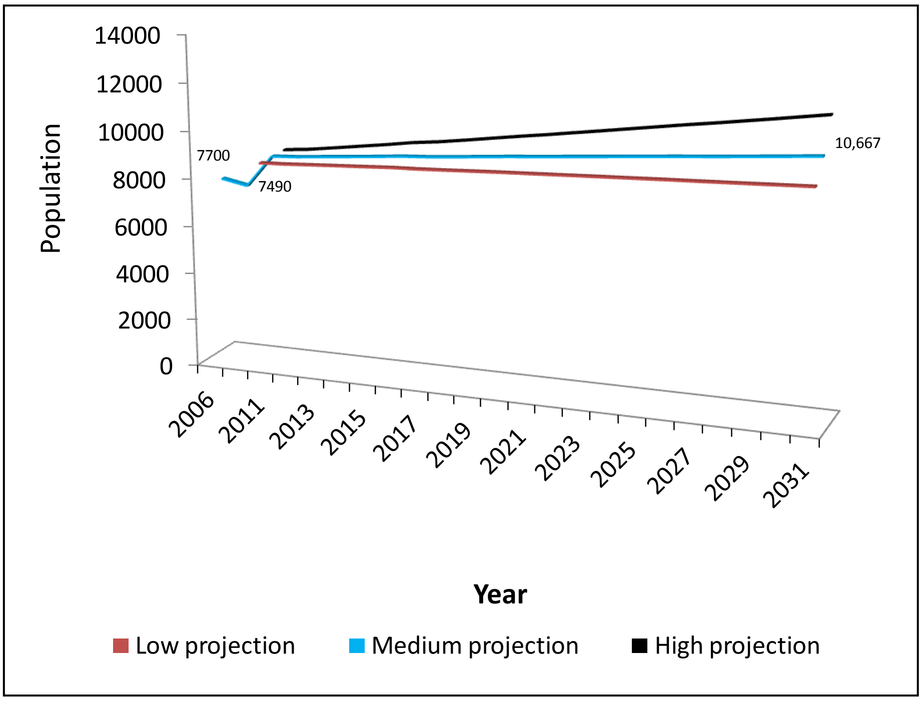

Figure 26. Projected population growth in the Torres Strait (all islands), 2011-2031 (Source: Queensland Office of Economic and Statistical Research)

5.2 Western Province population

5.2.1 Provincial trends and projections

In 2011 a national census was carried out in PNG (National Statistical Office 2012). Preliminary results were released in May 2012 providing provincial statistics, but no data disaggregated to district or Local Level Government units. Data for Western Province show that in 2000-2011 the population increased by 27,000 from 153,000 to 180,000 (an 18% increase) at a rate of 1.5% per annum (Fig. 27). This annual growth rate is considerably lower than in previous decades (1990-2000: 3.2%, 1980-1990: 3.4%), suggesting that the census figures may have been underestimated. However, there has been considerable uncertainty about the accuracy of previous censuses and hence growth rates (PNGSDP 2008). Nonetheless, since the first census in 1980 the population has probably more than doubled.

There is no population projection data available, and hence we made estimates using a numerical modelling approach. This made assumptions regarding the rate at which the Western Province growth rate will decline over time, informed by the rate of decline in the PNG population growth, which has begun to stabilise. We applied three potential models with high, medium and low growth trajectories. Assuming a medium growth rate model, the population could double by 2050, but at a high rate could double by 2040 (Fig. 27). It should be noted that these projections do not include potential immigration related to labour demands for the resource extraction projects outlined in 4.4 above, or emigration due to environmental or social impacts.

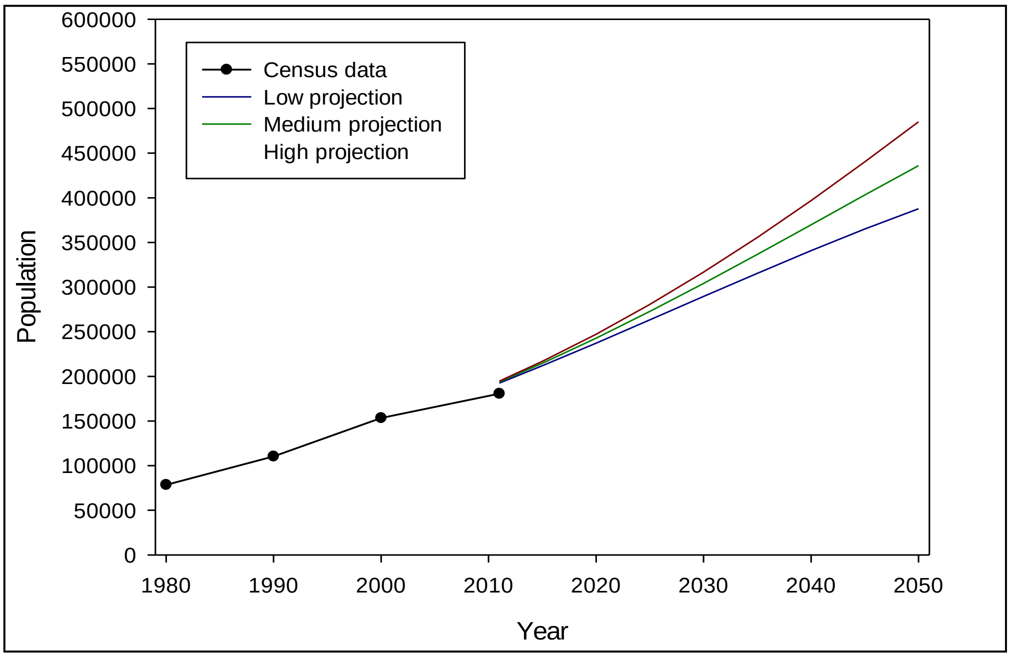

Figure 27. Population census data for Western Province, PNG in 1980-2011, and projected increases between 2012 and 2050 at low, medium and high projections. (Source: National Statistical Office 2012)

5.2.2 PNG Treaty Village and Daru trends and projections

Of direct relevance to the Torres Strait are the populations of the coastal 14 PNG Treaty Villages and Daru. These were not available from the 2011 census, but can be estimated from previous censuses. In 2000, a total of 4,762 people were counted in Treaty Villages, and 12,879 in Daru. Based on the 18% increase between 2000 and 2011 across Western Province, the Treaty Villages' population may have increased to 5,619 in 2011. Daru may have increased to 15,197.

Informal estimates from Provincial Government officials in Daru suggest that the population may have reached 20,000 (approximately 11% of the provincial total), although it is not clear if this includes migrants from Fly River and Treaty Village communities, or if this is only the resident population. However, this figure is perhaps an overestimate given that in 2009 the PNGSDP counted 13,496 in Daru (PNGSDP 2009b). Regardless, the population density on this island may be reaching unsustainable levels, illustrated by a cholera outbreak in November 2010 (DFAT 2010).

Hence, overall the combined population of the 14 PNG Treaty Villages plus Daru could have increased from 17,641 in 2000 to approximately 23,000 in 2011 (Fig. 28). Applying the same models as for the Western Province population, under the medium growth rate the population could at least double to 55,000 in 2050, and achieve the same number by 2035 under the high growth rate. Based on the census data, the majority of these could be living in Daru.

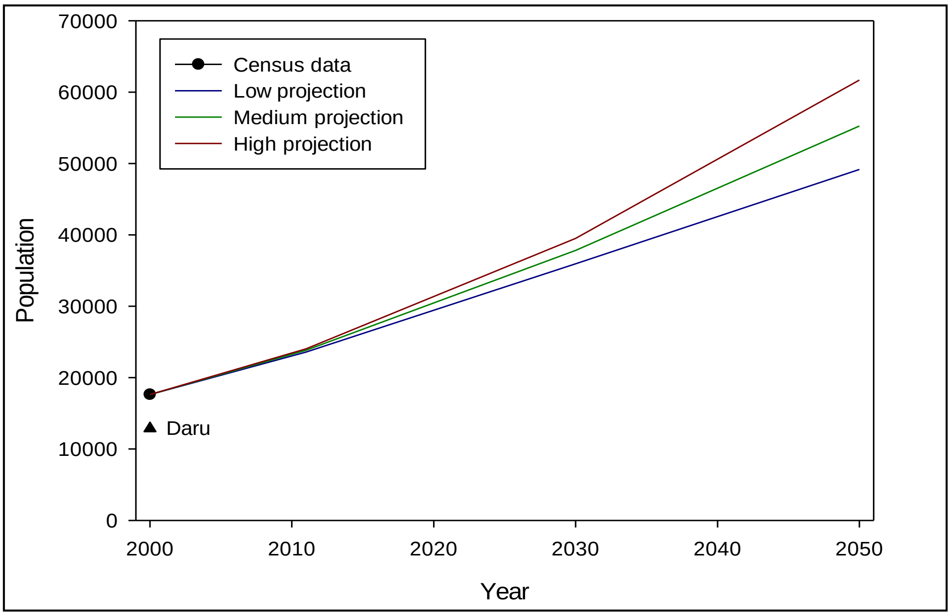

Figure 28. Estimated population data for the PNG Treaty Villages and Daru in 2000, and projected increases between 2012 and 2050 at low, medium and high projections.

5.2.3 Island population densities

Small islands naturally have finite amounts of land and water with which to maintain human populations, although these can be augmented by imported goods (e.g. food) or technological innovations (e.g. de-salination units). For remote islands of PNG where livelihoods are based largely on a subsistence economy, evidence indicates that above a threshold density of approximately 100 people/km^2, food and water security can not be guaranteed (Foale 2005; Butler et al. 2014).

We compared the densities of the Australian Torres Strait islands, plus the PNG islands of Daru and Parama, with this threshold (Table 14). In 2012, the highest Australian island densities were 522 people/km^2 on Poruma, followed by 403 people/km^2 on Warrber. Of the 13 Australian islands, five had densities exceeding the threshold of 100 people/km^2. Of the two PNG islands, Daru had the highest density of all islands, 1,287 people/km^2, far in excess of the threshold. Parama also exceeded the threshold, with 138 people/km^2.

Interpreting these data is complicated by the differing geographical characteristics of the islands and their economies. For the Australian islands, imported food, de-salination plants and other infrastructure greatly increase the carrying capacity of the islands, enabling a relatively good standard of living, as indicated by the high HDI. Also, the liveable area of some islands may be exaggerated due to the dominance of mangrove swamps (e.g. Saibai, Boigu). In general, the overall growth in population on Torres Strait islands (see Fig. 26) may place pressure on infrastructure, particularly in more densely-settled communities, although this is less likely on islands experiencing net emigration. Sea level rise may exacerbate this pressure on more exposed, low-lying islands.

For Daru a similar situation exists, but infrastructure and basic services are poorer, as suggested by the household surveys in 2012/13 (see Fig. 14), where only 50% of houses had electricity and piped water, and 25% had modern houses. Hence, even with these services the every high density of 1,287 people/km^2 may have exceeded its carrying capacity. Furthermore, the likely increase in population on Daru and Parama since 2012 will be placing even greater pressure on infrastructure and natural resources, and will also be exacerbated by sea level rise in the future.

Table 14. Population densities in 2012 for Australian Torres Strait and Western Province PNG islands, estimated from 2012 population data. (Source: ABS (Australia) and Sara Busilacchi unpublished data (PNG))

Island	Area (km^2)	Population (2000)	Density (people/km^2)
Badu (Australia)	101.7	879	8.6
Boigu (Australia)	72.8	233	3.2
Dauan (Australia)	3.7	164	44.1
Erub (Australia)	6.0	422	70.3
Yam (Australia)	1.7	357	210.0
Kubin/St. Paul (Australia)	175.4	494	2.8
Mabuiag (Australia)	6.4	292	45.6
Masig (Australia)	1.6	265	165.6
Mer (Australia)	4.3	411	95.6
Poruma (Australia)	0.4	194	521.8
Saibai (Australia)	103.7	539	5.2
Ugar (Australia)	0.4	85	229.3
Warraber (Australia)	0.7	282	402.9
Parama (PNG)	8.0	1,100	137.5
Daru (PNG)	14.1	18,150	1,287.2

6. Synthesis

These data can be synthesized in terms of projected trends for the Torres Strait island communities, and the neighbouring PNG Treaty Villages and Western Province (Table 15). Exogenous drivers affect the whole region, namely climate change and shipping. Endogenous drivers show some differences between the Australian Torres Strait Islands and the Western Province region and PNG Treaty Villages. Employment, education and health is improving in the Torres Strait, and this is reflected in a relatively high HDI of 0.736, which is also likely to be increasing. In Western Province and the PNG Treaty Villages these indicators are declining, and the very low HDI of 0.260 is unlikely to be improving, as indicated by the chronic occurrence of drug-resistant tuberculosis and cholera. Natural resource extraction is also escalating in Western Province, and related infrastructure. Population growth is occurring on both sides of the border, but is approximately double in Western Province and the PNG Treaty Villages (1.5% per annum) compared to the Torres Strait Islands (0.91%). Island population densities are increasing in most cases, but this is of greater concern for the PNG islands of Daru and Parama where infrastructure and services are poor, and carrying capacities may already have been exceeded.

Table 15. Synthesis of trends in drivers of change for the Torres Strait region (⇧ increasing trend; ⇧⇧ rapidly increasing trend; ⇩ decreasing trend; ⬄ no change; NA not applicable).

Driver of change	Indicator	Regional trend	Torres Strait Islands trend	Western Province PNG trend
Climate change	Annual surface temperature	⇧		
	Annual rainfall	⬄		
	Sea level rise	⇧		
Economic and social development	Employment, education, health		⇧	⇩
	Human Development Index		⇧	⬄
	Oil, gas and mining		NA	⇧⇧
	Logging and infrastructure		NA	⇧⇧
	Shipping	⇧		
Population change	Population		⇧	⇧⇧
	Island population densities		⇧	⇧⇧

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