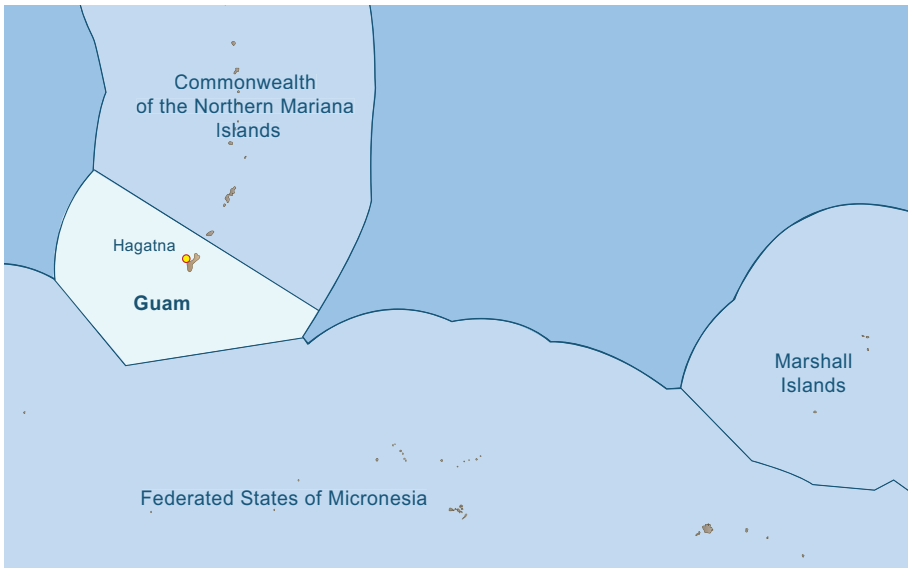
2.6 Guam



Key features

Population

Year	2010	2035	2050	2100
Population (x 1000)[a]	187	250	268	296
Population growth rate[a]	2.7	1.1	0.4	0

a = Data from SPC Statistics for Development Programme (www.spc.int/sdp).

EEZ area (km²) 214,059

Land area (km²) 541

Land as % of EEZ 0.25

Fisheries and aquaculture activities: Oceanic fisheries and coastal fisheries, with some freshwater and estuarine fisheries and coastal and pond aquaculture.

Membership of regional fisheries management arrangements: Western Pacific Regional Fisheries Management Council; Western and Central Pacific Fisheries Commission (participating territory).

Surface climate and the ocean

Existing features

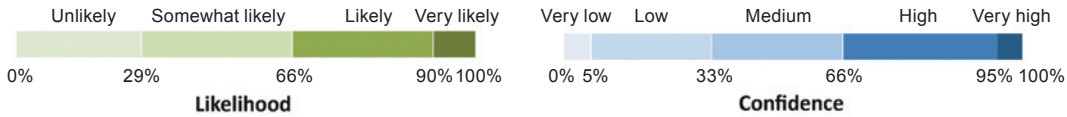
Guam has a tropical climate {Chapter 2}. Recent air temperatures have averaged 27.7°C and average rainfall is > 2150 mm per year. Guam lies within the North Pacific Tropical Gyre Province (NPTG) {Chapter 4, Figure 4.6}. The NPTG Province is created by anticyclonic atmospheric circulation and rainfall in the centre of the province is low. The rotation of the gyre deepens the vertical structure of the water column, making the surface waters nutrient poor {Chapter 4}. As a result, the primary production is very low.

Projected changes to surface climate

Air temperatures and rainfall in Guam are projected to increase due to climate change under the low (B1) and high (A2) emissions scenarios in 2035 and 2100 {see Chapter 1, Section 1.3 for definition of scenarios} relative to long-term averages {Chapter 2, Section 2.5, Table 2.6}.

Climate feature[a]	1980–1999 average	Projected change			
		B1 2035	A2 2035	B1 2100*	A2 2100
Air temperature (°C)	27.7	+0.5 to +1.0	+0.5 to +1.0	+1.0 to +1.5	+2.5 to +3.0
Rainfall (mm)	2168	+5 to +15%	+5 to +20%	+10 to +20%	+10 to +20%
		More extreme wet and dry periods			
Cyclones (no. per year)	n/a	➢ Total number of tropical cyclones may decrease ➢ Cyclones are likely to be more intense			

* Approximates A2 in 2050; a = for more detailed projections of rainfall, air temperature and cyclones in the vicinity of Guam, see www.cawcr.gov.au/projects/PCCSP; n/a = data not available.



Projected changes to the ocean

The projected changes to the key features of the tropical Pacific Ocean surrounding Guam relative to the long-term averages are expected to result in increases in sea surface temperature (SST), sea level and ocean acidification. Changes to ocean currents (increases in the North Pacific gyre) and reductions in nutrient supply are also expected to occur {Chapter 3, Sections 3.3 and 3.4, Tables 3.1 and 3.2}.

Ocean feature	1980–1999 average	Projected change			
		B1 2035	A2 2035	B1 2100*	A2 2100
Sea surface temperature (°C)	28.7[a]	+0.6 to +0.8	+0.7 to +0.8	+1.2 to +1.6	+2.2 to +2.7
Sea level (cm)	+6 since 1960				
IPCC **		+8	+8	+18 to +38	+23 to +51
Empirical models ***		+20 to +30	+20 to +30	+70 to +110	+90 to +140
Ocean pH (units)	8.08	-0.1	-0.1	-0.2	-0.3
Currents	Increase in North Pacific gyre	Continued increase in strength of North Pacific gyre			
Nutrient supply	Decreased slightly	Decrease due to increased stratification and shallower mixed layer			< -20%

* Approximates A2 in 2050; ** projections from the IPCC-AR4; *** projections from recent empirical models {Chapter 3, Section 3.3.8}; a = average for EEZ derived from the HadISST dataset.

Oceanic fisheries

Recent catch and value

Guam has a small, locally-based oceanic fishery within its exclusive economic zone (EEZ), mainly trolling for skipjack tuna. Recent average catches for this fishery have been 114 tonnes per year, worth ~ USD 250,000. Guam also licenses foreign fleets to fish in its EEZ, but recent average annual catches have been low (17 tonnes). See 'Coastal Fisheries' below for contributions of tuna to nearshore artisanal and small-scale commercial fisheries.

Local oceanic fisheries	Average annual catch (tonnes) 2004–2008	Average annual catch value (USD)* 2004–2008
Tuna		
Troll	103	240,000
Other oceanic fish[a]	11	10,800
Total	**114**	**250,800**

* Calculated using market value per tonne for 2004–2008; a = billfish catch only, valued at USD 1000 per tonne.

Existing oceanic fish habitat

The NPTG Province is characterised by low primary production due to the convergence of surface waters and downwelling. Local upwelling near islands can result in enriched surface productivity {Chapter 4, Section 3.2.4}. In general, however, the NTPG Province does not provide prime feeding areas for tuna.

Projected changes to oceanic fish habitat

Under climate change, the surface area of the NPTG Province is projected to increase only slightly and extend poleward. Key components of the food web (net primary production and zooplankton biomass) are expected to decrease significantly in NPTG, particularly under the A2 emissions scenario in 2100 {Chapter 4, Table 4.3}.

NPTG feature	Projected change (%)			
	B1 2035	A2 2035	B1 2100*	A2 2100
Surface area[a]	+1	+1	+1	+1
Location	Poleward			
Net primary production	-3	-5	-11	-22
Zooplankton biomass	-3	-4	-10	-18

* Approximates A2 in 2050; a = area derived from modelling of nutrients and salinity {Chapter 4, Table 4.3}.

Projected changes in oceanic fisheries production

Preliminary modelling suggests that under the B1 and A2 emissions scenarios, catches of skipjack tuna in the EEZ of Guam are expected to increase in 2035 and B1 in 2100, relative to the 20-year average (1980–2000). Catches are expected to decrease under the A2 scenario in 2100 {Chapter 8, Section 8.7}.

Projected change in skipjack tuna catch (%)		
B1/A2 2035	B1 2100*	A2 2100
+16	+10	-8

* Approximates A2 in 2050.

Coastal fisheries

Recent catch and value

The coastal fisheries of Guam are made up mainly of three components: demersal fish (bottom-dwelling fish associated with coral reef, mangrove and seagrass habitats), nearshore pelagic fish (including tuna, rainbow runner, wahoo and mahi-mahi), and invertebrates gleaned from intertidal and subtidal areas {Chapter 9, Section 9.2.1}. The total annual catch was estimated to be 114 tonnes in 2007, worth > USD 412,000. The commercial catch was 44 tonnes. Nearshore pelagic fish are estimated to make up ~ 70% of the total catch.

Feature	Coastal fisheries category				Total	Total value (USD m)*
	Demersal fish	Nearshore pelagic fish[b]	Targeted invertebrates	Inter/subtidal invertebrates		
Catch (tonnes)*	33	77	0	4	114	0.41
Contribution (%)[a]	29	68	0	3	100	

* Estimated total catch and value in 2007 (Gillett 2009)[1]; a = method for calculating disaggregated catch data for each category is outlined in Chapter 9 {Appendix 9.2, Supplementary Table 9.1}; b = catch comprised equally of tuna and non-tuna species.

Existing coastal fish habitat

Guam has relatively small areas of coral reefs {Chapter 5}, mangroves, deepwater and intertidal seagrasses, and intertidal sand and mud flats {Chapter 6}.

Habitat	Coral reef[a]	Mangrove[b]	Seagrass[b]	Intertidal flat
Area (km^2)	238	0.7	31	n/a

a = Includes barrier, patch and fringing reefs and reef lagoons {Chapter 5, Table 5.1}; b = values from Chapter 6, Table 6.1; n/a = data not available.

Projected changes to coastal fish habitat

Climate change is expected to add to the existing local threats to coral reefs, mangroves, seagrasses and intertidal flats in Guam, resulting in declines in the quality and area of all habitats {Chapters 5 and 6}.

Habitat feature[a]	Projected change (%)		
	B1/A2 2035	B1 2100*	A2 2100
Coral cover[b]	-25 to -65	-50 to -75	> -90
Mangrove area	-10	-60	-70
Seagrass area	-5 to -20	-5 to -35	-10 to -50

* Approximates A2 in 2050; a = no estimates in reduction of intertidal flats available; b = assumes there is strong management of coral reefs.

Projected changes in coastal fisheries production

Fisheries for demersal fish, nearshore pelagic fish and intertidal and subtidal invertebrates in Guam are projected to show progressive declines in productivity due to both the direct effects (e.g. increased SST) and indirect effects (changes to fish habitats) of climate change {Chapter 9, Section 9.5}.

Coastal fisheries category	Projected change (%)			Main effects
	B1/A2 2035	B1 2100*	A2 2100	
Demersal fish	-2 to -5	-20	-20 to -50	Habitat loss and reduced recruitment (due to increasing SST and reduced currents)
Nearshore pelagic fish[a]	0	-10	-15 to -20	Reduced production of zooplankton in food webs for non-tuna species and changes in distribution of tuna
Inter/subtidal invertebrates	0	-5	-10	Declines in aragonite saturation due to ocean acidification

* Approximates A2 in 2050; a = tuna dominate the nearshore pelagic fishery {Chapter 9, Tables 9.8 and 9.10}.

The overall projected change to coastal fisheries catch reflects the projected decrease in the productivity of all coastal fishery components. As a result, total catches from coastal fisheries in Guam are projected to decrease slightly under both scenarios in 2035 and continue to decline under both scenarios in 2100.

Coastal fisheries category	Contrib. (%)**	Projected change in productivity (P) and catch (%)					
		B1/A2 2035		B1 2100*		A2 2100	
		P***	Catch	P***	Catch	P***	Catch
Demersal fish	29	-3.5	-1	-20	-6	-35	-10
Nearshore pelagic fish	68	0	0	-10	-7	-17.5	-12
Inter/subtidal invertebrates	3	0	0	-5	-0.2	-10	-0.3
Total catch[a]			**-1**		**-13**		**-22**

* Approximates A2 in 2050; ** contribution of each component to total coastal fisheries catch in Guam; *** median projected change in productivity based on range in Chapter 9; a = assumes that proportion of each category remains constant.

Freshwater and estuarine fisheries

Recent catch and value

The main freshwater and estuarine species caught in Guam are eels, tilapia, milkfish and *Macrobrachium*. These species are mostly harvested by subsistence fishing. The estimated annual freshwater fish catch in 2007 was 3 tonnes, worth USD 10,000 {Chapter 10}.

Existing freshwater and estuarine fish habitat

The largest river in Guam, Talofofo, has a limited range of freshwater and estuarine fish habitats and supports a moderate diversity of fish and invertebrate species {Chapter 7, Table 7.1}.

Island	Largest river	Catchment area (km^2)	River length (km)
Guam	Talofofo	60	12.6

Projected changes to freshwater and estuarine fish habitat

The projected increase in rainfall for Guam {Chapter 2, Section 2.5.2} is expected to result in increases in the area and quality of all freshwater fish habitats. The greatest increases in freshwater habitats are expected to occur under A2 in 2100 {Chapter 7, Table 7.5}. Sea-level rise is expected to increase the area of estuarine habitat {Chapter 7}.

Projected changes to freshwater and estuarine fish habitat area (%)		
B1/A2 2035	**B1 2100***	**A2 2100**
-5 to +10	-5 to +10	-5 to +20

* Approximates A2 in 2050.

Projected changes in freshwater and estuarine fisheries production

Higher projected rainfall and river flows are expected to result in slightly improved production from freshwater and estuarine fisheries in Guam. Higher river flow increases the availability and quality of habitats, provides better cues for fish migration, and enhances reproduction and recruitment {Chapter 10, Section 10.5}.

Projected changes in freshwater and estuarine fish catch (%)		
B1/A2 2035	**B1 2100***	**A2 2100**
0 to +2.5	+2.5	+7.5

* Approximates A2 in 2050.

Aquaculture

Recent and potential production

Aquaculture commodities produced in Guam include tilapia and 30–80 tonnes of milkfish per year grown in freshwater ponds for food. Shrimp is the main commodity produced by coastal aquaculture. There is potential for further pond aquaculture of tilapia for food security.

Existing and projected environmental features

Higher rainfall and air temperatures are expected to have positive effects on pond aquaculture. However, increasing SST, rainfall and storm intensity are expected to reduce the survival and growth of shrimp in the long term due to increased incidence of diseases and possible damage to farm infrastructure {Chapter 11}.

Environmental feature	1980–1999 average	Projected change			
		B1 2035	A2 2035	B1 2100*	A2 2100
Air temperature (°C)	27.7	+0.5 to +1.0	+0.5 to +1.0	+1.0 to +1.5	+2.5 to +3.0
Rainfall (mm)	2168	+5 to +15%	+5 to +20%	+10 to +20%	+10 to +20%
Cyclones (no. per year)	n/a	➢ Total number of tropical cyclones may decrease ➢ Cyclones are likely to be more intense			
Sea surface temperature (°C)	28.7	+0.6 to +0.8	+0.7 to +0.8	+1.2 to +1.6	+2.2 to +2.7

* Approximates A2 in 2050; n/a = no data available.

Projected changes in aquaculture production

Pond aquaculture is expected to be enhanced by increased rainfall, river flows and warmer temperatures. Shrimp farming may eventually be affected adversely by increases in SST and rainfall and possibly stronger storm surge from more severe cyclones {Chapter 11, Table 11.5}.

Aquaculture commodity	Use	Projected change		
		B1/A2 2035	B1 2100*	A2 2100
Tilapia	Food security	↑	↑	↑
Milkfish	Food security	↑	↑	↑
Shrimp	Livelihoods	↑	↓	↓

* Approximates A2 in 2050.

Low — Medium — High: Projected increase

Low — Medium — High: Projected decrease

Economic and social implications

Economic development and government revenue

Current contributions

The small skipjack tuna fishery in Guam does not contribute to gross domestic product (GDP) (USD 3679 million) or government revenue (GR) (USD 428 million) {Chapter 12}.

Projected effects of climate change

The effects of climate change on the distribution and abundance of skipjack tuna {Chapter 8} are not expected to result in noticeable contributions to GDP and GR due to the large size of the national economy {Chapter 12}.

Food security

Guam is among the group of PICTs (Group 3) where the estimated sustainable production of fish and invertebrates from coastal habitats is unable to supply the national population with the 35 kg of fish per person per year recommended for good nutrition[i] {Chapter 12, Section 12.7.1}.

Current contributions of fish to food security

Average national fish consumption in Guam is estimated to be 27 kg per person per year[1], somewhat below the level recommended for good nutrition. Because coastal habitats in Guam are estimated to be able to supply only 4 kg of fish per person per year, fresh and imported canned tuna provides most of the fish consumed.

Effects of population growth

Guam will have a rapidly increasing total demand for fish for food due to the predicted population growth. The current shortfall between the fish available from coral reef habitats and the fish required for good nutrition is 31 kg per person per year. This gap will increase for the remainder this century.

Variable	2010	2035	2050	2100
Population (x 1000)	187	250	268	296
Fish available per person (kg/year)[a]	4	3	3	2
Gap (kg/person/year)[b]	31	32	32	33

a = Based on 3 tonnes of fish per km^2 of coral reef habitat {Chapter 9}; b = relative to recommended consumption of 35 kg per person per year.

i Based on fish contributing 50% of dietary protein as recommended by the SPC Public Health Programme (SPC 2008)[25].

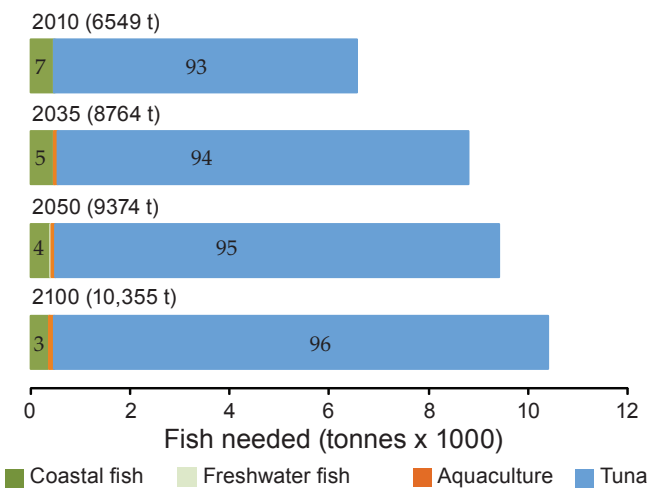
Additional effects of climate change

Guam faces further declines in the fish available per person from coastal habitats due to the combined effects of population growth and climate change. However, the projected declines in coastal fish production have little effect on the fish available per person compared to the effects of population growth.

Filling the gap

Tuna is the main resource available to Guam to help supply the shortfall in fish for food from coastal habitats. Pond aquaculture is only expected to be able to provide minor quantities of additional fish.

Given the limited existing catch of skipjack (~ 100 tonnes per year), the vast majority of fish needed to provide 35 kg of fish per person per year would need to be imported. However, because GDP per capita is relatively high, many people in Guam will have the ability to purchase other sources of animal protein and may not need 35 kg of fish per year for good nutrition.



Fish (in tonnes) needed for future food security in Guam, and the recommended contributions (%) of fisheries resources and aquaculture production required to meet future needs.

Livelihoods

Current contributions

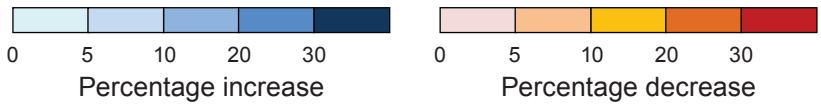
The total number of full-time and part-time jobs created through tuna fishing and processing in Guam has not been determined but is expected to only represent a very low percentage of total employment. Coastal fisheries also provide some opportunities to earn income for coastal communities, and 20 jobs have been created by aquaculture[4].

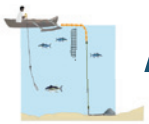
Projected effects of climate change

The effects of climate change on the potential to create more livelihoods based on fisheries and aquaculture are difficult to estimate because there is still scope to derive new jobs from oceanic fisheries, the nearshore component of coastal fisheries and pond aquaculture. However, the A2 emissions scenario is expected to eventually enhance or retard these opportunities as indicated below.

Year	Projected change under A2 scenario				
	Oceanic fisheries**	Coastal fisheries		Aquaculture	
		Nearshore pelagic fish	Other resources	Ponds	Coastal
Present*	⇧	⇧	⇩	⇧	⇧
2035	↑	No effect	↓	↑	↓
2050	No effect	↓	↓	↑	↓
2100	↓	↓	↓	↑	↓

* Indicates general direction of new opportunities for livelihoods based on the activity; ** based on projected changes in skipjack tuna catches; freshwater and estuarine fisheries not included due to their subsistence role.





Adaptations and suggested policies

The plans Guam has to derive greater socio-economic benefits from fisheries and aquaculture will depend heavily on interventions to:

1. improve access to tuna, and manage coastal fish habitats and fish stocks, to maximise future contributions of fish to food security; and
2. increase the number of livelihoods that can be based on fishing, tourism and pond aquaculture.

The adaptations and suggested policies to achieve these plans under a changing climate are summarised below (see Section 3 for details).

Economic development and government revenue

Adaptation no. (Section 3.2)	Summary of adaptation	Supporting policy no. (Section 3.3)
E3	Immediate conservation management measures for bigeye tuna	E8
E4	Energy efficiency programmes for industrial tuna fleets	E9
E5	Environmentally-friendly fishing operations	
E7	Safety at sea	E10
E9	Pan-Pacific tuna management	E2

Food security

Adaptation no. (Section 3.4)	Summary of adaptation	Supporting policy no. (Section 3.5)
F1	Manage and restore vegetation in catchments	F1, F2, F18
F2	Foster the care of coastal fish habitats	F1–F3, F18
F3	Provide for landward migration of coastal fish habitats	F4, F5, F18
F4	Allow for expansion of freshwater habitats	F4, F18
F5	Sustain production of coastal demersal fish and invertebrates	F6, F7, F13, F18
F6	Diversify catches of coastal demersal fish	F6, F13, F18
F7	Manage freshwater and estuarine fisheries to harness opportunities	
F8	Increase access to tuna for urban and rural populations	F8–F13, F18
F9	Develop pond aquaculture to diversify the supply of fish	F13–16, F18
F10	Develop coastal fisheries for small pelagic fish	F13, F17, F18
F11	Improve post-harvest methods	F17, F18

Sustainable livelihoods

Adaptation no. (Section 3.6)	Summary of adaptation	Supporting policy no. (Section 3.7)
L1	Improve technical and business skills of communities	L1, L2
L2	Rebuild populations of sea cucumbers and trochus	L2
L3	Develop coral reef ecotourism ventures	L3
L4	Diversify production of coastal aquaculture commodities	L4, L5
L5	Modify locations and infrastructure for coastal aquaculture	L6