National State of Oceans and Coasts 2018:

Blue Economy Growth

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National State of Oceans and Coasts 2018:
Blue Economy Growth of Singapore

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Acronyms and Abbreviations

3P	–	People, Public, Private
3Rs	–	reduce, reuse, recycle
A*Star	–	Agency for Science, Technology and Research
AAEE	–	American Academy of Environmental Engineers
ABC Waters	–	Active, Beautiful, Clean Waters
ACES	–	Asia Clean Energy Summit
ACPT	–	Asian Conference on Energy, Power and Transportation Electrification
ACRES	–	Animal Concerns Research and Education Society
AGVs	–	Autonomous Guided Vehicles
AIS	–	Automatic Identification System
AMWQC	–	ASEAN Marine Water Quality Criteria
APEC	–	Asia-Pacific Economic Cooperation
ARL	–	Acoustic Research Laboratory
ASEAN	–	Association of Southeast Asian Nations
ASMI	–	Association of Singapore Maritime Industries
AWGCME	–	ASEAN Working Group on Marine and Coastal Environment
BCA	–	Building and Construction Authority
BIOME	–	Biodiversity and Environment Database System
BOD	–	biochemical oxygen demand
BOS	–	balance of system
BWMC	–	International Convention for the Control and Management of Ships' Ballast Water and Sediments
BWMP	–	Ballast Water Management Plan
BWRB	–	Ballast Water Record Book
BYO	–	Bring Your Own campaign
CAS	–	Coastal Adaptation Study
CAVS	–	Centre for Aquaculture and Veterinary Science at Temasek Polytechnic
CBD	–	Convention on Biological Diversity
CBEP	–	Capacity Building Executive Programme
CBPD	–	Central Building Plan Department
CCRS	–	Centre for Climate Research Singapore
CCTV	–	Closed Circuit Television System
CCZ	–	Clarion Clipperton Zone
CDC	–	Community Development Council
CDS	–	Catch Documentation Scheme
CIL	–	NUS's Centre for International Law
CIN	–	Community in Nature initiative
CITES	–	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMBS	–	Comprehensive Marine Biodiversity Survey
CME	–	coastal and marine environment
CMEPC	–	Policy Committee
COLREGS	–	International Regulations for Preventing Collisions at Sea
COMET	–	Committee for Marine Projects
COPEH	–	Code of Practice on Environmental Health
CREATE	–	Campus for Research Excellence and Technological Enterprise
CTWL	–	closing the waste loop
DA	–	Designated Authority
DGPS	–	Differential Global Positioning System
DO	–	dissolved oxygen
DTSS	–	Deep Tunnel Sewerage System
dwt	–	deadweight tonnes
EAS	–	East Asian Seas
ECM	–	Earth Control Measures
ECP	–	East Coast Park
EDB	–	Economic Development Board
EDI	–	electrodeionisation
EIA	–	Environment Impact Assessment
EIPO	–	Energy Innovation Programme Office
ELPs	–	SkillsFuture Earn and Learn Programmes
EMID	–	Ecological Monitoring, Informatics and Dynamics Lab
EMR	–	Ecological Mangrove Restoration
EOS	–	Earth Observatory of Singapore
EPHA	–	Environmental Public Health Act
EPHA	–	Environmental Public Health Act
EPI	–	Environmental Performance Index
ERI@N	–	Energy Research Institute @ NTU

ESS – Energy Storage System
FDWs – Foreign domestic workers
FPSO – Floating Production Storage and Offloading
FRSC – Future Ready Shipping Conference
FotP – Friends of the Parks
ft – foot; feet
GAP-FF – Good Aquaculture Practice for Fish Farming
GDP – gross domestic product
GFA – gross floor area
GHG – greenhouse gas
GNI – gross national income
GVA – gross value added
GWC – general waste collectors
ha – hectare
HABs – harmful algal blooms
HDB – Housing and Development Board
HDI – Human Development Index
HFT – Harbourfront Ferry Terminal
HNS – hazardous and noxious substances
HSBC – Hongkong and Shanghai Banking Corporation
IBA – Important Bird Area
IBWMC – International Ballast Water Management Certificate
ICM – integrated coastal management
ICOPCE – International Chemical and Oil Pollution Conference and Exhibition
ICS – Institute of Chartered Shipbrokers
IE Singapore – International Enterprise Singapore
IEEE – Institute of Electrical and Electronics Engineers
IFS – International Finance Scheme
IMCSD – Inter-Ministerial Committee on Sustainable Development
IMO – International Maritime Organization
IPCC – Intergovernmental Panel on Climate Change
IPT – International Passenger Terminal
ISA – International Seabed Authority
ISC – Information Sharing Centre
ISPS – International Ship and Port Facility Security Code
ITCP – IMO's Integrated Technical Cooperation Programme
ITE – Institute of Technical Education
ITM – Industry Transformation Map
IUCM – integrated urban coastal management
IUU – Illegal, Unreported and Unregulated Fishing
IV – intermediate verification
IVA – International Visitor Arrivals
IWMF – Integrated Waste Management Facility
JFP – Jurong Fishery Port
JTC – Jurong Town Corporation
kg – kilogram
km – kilometer
km^2 – square kilometer
kW – kilowatt
kWh – kilowatt-hour
L – liter
LED – light-emitting diode
LNG – liquefied natural gas
LNR – Labrador Nature Reserve
m – meter
m2 – square meter
m3 – cubic meter
M&OE – Marine and Offshore Engineering
MAC – Marine Aquaculture Centre
MARPOL – International Convention for the Prevention of Pollution from Ships
MAS – marker-assisted selection
MBS – Marina Bay Sands®
MBCCS – Marina Bay Cruise Centre Singapore
MBEL – Marine Biology and Ecology Laboratory
MCAP – Marine Conservation Action Plan
MEAP – Marine Emergency Action Procedure
MEPS – Minimum Energy Performance Standards
MESD – Centre of Excellence in Maritime Energy and Sustainable Development

MEWR – Ministry of the Environment and Water Resources
MINT – Maritime Innovation and Technology Fund
MOU – Memorandum of Understanding
MPA – Maritime and Port Authority of Singapore
MFA – Ministry of Foreign Affairs, Singapore
MND – Ministry of National Development
MOFA – Ministry of Foreign Affairs, Japan
MOM – Ministry of Manpower
MOT – Ministry of Transport
MPH – Mandai Park Holdings
MSGI – Maritime Singapore Green Initiative
MSRDP – Marine Science Research and Development Programme
MTI – Ministry of Trade and Industry
MWp – Mega Watt peak
NBC – National Biodiversity Centre
NBSAP – National Biodiversity Strategy and Action Plan
NCA – Natural Capital Assessment
NCCS – National Climate Change Secretariat
NCMP – Nature Conservation Masterplan
n.d. – no date
NEA – National Environment Agency
NGOs – non-governmental organisations
NGP – Next Generation Port
NHB – National Heritage Board
NOAA – National Oceanic and Atmospheric Administration
NParks – National Parks Board
NRF – National Research Foundation
NSS – Nature Society (Singapore)
NUS – National University of Singapore
O&G – oil and gas
OECD – Organisation for Economic Co-operation and Development
OHI – Ocean Health Index
OMS – Ocean Mineral Singapore Pte Ltd
OMS – Operational Management System
OPEC – Organization of the Petroleum Exporting Countries
ORE – ocean renewable energy
P&I – International Group Protection and Indemnity Clubs
PCD – Pollution Control Department
PCPs – Professional Conversion Programmes
PEMSEA – Partnerships in Environmental Management for the Seas of East Asia
PMETs – Professionals, Managers, Executives and Technicians
PMO – Prime Minister's Office
PORL – Physical Oceanography Research Laboratory
PPSA – Prevention of Pollution of the Sea Act
PPT – Pasir Panjang Terminal
PSA – Port of Singapore Authority
PUB – Public Utilities Board
PV – photovoltaic
PWCs – public waste collectors
R&D – research an development
RCAs – Research Collaboration Agreements
ReCAAP – Regional Co-operation Agreement on Combating Piracy and Armed Robbery Against Ships in Asia
REIDS – Renewable Energy Integration Demonstrator-Singapore
RFMOs – Regional Fisheries Management Organisations
RFP – Request for Proposals
RFT – Regional Ferry Terminal
RIE – Research, Innovation and Enterprise Plan
ROs – Recognised Organisations
RPOA-Capacity – Regional Plan of Action for the Management of Fishing Capacity
RPOA-IUU – Regional Plan of Action to combat Illegal, Unreported and Unregulated Fishing
RUM – Restore Ubin Mangrove
RV – renewal verification
SAOFFG – Southeastern Asia-Oceania Flash Flood Guidance
SBWR – Sungei Buloh Wetlands Reserve
SCELSE – Singapore Centre on Environmental Life Sciences Engineering
SCMA – Singapore Chamber of Maritime Arbitration
SCP – Singapore Cooperation Programme
SDA – Sewerage and Drainage Act
SDC – Sentosa Development Corporation
SDGs – Sustainable Development Goals
SDS-SEA – Sustainable Development Strategy for the Seas of East Asia

S.E.A.A. – South East Asia Aquarium
SEEA – UN System of Economic and Environment Accounts
SERIS – Solar Energy Research Institute of Singapore
SFP – Senoko Fishery Port
SGX – Singapore Exchange
SIDS – Small Island Developing States
SIMP – Sisters' Islands Marine Park
SIT – Singapore Institute of Technology
SIWW – Singapore International Water Week
SJADES – South Java Deep Sea Biodiversity Expedition
SJINML – St John's Island National Marine Lab
SL – subsidiary legislation
SLA – Singapore Land Authority
SLR – sea-level rise
SMART – Singapore-MIT Alliance for Research and Technology
SMEs – small- and medium-sized enterprises
SMEEU – Shipbuilding and Marine Engineering Employees' Union
SNA – System of National Accounts
SOC – State of Oceans and Coasts
SoCPF – Statement of Compliance of a Port Facility
SOLAS – International Convention for the Safety of Life at Sea
SOP – Standard Operating Procedure for Joint Oil Spill Combat in the Straits of Malacca and Singapore
SPA – Singapore Packaging Agreement
SRW – Singapore Regional Waters
SSG – SkillsFuture Singapore
SST – sea surface temperature
STB – Singapore Tourism Board
STRAITREP – Mandatory Ship Reporting System in the Straits of Malacca and Singapore
SWiMMS – Singapore Wild Marine Mammal Survey
SWITCH – Simple Ways I Take to Change my Habits
SWWD – Singapore World Water Day
TACs – trade associations and chambers
TCCME – Technical Committee on Coastal and Marine Environment
TCOMS – Technology Centre for Offshore and Marine Singapore
TEU – twenty-foot equivalent units
TMEC – Tropical Marine Energy Centre
TMFT – Tanah Merah Ferry Terminal
TMSI – Tropical Marine Science Institute
TR – Technical Reference
TSS – total suspended solids
TSS – Traffic Separation Schemes
TWRP – Tuas Water Reclamation Plant
ULL – Ubin Living Lab
UN – United Nations
UNCLOS – UN Law of the Sea Convention
UNCSD – United Nation Conference on Sustainable Development
UNCTAD – United Nations Conference of Trade and Development
UNDP – United Nations Development Programme
UNESCO – United Nations Educational, Scientific and Cultural Organisation
UNFCC – United Nations Framework Convention on Climate Change
UNWTO – UN World Tourism Organisation
URA – Urban Redevelopment Board
VLCC – very large crude carrier
VTIS – Vessel Traffic Information System
W&M – wind and marine
WELS – water efficiency labelling scheme
WHC – World Heritage Committee
WHO – World Health Organization
WMO – World Meteorological Organization
WOG – Whole-of-Government
WRS – Wildlife Reserves Singapore
WMRAS – Waste Management and Recycling Association of Singapore
WSG – Workforce Singapore
WTE – waste-to-energy
WTR – waste-to-resource
WWII – World War II
WWF – World Wide Fund
WWS – Waterways Watch Society

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- Ministry of Trade and Industry (MTI)
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- National University of Singapore (NUS)
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- Singapore Tourism Board (STB)
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EXECUTIVE SUMMARY

Background

The ministers of the East Asian Seas (EAS) Region adopted the **Da Nang Compact** during the EAS Congress 2015 held in Da Nang, Viet Nam in November 2015. One of its targets is the development of a Regional State of Oceans and Coasts (SOC) report. Singapore prepared this National State of Oceans and Coasts report as its contribution to the regional report. The regional and national SOC reports also aims to contribute to the assessment of development in blue economy, and monitoring of progress on the implementation of the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA), the UN Sustainable Development Goals (SDGs), other international agreements subscribed to by Singapore, and related national laws and policies on oceans and coasts.

The definition of blue economy is given in the **Changwon Declaration 2012**,[a] which was adopted by the ministers of the East Asian Seas (EAS) Region as a way to respond to the challenges of the changing environment and climate as well as fostering economic development through activities that reduce negative impacts on ocean health and communities.

Singapore's SOC Report aims to facilitate our understanding of the role of the ocean and its contribution to the national economy; impacts of human activities on ocean health and sustainability; potential areas for investments in environmentally-sound technologies and infrastructure; and the interventions and innovative mechanisms needed to respond to changing environment and climate. Knowing that sustainable use of the oceans is coupled with the UN Sustainable Development Goal (SDG) 14, Life Below Water, it is evident that preserving the health of our oceans is a fundamental prerequisite for business to operate in the long-term and by tackling the challenges of today.

The progressively intense and diversified use of Singapore's coastal and marine environment (CME) necessitates an integrated approach for effective coastal management and its sustainable use. The SOC Reporting mechanism is also employed to assess the overall effectiveness of Integrated Coastal Management (ICM) implementation. In this report, we look back over a five- to ten-year period to examine the latest trends in the state of our coasts and analyse how and why the CME is changing and whether these trends fit within the context of sustainability and the blue economy development. The report provides a comprehensive outlook of different areas of sustainable development that contribute to blue economy growth in Singapore.

[a] *"We understand the Blue Economy to be a practical ocean-based economic model using green infrastructure and technologies, innovative financing mechanisms, and proactive institutional arrangements for meeting the twin goals of protecting our oceans and coasts and enhancing its potential contribution to sustainable development, including improving human well-being, and reducing environmental risks and ecological scarcities."* (Changwon Declaration 2012).

The Seas and People of Singapore

Singapore is a small, heavily urbanised, island-state in Southeast Asia situated at the southern tip of the Malayan Peninsula between Malaysia and Indonesia. It is located between latitudes 1°09'N and 1°29'N and longitudes 103°3'E and 104°25'E, approximately 137 km north of the equator. Located between the Indian Ocean and the South China Sea, Singapore is bordered on the north by the narrow Johor Strait, which separates it from Peninsular Malaysia, and on the south by the Singapore Strait (**Figure 1**). Johor Strait is divided into East and West Johor Straits by the Singapore-Malaysia causeway. The Strait receives water mainly from Sungai Johor and Sungai Pulai, both located in Malaysia.

Singapore consists of one main island and over 60 smaller islands and islets, with a total land area of approximately 719.9 square kilometres (km^2) by end of 2017 (Department of Statistics, 2018). After Singapore Island itself, the subsequent largest islands are Pulau Tekong Besar to the northeast (25.5 km^2), Pulau Ubin (10.2 km^2), and Sentosa (5 km^2). The coastline of the main island stretches 197 km. The area of Singapore's territorial seas up to 12 NM is 744 km^2.[b]

Biogeographically, Singapore is enclosed between two of the largest marine ecoregions[c] of the world – the Western Indo-Pacific and Central Indo-Pacific regions (Spalding, et al., 2007) – and additionally sits near the Coral Triangle.

Singapore can be divided into three major areas – the central hilly area; the western undulating area; and the eastern coastal area consisting of alluvium and sediment. Singapore currently has four legally-gazetted Nature Reserves and another 20 administratively protected Nature Areas that cover the majority of natural habitats, such as primary dryland forest, tall secondary forest, freshwater swamps, rocky shores, mangroves, mudflats, seagrass beds, and coral reefs. The Singapore River, located within the central region of the island, is the principal river of Singapore, and measures 3.2 km in length from its mouth to Kim Seng Bridge (Savage, et al., 2004).

The shape of the coastline together with the adjacent deep waters gives rise to Singapore's natural harbour. Singapore is at the south entry of the Malacca Straits, which is along the main shipping route between Europe and the Far East.[d] Due to its strategic location, the nation's trade and economy are highly dependent on the maritime industry. Its well-sheltered deep harbour makes it an excellent stopover port for a wide variety of economic maritime trade.

Population. The population growth rates in Singapore have remained relatively low and stable over a 3-year time period. As of end of June 2017 total population of Singapore was 5.61 million, an

[b] The data are taken from Earth Trends Environmental Information of the World Resources Institute http://earthtrends.wri.org/text/coastal-marine/variable-56.html, and derived from L. Pruett and J. Cimino, unpublished data, Global Maritime Boundaries Database (GMBD), Veridian - MRJ Technology Solutions (Fairfax, Virginia, January, 2000).

[c] Marine ecoregions (ecological region) are areas of relatively homogenous species composition, clearly distinct from adjacent systems. The species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features. (Spalding et al., 2007).

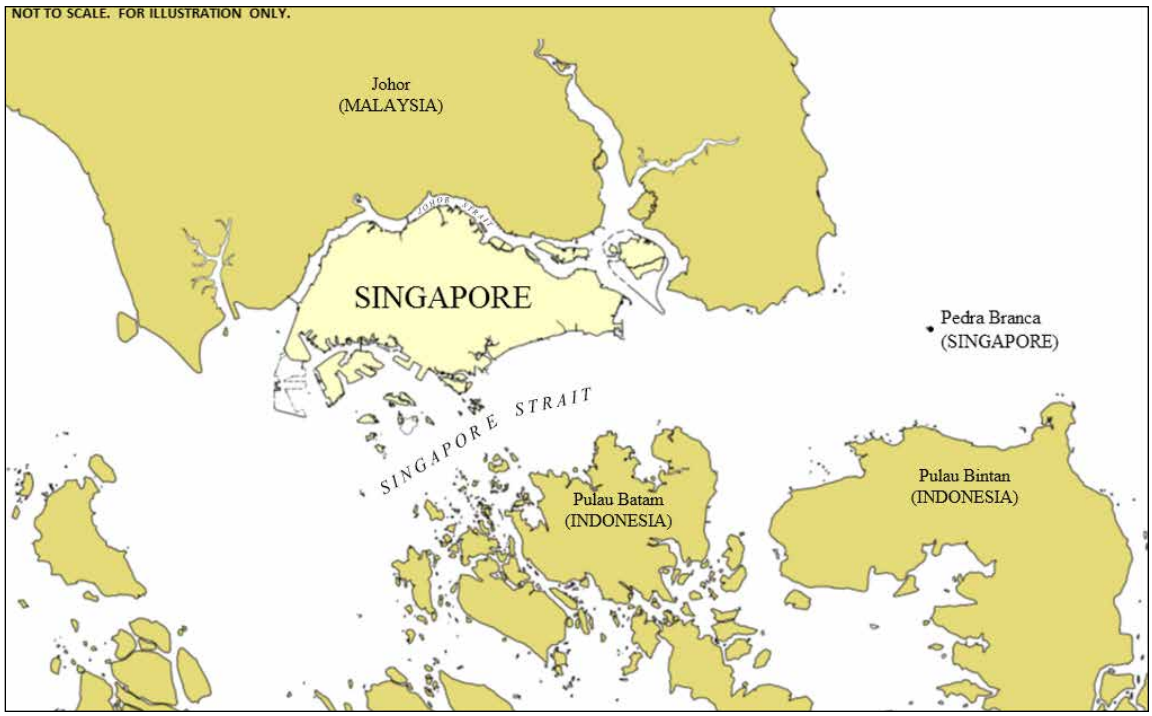
[d] Chia, L.S. & Ong, L.C., 2011. The Coastal Profile of Singapore. National Parks Board, Singapore.

increase of 1.3% from previous year's period. This figure comprises of resident population (citizen and permanent residents) and non-resident population.

Economy. Singapore industrialised through an import substitution strategy to reduce its reliance on entrepôt trade. Various economic agencies were established to spearhead different aspects of economic development, such as the Economic Development Board (EDB) in 1961, and the Singapore Tourism Board (STB) in 1964. From 1960 to 1964, Singapore's gross domestic product (GDP) growth averaged 5.2% per annum (p.a.). This later increased significantly between 1965 and 1978, when Singapore's GDP growth averaged 10% p.a., with the manufacturing sector's share of GDP growing rapidly from 14% to 24%. This was largely due to the adoption of an export-oriented strategy by attracting foreign investors to Singapore to develop the manufacturing and financial sectors. In 2017, Singapore's GDP amount to around US$310 billion (in constant 2010 US$ prices).[e]

Human development. Singapore's human development index (HDI) value for 2017 is 0.932—which put the country in the very high human development category—positioning it at 9 out of 189 countries and territories. In 2017, gross national income (GNI) per capita was US$ 82,503 (at 2011 PPP prices); life expectancy at birth was 83.2 years; mean years of schooling were 11.5 years; and expected years of schooling were 16.2 years.[f]

Figure 1: Map of Singapore.



Source: MPA

[e] World Bank. World Development Indicators. https://data.worldbank.org/country/singapore

[f] UNDP. 2018. Human Development Indices and Indicators: 2018 Statistical Update. (http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/SGP.pdf).

Table 1: Singapore: Geographic and Socioeconomic Indicators.

Indicator	As of 2017
Land area[1]	719.9 square kilometres (km^2)
Coastline[1]	209 km (as of January 2019)
Population[2]	5.61 million
Population density[2]	7,797 per km^2
Coastal population[3]	100% of total population (entire population live within 100 km of the coasts)
Ocean economy[3]	7% of GDP (shipping, port, and offshore and marine engineering sectors, and maritime services)
Employment in ocean economy[3]	170,000
Estimated value of coastal and marine ecosystems	n.a.
Percentage of coastline with ICM[3]	100% (integrated urban coastal management)
Marine protected area[2] (percentage of territorial waters)	1.5%
Ocean health index (OHI)[4]	59 (rank at 183 among 221 countries and territories.)
Gross domestic product[2] (GDP, in constant 2010 US$ prices)	US$310 billion
Human development index (HDI)[5]	0.932—very high human development category—Singapore ranks 9 out of 189 countries and territories
Gross national income (GNI) per capita[5] (at 2011 PPP prices)	US$ 82,503
Access to safely managed water supply[2]	100%
Access to safely managed sanitation[2]	100%

Sources:
1 *Singapore Land Authority (SLA)*
2 *World Bank. World Development Indicators. https://data.worldbank.org/country/singapore*
3 *NParks estimates*
4 *www.oceanhealthindex.org/region-scores/scores/singapore.*
5 *UNDP. 2018. Human Development Indices and Indicators: 2018 Statistical Update. http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/SGP.pdf.*

Singapore's Ocean Economy

The marine and coastal areas of Singapore are widely used for an array of industries comprising shipping, transportation, petroleum, and petrochemical manufacturing, in addition to non-industrial activities, such as residential development and recreational usage. Singapore's maritime industry is a key pillar of Singapore's economy. Made up of shipping, port, maritime services, and offshore and marine engineering sectors, Singapore's maritime industry contributes 7% of Singapore's GDP, and employs over 170,000 people.

Valuation of Ecosystem Services

The Natural Capital Singapore project was initiated on 1 January 2018 to conduct the country's first national assessment of the natural capital and ecosystem services, and the first assessment for a

tropical, heavily urbanized country. By quantifying Singapore's Natural Capital, this three-year project will help government agencies and other stakeholders to assess the trade-offs between urban development and environmental concerns, and to make more informed policy and management decisions. Led by the Singapore-ETH Centre and Department of Geography at NUS, the project brings together a multi-disciplinary team from ETH Zurich, NUS, Nanyang Technological University (NTU), Singapore-MIT Alliance for Research and Technology (SMART) and NParks. The assessment will provide the first national-scale baseline of the status of Singapore's ecosystems and the first estimate of their societal and economic values.

Transforming to Blue Economy

The blue economy, as discussed during the East Asian Seas (EAS) Congress 2012, refers to a sustainable ocean-based economic model; one that employs environmentally-sound and innovative infrastructure, technologies, and practices, including institutional and financing arrangements, for meeting the goals of: (a) sustainable and inclusive development; (b) protecting our coasts and oceans, and reducing environmental risks and ecological scarcities; (c) addressing water, energy, and food security; (d) protecting the health, livelihoods, and welfare of the people in the coastal zone; and (e) fostering ecosystem-based climate change mitigation and adaptation measures. **Table 2** shows the developments in ocean economic activities, and new trends in blue economy.

Table 2: Ocean Economy and Developments in Blue Economy.

Ocean economy	Blue Economy Initiatives
Made up of shipping, port, offshore and marine engineering (manufacture and repair of ships, boat, marine engines, oil rigs, oil field and gas field machinery and equipment), and maritime services sectors, **Singapore's maritime industry contributes 7% of Singapore's GDP** and **employs over 170,000 people**.	**Sustainable ports** • **Maritime Singapore Green Initiative** (MSGI): consists of 5 programmes: Green Ships, Green Ports, Green Technology, Green Awareness, and Green Energy. - Green Port Programme: As of end Oct 2018, more than 4,500 vessel calls switching to marine fuel with sulphur content not exceeding 1% in 2016. - As of 2018, 108 companies have voluntarily signed the Green Pledge to demonstrate their commitment in promoting clean and sustainable shipping in Singapore. - As of end of October 2018, 479 Singapore-flagged ships qualified for the Green Ship Programme. • **LNG bunker-ready port**: Committed to providing a broad range of fuel solutions, including LNG, to meet the future energy needs of the global shipping industry; Embarked on a three-year LNG bunkering pilot programme from 1 January 2017, in preparation for the wider adoption of LNG as a marine fuel; Working with eleven other ports to establish a global network of LNG bunker ready ports. • **Ballast water management**: Singapore provides ballast water sediment reception facilities in ports and terminals where the cleaning and repair of ballast tanks occur.
Ports and shipping Port of Singapore is the world's top transhipment hub and the second busiest container port.	
Coastal and marine tourism Singapore's cruise industry directly contributed US$515 million to the nation's economy in 2016.	**Sustainable tourism** • Ecotourism, nature reserves and marine parks • Dive trails at Sisters' Islands Marine Park: responsible diving protocols • Guided bird-watching tours and workshops are organized at the Sungei Buloh Wetland Reserve during the migratory season between September and March.

Ocean economy	Blue Economy Initiatives
Fisheries and aquaculture About 1,108 tonnes of wild caught fish were harvested from Singapore fisheries by the local commercial fleet in 2017. Aquaculture production in 2017 was 5,390 tonnes.	**Biotechnology and aquaculture** • Application of Recirculation Aquaculture Systems technology, with culture protocols, development of closed containment systems for coastal fish farms • Selective breeding technology for development of faster-growing fish
Energy	**Marine renewable energy technology** • Target of reducing greenhouse gas emissions by 36% compared to 2005 levels by 2030. • Green-e Renewable Energy Standard and Green-e Energy certification of renewable energy. • Ocean renewable energy (ORE): research, development of test bedding sites for tidal power.
Water	**Desalination** • Three desalination plants, with two more in the pipeline to be completed by 2020. • Focus on technological improvements to reduce energy use and cost **Wastewater treatment and water reclamation** • **100% of wastewater is collected and treated.** • **Reuse of treated wastewater: NEWater**, or Singapore's brand of ultra-clean high-grade reclaimed water, is the pillar of its water sustainability and water security.
	Solid waste management measures • **All waste is collected and treated**; promotion of 3Rs (reduce, reuse, recycle) • Singapore aims to achieve an overall national recycling rate of 70% by 2030 as part of the Sustainable Singapore Blueprint 2015. The ultimate goal is to work towards becoming a Zero Waste Nation. • All incinerable waste that is not recycled is incinerated at **waste-to-energy plants** to reduce the waste volume by 90%, and produce energy. • Only non-incinerable waste that is not recycled is sent to the Semakau Landfill. • Reduction of packaging waste through the **Singapore Packaging Agreement**.
	Habitat restoration and management • **Mangrove rehabilitation and coastal protection**: innovative combination of hard and soft engineering solutions to arrest coastal erosion, and restore mangrove areas; Pulau Tekong coastal protection project • **Marine and coastal parks**. Four Nature Reserves (3,347ha), over 400 parks and the park connector network (2,792ha), with an overall total area of around 15,570 ha. In 2016, the marine and coastal parks and reserves cover an area of 1721.39 ha. The Sisters' Islands Marine Park is Singapore's first marine park. • **Coral restoration and conservation**: Coral colonies are grown in a nursery and transplanted back onto the degraded reefs. • **Endangered species recovery**: to safeguard the survival and sustainability of species native to or of particular significance, e.g., marine turtles, giant clams, etc.

1. Maritime industry

1.1 Maritime Services

Singapore offers a comprehensive range of both technical and commercial maritime services, such as finance, broking, insurance, surveying, legal and arbitration services.

1.2 Ship-Building and Offshore and Marine Engineering.

Shipyards are mostly located at the western part of Singapore. There are smaller operations located in other parts of Singapore. The maritime manufacturing output in 2016 was S$13.1 billion.[g] The total value added was S$3.8 billion in 2016, about 0.9% of Singapore's GDP.[h]

1.3 Ports and shipping

The Port of Singapore includes terminals located at Tanjong Pagar, Keppel, Brani, Pasir Panjang, Sembawang and Jurong. They can accommodate all types of vessels, including container ships, bulk carriers, ro-ro ships, cargo freighters and coasters. The terminals are managed by two commercial port operators, PSA Singapore Terminals, which manages the major share of container handling in Singapore, and Jurong Port Pte Ltd, which is Singapore's main bulk and conventional cargo terminal operator.

Pressures and threats

- Singapore is the world's top transhipment hub and the second busiest container ports.[i] Every year, Singapore attracts 140,000 vessel calls, a large number of which are carrying crude oil or related cargo. With heavy vessel-traffic amidst limited sea space, the Straits of Singapore and the waters in its vicinity are prone to maritime accidents. In the period 2009-2014, there were several accidents, which resulted in major oil spills. An incident in May 2010 resulted in approximately 2,500 tonnes of light crude spilled, affecting biodiversity-rich areas, such as Tanah Merah and Pulau Ubin.
- Apart from oil spills, Singapore's status as one of the busiest ports in the world also gives rise to other threats, such as ship groundings and other navigation-related impacts like erosion from ship wake. In order to maintain shipping fairways and anchorages, the Maritime and Port Authority of Singapore (MPA) conducts dredging operations in order to maintain the required depth for ships. The high volume of ship traffic also generates waves that potentially cause erosion along our shores, particularly those of the islands located off the southern coast.

[g] Values are calculated using aggregated total of the following SSICs: 1) Manufacture and repair of marine engine, 2) Manufacture and repair of oil rigs, 3) Manufacture and repair of other oil field and gas field machinery and equipment, and 4) Building of pleasure boats and sporting boats.

[h] 2016 GDP at Current Market Prices: S$428 billion.

[i] Sin, T.M., Ang, H.P., Buurman, J., Lee, A.C., Leong, Y.L., Ooi, S.K. and Teo, S.L.M. 2016. The Urban Marine Environment of Singapore. Regional Studies in Marine Science.

Response

- **Sea Transport Industry Transformation Map (ITM)**. MPA, in partnership with the industry, unions and other government agencies, developed the Sea Transport ITM, which was launched in January 2018. The Sea Transport ITM builds upon MPA's strategic, long-term plans to develop Singapore's next-generation port, and strengthen the international maritime centre, with an aim to grow the sector's value added by S$4.5 billion and create more than 5,000 good jobs by 2025.
- **Oil spill contingency plan and response**. MPA has in place the Marine Emergency Action Procedure (MEAP) to deal with marine incidents effectively. To test and demonstrate Singapore's readiness to respond effectively to marine incidents, emergency exercises are conducted regularly. The Oil Spill Contingency Plan is a supplement to the MEAP. In dealing with incidents involving bulk chemicals, hazardous and noxious substances (HNS) carried by ship at sea and at terminals, MPA has developed the Chemical Contingency Plan (Marine), which is also a supplement to the MEAP. It is jointly implemented with government agencies. As the impact of oil spills may be transboundary, there is also a Standard Operating Procedure for Joint Oil Spill Combat in the Straits of Malacca and Singapore (SOP) set by the Revolving Fund Committee, comprised of the littoral States of Indonesia, Malaysia and Singapore. The SOP, which was drawn up following the establishment of the Revolving Fund, covers areas such as the response areas and division of responsibility among the littoral States, communication and information sharing procedures, inter-state assistance, and reimbursement procedures.
- **Aids to Navigation**. The Hydrographic Department of MPA manages the operation and maintenance of five lighthouses and a few hundred beacons, navigational buoys and mooring buoys. An integrated wireless monitoring system is employed to ensure that the lanterns of the lighthouses are operational. It also operates a Differential Global Positioning System (DGPS) broadcast service to enhance navigational safety in our port waters and the Singapore Strait. MPA also ensures accurate charting of our waters and the timely distribution of updated hydrographic information to enable ships to navigate safely in our busy waterways.
- **MPA's Vessel Traffic Information System (VTIS)** allows the tracking of vessels' movements in the port waters and Singapore Strait in real time. It integrates information from various sources such as radar, Automatic Identification System (AIS), Maritime Communication System, Closed Circuit Television System (CCTV) and ship databases into one system to communicate and monitor vessels' movements. The VTIS enables MPA to provide timely information and advice to help vessels transit safely through the Singapore Strait, as well as manage traffic within our port waters.
- **Addressing pollution from ships**. Singapore is party to all six Annexes of the International Maritime Organisation (IMO)'s MARPOL convention, the main international convention covering prevention of pollution of the marine environment by ships. In Singapore, MARPOL

is implemented under the Prevention of Pollution of the Sea Act (PPSA) and its associated regulations, which provide powers to impose fines of up to $1 million or imprisonment terms of up to two years, or both, for non-compliance with MARPOL. The regulations are applicable to: (i) Singapore-registered ships wherever they may be; and (ii) foreign-registered ships in Singapore waters.

- **Port reception facilities for garbage collection**. Singapore provides daily reception facilities from 0730 hours to 1730 hours for the collection of garbage from ships in the anchorages. Five garbage collection crafts are deployed to pick up garbage from ships. No additional fees are collected from ships for disposal of garbage unless special requests to dispose garbage at a specific timing and location are made where S$900 will be charged.
- **Ballast water management**. Singapore has acceded to the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWMC) which came into force internationally on 8th September 2017. Like MARPOL, the BWMC is administered through the Prevention of Pollution of the Sea Act (PPSA). All applicable Singapore-registered ships of 400 gross tonnes and above (excluding floating platforms, floating storage units and floating production storage and offloading units) are required to carry the following on board:
  - International Ballast Water Management Certificate (IBWMC);
  - Ballast Water Management Plan (BWMP) approved by Recognised Organisations on behalf of MPA; and
  - Ballast Water Record Book (BWRB).

  As part of the BWMC obligations, Singapore is required to provide for ballast water sediment reception facilities in ports and terminals where the cleaning or repairs of ballast tanks occurs.

2. Coastal and marine tourism

Singapore has transformed from a humble trading post to a major player in the global tourism arena for its world-class attractions, rich heritage and innovative infrastructure.

The statistics on tourism are provided for the whole of Singapore and do not differentiate between those patronising coastal tourism facilities and establishments from others that do not. In 2016, Singapore's international visitor arrivals increased by 7.7% to 16.4 million, with tourism receipts recording S$25.7 billion. The direct contribution of travel and tourism to GDP was S$17.1 billion (US$12.4 billion) or 4.3% of total GDP in 2016.[j] The total contribution of travel and tourism to GDP was S$39.7 billion (US$28.7 billion) or 9.9% of GDP in 2016. Moreover, travel and tourism directly supported 164,000 jobs (4.5% of total employment).

[j] WTTC (2017). Travel and Tourism Economic Impact 2017 Singapore.

2.1 Marine and coastal parks

NParks manages the four Nature Reserves (3,347ha), over 400 parks and the park connector network (2,792ha), with an overall total area of around 15,570 ha.

2.2 Cruise tourism

Singapore hopes to benefit from a rise in cruise tourism, after the joint Association of Southeast Asian Nations (ASEAN) Declaration on Cruise Tourism, led by Singapore – the ASEAN lead coordinator for cruise development – was officially adopted at the ASEAN Tourism Forum in January 2018 in Chiang Mai, Thailand. Singapore's cruise industry directly contributed S$706 million to the nation's economy in 2016, marking a 36% rise from 2010 (Singapore Tourism Board, 2016/2017). This figure excludes the indirect spending on land by establishments specifically catering to cruise tourists. In 2017, there were 421 ship calls, and the cruise passenger throughput was 1.38 million. Currently, Singapore has two cruise terminals, Singapore Cruise Centre at Harbourfront, and the Marina Bay Cruise Centre Singapore.

Threats and pressures

With the continued exponential growth of tourism, impacts of mass tourism, and the sustainability of this increase are at the forefront of many government agencies.

Response

In Singapore's urban context, multiple agencies work together to ensure the tight management of any potential impacts of mass tourism for the small island nation. While STB is responsible for sustainable tourism at the national level; other agencies responsible for the planning and management of sustainable resources in Singapore include the Urban Redevelopment Board (URA), Sentosa Development Corporation (SDC), NParks, and the National Heritage Board (NHB). Furthermore, aspects of environmental protection relating to tourism, in terms of creating and enforcing environmentally-sensitive polices, lie under the purview of the Ministry of Environment and Water Resources (MEWR), together with its two statutory boards, NEA and the Public Utilities Board (PUB). Maritime and Port Authority of Singapore (MPA) is the lead agency responsible for the protection of the marine environment from ship-based sources of pollutants, and enforces the requirements of the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL Convention) in Singapore waters.

3. Fisheries, aquaculture and fish ports

Singaporeans consume about 21 kg of seafood yearly. In 2017, Singaporeans consumed around 120,013 tonnes. Of which, local seafood production accounts for about 4% of local seafood consumption.

3.1 Fisheries

Singapore has a small commercial fishing fleet of seven offshore vessels and one inshore vessel, all of which are less than 24 m in length. All commercial fishing vessels in Singapore are licenced to conduct fishing activities within Singapore waters, and are Singapore-owned and operated. Singapore also has a high-seas plying fish carrier that receives transhipment of fish from foreign flagged fishing vessels operating in Regional Fisheries Management Organisations (RFMOs)-managed waters. All fish caught by Singapore's fishing vessels are consumed domestically. About 1,235 tonnes of wild caught fish were harvested from Singapore fisheries by the local commercial fleet in 2016. Singapore fishing industry receives no government subsidies for the conduct of fishing activities.

3.2 Aquaculture

The main bulk of foodfish production comes from coastal farming in floating net cages along the Strait of Johor. There are currently 114 coastal fish farms (figures as of Jun 2018). Common cultured marine foodfish species include Seabass (Lates calcarifer), groupers (Epinephelus spp.), snappers (Lutjanus spp.), milkfish (Chanos chanos) and mullet (Mugil spp.). Green mussel (Perna viridis) forms the bulk of shellfish production in Singapore.

3.3 Fish ports

Singapore has two fish ports – Jurong Fishery Port and Senoko Fishery Port – providing 24-hour service daily to foreign and local fishing vessels for bunkering, discharging and transhipment of fish. Apart from locally-caught seafood, the two fish ports handled 14% of Singapore's imported seafood in 2017. Both ports enforce the Wholesome Meat and Fish Act, and the Fisheries Act, and their respective subsidiary legislations.

Threats and pressures

There is limited fishing pressure and capacity in Singapore due to the small fishing fleet. However, aquaculture farms today are facing the threats from harmful algal blooms (HAB) and climate change.

Response

- **Addressing Illegal, Unreported and Unregulated (IUU) Fishing**. IUU fishing has emerged as a food security challenge. Singapore has been a signatory to the Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated Fishing in the Region (RPOA-IUU) since 2007. The RPOA-IUU is a voluntary instrument whose objective is to enhance and strengthen fisheries management in the region, in order to sustain fisheries and marine resources and to optimise the benefits of adopting responsible fishing practices.

  As a significant transhipment hub, Singapore plays a central role as a trading and distribution hub for fishery products. Internationally, Singapore cooperates with RFMOs through their Catch Documentation Scheme (CDS) for the trade in RFMO fish species to ensure that they do not come from IUU fishing.

  Commercial fishing vessels and the types of fishing gear used are licenced and renewed annually. Locations of commercial fishing activities and all seafood caught on Singapore's commercial fishing vessels are monitored, recorded and shared by the fishing vessels.

- **Addressing HABs. For HABs**, a multi-pronged approach was established to help the industry mitigate its effects. This includes working with research institutions to better understand local HAB species, training farms to develop contingency plans to reduce environmental stressors, and close monitoring of water quality. For longer-term solutions, which would also negate effects from oil spills and climate change, coastal farms are encouraged to adopt the Closed Containment Aquaculture Systems as effective and bio-secure production methods.

- **Ensuring safety, quality, and sustainability**. To improve the standard and sustainability of the aquaculture industry, the Agri-Food and Veterinary Authority of Singapore (AVA) launched the Good Aquaculture Practice for Fish Farming (GAP-FF) scheme in 2014. GAP-FF is a set of guidelines that were developed with reference to internationally-recognized standards, and adapted to ensure they are relevant to the local farming industry. The objective of the GAP-FF scheme is to promote responsible management practices in food fish farming as well as to provide assurance to both retailers and consumers by setting the benchmark for the production of safe and quality fish.

State of Ocean Health Underpinning the Blue Economy

1. Water Quality

At present, Singapore references the ASEAN Marine Water Quality Criteria (AMWQC) and ASEAN Long-Term Goals to benchmark the country's coastal and inland water quality. Individual agencies have also adopted guidelines for specific beneficial uses in line with those of international organisations. Given Singapore's limited water resources, it is critical that water pollution and quality are carefully monitored and regulated. The Pollution Control Department (PCD) of the National Environment Agency (NEA) regularly monitors the water quality of various inland water bodies and coastal areas (**Table 3**). The water quality of the catchment and non-catchment areas remained 'good' in 2017.

Table 3: Monitoring Result of Inland Waters.

Parameters Monitored	Year	Water Catchment Streams (% of time)	Non-water catchment rivers/streams (% of time)
Dissolved Oxygen (>2mg/L)	2016	99%	95%
	2017	97%	100%
Biochemical Oxygen Demand (<10mg/L)	2016	97%	92%
	2017	98%	95%
Total Suspended Solids (<200mg/L)	2016	100%	95%
	2017	100%	98%

Source: NEA

Regular water samples are collected from various sampling points along the Straits of Johor and the Straits of Singapore. The water samples are analysed for physical, chemical and microbiological parameters. The monitoring results for *Enterococcus* counts under the coastal water quality monitoring programme are shown in **Table 4** below.

Table 4: Monitoring Results of Coastal Waters.

Parameters Monitored		Straits of Johor East (% of time)	Straits of Johor West (% of time)	Straits of Singapore (% of time)
Enterococcus Count (<200 per 100 ml)	2016	98%	97%	98%
	2017	97%	94%	100%

Source: NEA

NEA also introduced guidelines for recreational water quality at beaches and freshwater bodies in 2008. Under the guidelines, primary contact activity is only allowed when the 95th percentile Enterococcus bacteria counts in the beach water do not exceed 200 counts per 100 ml. Under the

annual water quality review carried out in 2017, all seven beaches (Sentosa Island, Seletar Island, Sembawang Park, Changi, East Coast Park, Pasir Ris and Punggol) met the guidelines and were graded as "Good".

Pressures and threats

The pressures affecting Singapore include sewage, industrial effluents, urban/river runoff, nutrients, oil spills, marine litter, polycyclic aromatic hydrocarbons (PAHs), sediments, and physical alteration of coastal and marine habitats.

Response

NEA ensures that solid waste is properly collected and treated, and that there is no illegal dumping of solid waste and toxic industrial wastes. The Public Utilities Board (PUB) administers the Sewerage and Drainage Act (SDA), and the Sewerage and Drainage (Trade Effluent) Regulations for the treatment and discharge of domestic and industrial wastewater into public sewers, respectively. For industries, pollution prevention starts at the planning stage and appropriate zoning of land uses. Discussions are held with NEA to establish if the pollution that ensues from new industries can be controlled. Only industries that can demonstrate their ability to manage, store and dispose of their toxic wastes effectively are allowed to be established.

2. Coastal and Marine Ecosystems and Biodiversity

Located within the Sundaland biodiversity hotspot, Singapore has a rich array of native biodiversity in numerous habitats ranging from dryland forest, tall secondary forest to coastal habitats like freshwater swamps, rocky shores, mangroves, mudflats, seagrass beds, and coral reefs.

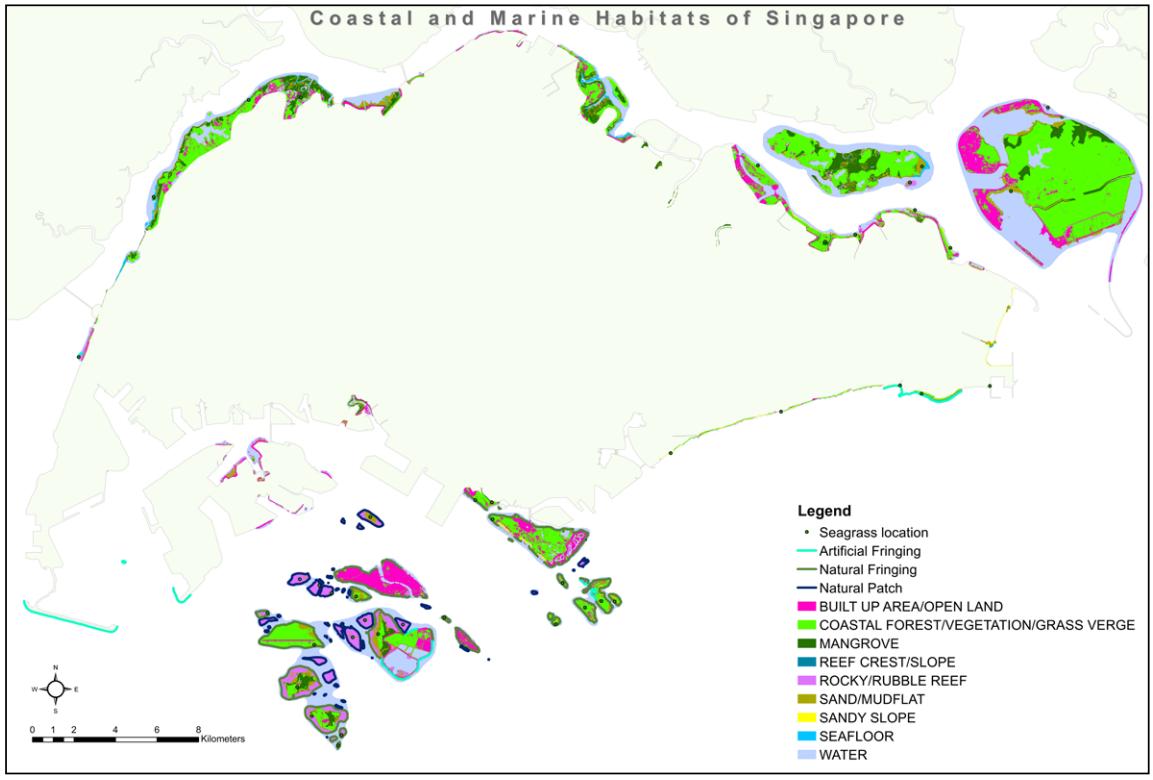
The northern shores and northern offshore islands are where the largest patches of mangrove forest are found. The northern shores are also characterized by vast area of sand and mudflats since it receives sediments from small rivers in Singapore and from Sungai Johor and Sungai Pulai. Sandy beaches, and reef-dominating habitats are found in the south. Patch reefs and fringing reefs are the common features of the southern islands. Seagrass meadows are also found in many intertidal areas both north and south of the coasts. Man-made habitats, such as lagoons and seawalls, also contribute towards biodiversity in Singapore's urban context. The main coastal and marine habitats in Singapore occur in the supra-tidal, intertidal and subtidal zones. **Figure 2** shows the distribution and location of these habitats. The state of Singapore's coastal and marine habitats, and the pressures and threats they are facing are described in **Table 5**.

Table 5. Status of Singapore's Coastal and Marine Habitats.

Habitat	Area (km^2)	Status
Mangroves	6.59	Singapore currently has some 35 'true' mangrove plant species, which comprise more than half of the 70 'true' mangrove species found in Asia Mostly occurring along the northern shores and several off-shore islands of Singapore, the remaining forests are estimated to comprise a total area of 6.59km. The largest patches of mangrove are found at Sungei Buloh Wetland Reserve, Pulau Ubin, and Pulau Tekong. While mangrove diversity is high, species are usually represented by small population numbers. About 45 per cent of mangrove species are currently considered endangered or critically endangered. Pressures and threats. Development pressures, such as damming up of rivers (to form reservoirs) and canalisation of streams or waterways, land reclamation and natural degradation such as coastal erosion have resulted in the reduction of mangrove forest, which in turn drive out species dependent on mangrove habitats for survival. The threat of rising sea levels may also inundate coastal areas and mangroves.
Coral reefs (sub-tidal)	1.26	Coral reefs consist of fringing and patch types, with live coral cover ranging between 10 to 60 per cent of existing reefs. There are about 250 species of hard coral from 55 genera which accounts for more than 25 per cent of the world's coral species. The reefs support over 120 species of reef fish and undetermined number of gorgonians, nudibranchs and other invertebrates. Synchronised mass spawning of corals has been observed at Singapore reefs (Guest, et al., 2002) indicating that the reefs are healthy and breeding. Pressures and threats. Threats to coral reefs are coastal development, modifications and climate change. Urban development pressure along Singapore's coast in the past decades has decreased the coral reef cover by about 60 per cent (Chou, 2016; Burke, et al., 2002).
Intertidal (including seagrass, mudflats, reef flats, rocky shores, and sandy beaches)	15.84	Due to Singapore's semi-diurnal tides, the plants and animals in the intertidal areas are exposed to the air twice a day. The communities experience a wide range of stresses associated with tidal range and wave action. Rocky shores used to dominate the southwestern coastline and some southern islands of Singapore, but much of it has been reclaimed. The coastline along the northern shore consists predominantly of sandflats and mudflats. Singapore's seagrass species diversity is relatively high with 12 out of the total 23 Indo-Pacific species. The larger seagrass meadows are currently found at Chek Jawa on Pulau Ubin, Pulau Semakau and Cyrene Reef. Pressures and threats. Development pressures and coastal modifications continue to be the main threats to Singapore's remaining intertidal habitats. Sedimentation and water clarity issues stemming from coastal works also threaten the marine biodiversity in Singapore's waters.

Source: NParks

Figure 2: Coastal and Marine Habitats of Singapore.



Source: NParks

Governance Structure Supporting Blue Economy

There is a strong legal framework in Singapore, with several ICM enabling laws. In hierarchical order, Singapore's legislative system consists of the Constitution of the Republic, followed by the Acts enacted by Parliament, and the subsidiary legislations (such as regulations).

There are 19 Statutory Boards/Divisions from eight Ministries and one Organ of State with specific interests, policies and strategies with regards to the governance or use of the coastal and marine environment. The general interests and role of key Ministries and Agencies pertinent to Singapore's CME are summarized in **Table 6**.

Table 6: Key Government Stakeholders of Singapore's Coastal and Marine Environment.

Ministry	Agency/Division/ Department	Current interests / roles relating to CME
Attorney-General's Chambers (AGC)	International Affairs	Provide legal advice on international law, represents the state at various international platforms, translates international obligation into domestic legislation. Facilitates policy and legislation relating to international/multilateral obligations
	Legislative Division	Drafts and vets government bills and laws to empower government departments and statutory boards
Ministry of the Environment and Water Resources (MEWR)	International Relations Division	National Focal point for most environment international agreements and arrangements, represents Singapore at international fora and meetings
	NEA	Environment protection. Key strategies adopted include control of land based source to prevent pollution to the marine environment, monitoring of the inland and coastal waters to assess the adequacy and effectiveness of the water pollution control programmes
	PUB	Integrated freshwater management. Manages and regulates the freshwater environments and Singapore's water supply
Ministry of Foreign Affairs (MFA)	Directorates	Safeguards the strategic interests of Singapore relating to CME issues. Ratification of multilateral and international conventions relating to the environment. Provides directions with regards to Singapore's strategic positioning in CME affairs
Ministry of Home Affairs (MHA)	PCG	Provides and enforces maritime security
	SCDF	Provides humanitarian service and emergency responses in the event of fires and disasters
Ministry of National Defense (MINDEF)	SAF	Uses and manages the Live Firing Islands, enforcement of maritime security and terrorist deterrent
	RSN	Secures the sovereignty of Singapore's waters. Enforcement of maritime security and security and terrorist deterrent
Ministry of Law (MINLAW)	SLA	Manages state lands including those of the CME and the foreshore
Ministry of National Development (MND)	NParks	Manages natures reserves, including coastal nature reserves, and coastal and marine parks. NParks is also a scientific authority on nature conservation, natural heritage conservation in all ecosystems
	URA	Carries out land use planning, regulates developments, and facilitates and coordinates the EIA process
	BCA (Coastal Protection Department)	Appointed as lead agency to carry out strategic studies in response to Sea-Level Rise
	AVA	Licencing of marine fish farms in designated fish farming sites and regulation of commercial fishing vessels
	HDB	Coastal modification works, coastal restoration and sand dredging
Ministry of Transport (MOT)	MPA	Prevention of pollution from ships, oil and chemical spills, response and preparedness

Table 6: Key government stakeholders of Singapore's coastal and marine environment. (cont.)

Ministry	Agency/Division/ Department	Current interests / roles relating to CME
Ministry of Trade and Industry (MTI)	STB	Tourism appeal and development of Southern Islands. Uses the CME
	JTC	Development of industrial real estate from land reclamation. Uses the CME
	SDC	Tourism appeal of Sentosa, development and management of Southern Islands. Uses / Manages non live-firing southern island Administration of industries with potential and actual impact on CME environment such as oil and gas industries. Uses the CME

Integrated Urban Coastal Management (IUCM)

In 2009, Singapore adopted and implemented a more specific form of the internationally recognised ICM – developed by PEMSEA – known as IUCM. The legal framework involves various legislations that enable the management and regulation of the coastal and marine environment – and forms the backbone of the IUCM efforts. The framework essentially covers biodiversity conservation and the protection of CME, resource management, pollution control and waste management, marine activities, coastal hazards management, recreation and tourism, and heritage conservation.

There are some 26 Acts and 44 regulations relevant to ICM in existence that cover aspects, such as pollution control and waste management (eight Acts, 30 Regulations); planning and land use management (seven Acts); maritime activity (two Acts and eight Regulations); nature conservation (five Acts and nine Rules and Regulations); fisheries (two Acts, six Rules and Regulations); and coastal industrial real estate (one Act). Most notably, the Environmental Protection and Management Act aims to consolidate the laws related to environmental pollution control and to stipulate the protection and management of the environment.

The Coastal and Marine Environment Policy Committee (CMEPC) is an inter-ministerial committee that was formed in 2007 to provide coordinated, holistic and strategy policy direction for CME-related issues. The CMEPC's main task is to coordinate a balanced approach towards coastal management, focusing on strategic issues such as development activities, port and shipping activities, navigational freedom, and environmental sustainability. The CMEPC endorses the adoption and implementation of Singapore's IUCM framework.

Conclusion

Sustainable development has underpinned Singapore's policymaking since our independence. Faced with limited land and resources, the country's pioneer leaders had to quickly address pressing concerns while adopting a long-term perspective in policymaking. They concentrated efforts in developing education, security, infrastructure, healthcare, and housing, while bearing in mind the need to be prudent and strategic to maximize resources. To sustain growth and keep up with the times, successive generations of leaders made a conscious effort to continually re-invest the resources, which the economy has generated, into the development of human capital, R&D, and the identification of new areas of growth.

In pursuing economic development, the country has been careful not to disrupt its natural environment. A Garden City was created, abundant with lush greenery and clean surroundings to make life more pleasant for people to live, work, and play in. Today, Singapore is widely-recognised as a City in a Garden, with nearly 50% green cover and 72 ha of rooftop gardens and green walls. Singapore chose clean energy solutions. Singapore is among the 20 most carbon-efficient countries, with natural gas supplying 95% of electricity. For the country's leaders, it was no mean feat to maintain this delicate balance between economic, social, and environmental priorities to achieve long-term, sustainable development.

To effectively develop and implement integrated and sustainable policies, Singapore adopts a Whole-of-Government (WOG) approach. As challenges become increasingly complex and cross-cutting, the WOG approach entails the sharing of information among public agencies, which widens agencies' worldviews and uncovers emergent challenges and opportunities early. Agencies assess problems from multiple perspectives, and better consider the spill-over effects of policy actions and implications on each other's plans. The WOG approach has grown in importance and serves as the national planning framework.

The country also adopted a Whole-of-Nation, bottom-up approach to develop creative, sustainable solutions, including supporting and collaborating with multiple stakeholders, to realise desired and holistic outcomes. As Singapore works towards building a smart city, a people-centric approach has been adopted. For example, extensive consultations with the private sector and civil society, which supply the know-how, and citizens, who provide feedback for continuous improvement. This approach also secures greater buy-in and commitment to action by all segments of society.

Sustainable development is a journey. Maintaining the momentum on this journey requires constant commitment and attention to the landscape of opportunities and challenges ahead, even as the country celebrates its progress and success. Blue economy is an integral part of this journey.

Table 7. SUMMARY: State of Oceans and Coasts.

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	**Top 3 issues**	**(a) key policies/ laws; (b) national action plan**	**Best practice or blue economy initiative**
State of ocean economy				
Ocean economy • GVA; contribution to GDP	To be based of DOS data			
Fisheries and aquaculture • Output; GVA	↑ Slightly increasing	• Environmental externalities such as pollution and HAB events. • Competition from other countries, lowering profits for farmers • Combatting IUU fishing and preventing the entry of IUU fish into the supply chain.	• Fisheries Act and Subsidary legislation • Funding to encourage the uptake of technologies and enhance the capability and capacity of industry players	• Adoption of technologies such as the closed containment aquaculture systems • Good aquaculture practices for fish farming
Tourism • No. of tourists • GVA	↑			
Ports and shipping • Passenger volume • Cargo and container throughput volume • GVA	↑ Increasing • Cargo and container throughput in 2017 has increased since 2016. (See Section 6.2.4: Port Performance Indicators). MPA does not report data on passenger volume or GVA.		• Prevention Of Pollution of the Sea Act • The Maritime Singapore Green Initiative – comprising the Green Ship Programme, Green Port Programme, Green Technology Programme Green Awareness Programme and Green Energy Programme - provides incentives to companies that adopt clean and green shipping practices over and above the minimum required by IMO.	• The Maritime Singapore Green Pledge, part of the Green Awareness Programme, is signed by organisations that have expressed a commitment to environmentally-friendly shipping. It has garnered more than 100 signatures.

Table 7. SUMMARY: State of Oceans and Coasts. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	**Top 3 issues**	**(a) key policies/ laws; (b) national action plan**	**Best practice or blue economy initiative**
Ship building and marine offshore engineering **2016 Output: S$13.1bn; GVA: S$3.8bn**	↓ While output and value added may begin to stabilize in 2018, a firmer recovery is not expected until 2019 and beyond.	• Uncertain oil prices	• Enhance productivity • Encourage innovation & R&D • Align jobs and skills of workers	Capture near term growth opportunities in the Liquefied Natural Gas (LNG) market and renewables.
Employment in ocean economy	Based off MOM + CPFB information			
Mainstreaming of valuation of ecosystem services; natural capital accounting	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021
State of ocean health				
Fish stocks	N.A	N.A	N.A	N.A
Catch per unit effort	N.A	N.A	N.A	N.A
Mangroves - area; cover - condition	↑ Slightly increased recently in coverage. Condition varies in different mangrove patches	• Coastal development • Coastal erosion • Sea-level rise	• Nature Conservation Masterplan • Marine Conservation Action Plan	• Pulau Telong Mangrove Restoration • Mangrove salvation and propagation programme
Coral reefs - area; cover - condition	↑ Slightly increased recently Slightly increased recently in species due to new discovery Condition varies in different reefs	• Land reclamation • Sedimentation • Climate change	• Nature Conservation Masterplan • Marine Conservation Action Plan	• NParks' Plant-A-Coral, Seed-A-Reef programme • Coral Reef Monitoring Programme • Reef Enhancement Units • Coral nursery
Intertidal habitats - area; cover - condition	↓ Slightly decreased in coverage Condition varies in different areas Increase in species counts due to recent discovery	• Land reclamation • Coastal pollution including oil spills and chemical spills • Coastal erosion	• Nature Conservation Masterplan • Marine Conservation Action Plan	• Marine Ecotoxicology Biomonitoring • Habitat enhancement on artificial shores
Prevention of extinction of known threatened species	There have been records of new discovery and rediscovery	• Habitat loss • Lack of historical records	• Nature Conservation Masterplan • Marine Conservation Action Plan • WABA	• Red Data Book Update • Comprehensive Marine Biodiversity Survey • DNA technology • Species recovery programme

Table 7. SUMMARY: State of Oceans and Coasts. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Marine water quality **- DO** **- N** **- P** **- TSS, TDS** **- Heavy metals** **- POPs, PTS** **- microplastics** **etc.**	N.A -Baseline data being collated	N.A	Environmental Protection and Management Act; Environmental Public Heath Act; Public Utilities Act; Sewerage and Drainage Act; Water Quality Guidelines 2008	Sewerage system - Wastewater treatment and reuse - Real-time continuous water quality monitoring system for coastal waters
Marine protected areas (% of territorial waters)	N.A	N.A	Marine Conservation Action Plan; National Biodiversity Strategy and Action Plan; Nature Conservation Masterplan	Sisters Islands Marine Park
Pressures and threats				
Population growth in the coastal areas				
IUU fishing	No change	• Limited legislative powers pending review of Fisheries Act • Limited manpower • Capacity development	Fisheries Act	Review of current legislation to enhance powers to combat IUU fishing
Habitat conversion and destruction; reclamation	↑	• Limited land and sea space • Growing population • Climate Change	Strategic long term land use planning	Whole-of-Government approach to land use planning Habitat enhancement and Building with Nature
Coastal erosion and sedimentation	N.A.	The effects and impact of coastal erosion are dependent on the local site conditions and these vary from location to location. Hence, coastal protection and shoreline restoration work had to be site-specific rather than a "one size fits all" strategy.	BCA's Coastal Adaptation Study (CAS), which is still ongoing, will develop a national framework to safeguard Singapore's long-term coastal protection needs.	To help mitigate beach erosion at the East Coast Park, novel coastal protection measures were implemented at selected sections of the beach as a pilot project. Based on our monitoring of these sections annually, the measures are effective, and can be considered at other locations where feasible.
Wastewater (untreated) discharge	N.A	N.A	N.A	N.A

Table 7. SUMMARY: State of Oceans and Coasts. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Solid waste generation and dumping	In 2017, 7.70 million tonnes of solid waste was generated, a decrease of 110,000 tonnes from 7.81 million tonnes in 2016.		• NEA actively promotes the 3Rs (reduce, reuse and recycle) to reduce waste and recover resource. • Our solid waste management system ensures that all waste is collected for proper disposal/ recycling and do not end up in water courses leading to the seas and oceans.	
Plastic waste generation	The amount of plastic waste generated decreased slightly from 822,200 tonnes in 2016 to 815,200 tonnes in 2017.		• Working with industry and non-governmental organisations (NGOs) to reduce packaging waste through Singapore Packaging Agreement • Supporting and working with environment groups and retailers to implement ground-up initiatives to reduce the consumption of plastic bags and disposables • Study to establish the commercial and financial viability of proven recycling solutions and technologies that can be applied in Singapore for waste steams including plastic waste • Closing the Waste Loop (CTWL) R&D Initiative to develop technologies and solutions to tackle increasing waste generation, scarcity of resources and land constraints for waste management • Upcoming initiative to implement mandatory reporting requirements for sustainable packaging waste management	
Oil spills	N.A	N.A	• Prevention of Pollution of the Sea Act	• Marine Emergency Action Procedure
Greenhouse gas emissions	↑	Singapore is alternative energy disadvantaged, and is a highly urbanized, densely populated city-state, which makes deploying large-scale renewable energy difficult.	Key policies include the Energy Conservation Act which targets large energy users, introduction of a carbon tax from 2019, etc. Singapore's Climate Action Plan was published in 2016.	Singapore has switched away from fuel oil to natural gas, the cleanest fossil fuel, for electricity generation; the proportion of Singapore's electricity generated by natural gas has risen to about 95% in 2016
Population with access to sanitation and wastewater management systems	N.A	N.A	N.A	N.A

Table 7. SUMMARY: State of Oceans and Coasts. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Population covered by solid waste management services	N.A	N.A	N.A	N.A
Tourist establishments with habitat, solid waste and wastewater management	N.A	N.A	N.A	N.A
Ports and ships with environmental management systems	As of December 2017, some 436 Singapore-flagged ships qualified for the Green Ship Programme under the MSGI, up from 37 ships in 2012			Maritime Singapore Green Initiative
Waste management in offshore oil and gas	N.A	N.A	N.A	N.A
Sea level rise	↑	Climate science is constantly evolving, which means that projections for rises in mean sea level may change. Hence, our national framework for coastal protection need to remain flexible and adaptive.	BCA's Coastal Adaptation Study (CAS), which is still ongoing, will develop a national framework for Singapore's long-term coastal protection needs.	From 2011, we have required all new reclaimed land to be at least 4m above the mean sea level, up from 3m previously.
Coral bleaching	Varied depending on the year. Post-bleaching recovery appeared to be rapid	• Climate change and variability in weather patterns • Coastal activities	• Nature Conservation Masterplan • Marine Conservation Action Plan	Coral bleaching monitoring is conducted following NOAA's advisory for the region and Sea Surface Temperature data
Storms, typhoons, heavy rains, storm surge, flooding	↑	Increasing rainfall intensity - the annual maximum rainfall intensity in an hour has increased from 80 millimetres in 1980 to 107 millimetres in 2012	PUB seeks to capture, convey and discharge excess rainwater through its "Source-Pathway-Receptor" approach. By building detention tanks, widening drains, and raising ground levels across Singapore, PUB helps to mitigate flood risk in Singapore.	From 2011 to 2017, the Government has invested S$1.2 billion to upgrade drainage infrastructure, and these measures have been effective in relieving Singapore of widespread and prolonged floods.

1 Introduction

Covering over 71 per cent of the Earth's surface (approximately 360 million square kilometres), our oceans contain 97 per cent of our Earth's available water (NOAA, 2018). The sheer magnitude of our oceans gives rise to their enormous influence on both our physical planet and the very existence of our civilisation.

Inextricably linked to the climate of the Earth, in terms of the regulation of air temperature and precipitation; the oceans are also an extensive source of food, energy, minerals and a means of transportation. The earth's oceans provide vital inputs to the global economy. With over 80 per cent of global trade by volume and around 70 per cent by value transported by sea (United Nations Conference on Trade and Development, 2017), they constitute the lifeblood for growth and development on a worldwide scale. Sustaining more than just fisheries and aquaculture, our oceans are essential to industries as varied as tourism to offshore oil and gas and are becoming increasingly recognised as crucial in the face of many challenges such as food security, alternative/renewable energy sources and accelerating climate change. The 2010 estimations from the OECD's Ocean Economy Database valued the ocean economy's output at USD 1.5 trillion (measured in terms of the ocean-based industries' contribution to economic output and employment), or approximately 2.5% of world gross value added (GVA) (Jolly, 2016). More recently at The UN Ocean Conference held in June 2017, this number was estimated at between USD 3-6 trillion/year. Millions of people therefore directly or indirectly rely upon them for their livelihoods. It is a precious resource which sustains life on this earth and therefore, assessing its health and safeguarding its value is of utmost importance.

In the face of a new and intensive wave of economic activity in the ocean, scientific evidence is cautioning us that the world's oceans are experiencing unprecedented anthropogenic pressures, and that the time to react and be proactive is now. The shift from conventional economic activities in the ocean to a sustainable ocean economy, has the potential to bring about tremendous economic and investment opportunities. Singapore being an island-nation, the ocean plays an indispensable role in our home economy, and will feature increasingly in our continued economic growth and development. Here on our tiny island, Singapore looks towards innovation to bridge the gap between sustainability and economic growth in the ocean.

1.1 Coverage and Theme of the National State of the Oceans and Coasts Report – The Emergence of the Blue Economy

1.1.1 Background

PEMSEA developed the SOC reporting system to enable governments and other organizations monitor the implementation of their ICM programmes, whilst assessing the impact and benefits. The SOC facilitates documentation and measurement of the effectiveness of policy and management interventions in support of sustainable coastal development.

In July 2012, Ministers from ten PEMSEA Partner Countries of the East Asian Seas (EAS) region signed the Changwon Declaration towards an Ocean-Based Blue Economy: Moving Ahead with the Sustainable Development Strategy for the Seas of East Asia. The Declaration paved the way for embracing the blue economy paradigm, which employs an alternative economic growth strategy in the coasts and oceans with low environmental impacts, in line with the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs).

The signing of the Da Nang Compact in November 2015 by Ministers and Senior Government Officials from 11 PEMSEA Partner Countries (including Singapore), saw the adoption of the Five-Year Regional Implementation Plan for the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) and four post-2015 Strategic Targets.

Whereby Target 2 - of the four strategic time-bound targets from SDS-SEA - outlined the requirement that "by 2018, a regional State of Oceans and Coasts reporting system to monitor progress, impacts and benefits, and to continually improve planning and management of SDS-SEA implementation".

1.1.2 The Concept of the Blue Economy

Whilst the concepts of "sustainable development" and the "Green Economy" are fairly commonplace, the Blue Economy is less well-known and has only recently emerged as a new vernacular in modern marine resource management and ocean governance. Notable international organizations like the United Nations and Asia-Pacific Economic Cooperation (APEC), along with several East Asian economies, have taken up the call for developing blue economy in the region. Coasts and oceans are some of the most productive ecosystems on the Earth, which deliver an array of benefits and services that either directly or indirectly support economic activity and growth.

Services including defence from natural hazards; weather regulation; shoreline stabilization; carbon sequestration; wild-catch fisheries; energy from wind, waves and offshore oil; sea-bound trade; tourism and recreation; amongst many others. Estimates of the value of this annual global ocean economic activity range between three to five trillion dollars, with the ocean economy accounting for 15-20% of total GDP for some East Asian countries (Partnership in Environmental Management for Seas of East Asia, n.d.).

By undertaking an assessment of the blue economy here in Singapore, our main objectives are to facilitate a deeper understanding of the role of the ocean and its contribution to the national economy; impacts of human activities on ocean health and sustainability; potential areas for investments in environmentally-sound technologies and infrastructure; and the interventions and innovative mechanisms needed to respond to changing environment and climate.

Nine key industries were classified as impacting blue economy growth:

1. Fisheries and Aquaculture
2. Ports, Shipping and Marine Transport
3. Tourism, Resorts and Coastal Development
4. Marine Technology and Environmental Services
5. Oil and Gas
6. Ocean-related Manufacturing
7. Seabed Mining
8. Renewable Energy
9. Marine Biotechnology

This list is not exhaustive, as there are many associated industries and economic activities that could have a function in the blue economy, e.g., Marine Finance and Legal Services. This report discusses the relevant contributors to Singapore's ocean economy.

1.2 Rationale of the SOC Report

1.2.1 Context of the SOC Report

The SOC reporting mechanism can be encapsulated as: monitoring SDGs and SDS-SEA, and promoting blue economy. Knowing that sustainable use of the oceans is coupled with the UN Sustainable Development Goal (SDG) 14, Life Below Water, it is evident that preserving the health of our oceans is a fundamental prerequisite for business to operate in the long-term and by tackling the challenges of today.

Since 2008, more than 50% of the world's population resides in cities. It was estimated in 2007 that 40% of the world's population live within 100km of the coast (United Nations, 2007). Human population is projected to continue growing while the availability of land and resources will be increasingly limited. Optimising resource use and ensuring sustainable development of coastal cities is therefore a global imperative. As a microcosm of these conditions, Singapore's experience in sustainable development can provide lessons for other coastal cities. The report provides a comprehensive outlook of different areas of sustainable development, which contribute to blue economy growth in Singapore.

SOC reporting provides a number of benefits:

- An integrated and comprehensive evaluation process for ICM implementation that serves as a basis for reviewing and improving the management of coastal resources.
- Validation of policy, environmental, social and economic conditions in coastal areas to support policy development and decision-making.
- Systematic monitoring and alignment with local, national and international sustainable development targets.
- A standardized monitoring process allowing comparison across multiple ICM program sites.

1.2.2 Purpose of This Report

The progressively intense and diversified use of Singapore's coastal and marine environment (CME) necessitates an integrated approach for effective coastal management and its sustainable use. The State of the Oceans and Coasts (SOC) Report 2018 presents key developments in emerging industries and innovations that sees us transition away from a conventional economy in the ocean to a "blue" or sustainable economy, which is the theme of the report.

Utilising the common approach outlined by PEMSEA on the blue economy, this assessment aims to facilitate our understanding of the role of the ocean and its contribution to the national economy; impacts of human activities on ocean health and sustainability; potential areas for investments in environmentally-sound technologies and infrastructure; and the interventions and innovative mechanisms needed to respond to changing environment and climate.

In this edition, we look back over a five to ten year period to examine the latest trends in the state of our coasts and analyze how and why the CME is changing and whether these trends fit within the context of sustainability and the blue economy development.

1.2.3 What is Blue Economy?

One of the most important but little noticed change over the past decades is how our perspective on the world's oceans has changed. Oceans were first considered vast and limitless. Following centuries of exploration, oceans became areas for shipping, deep sea fishing, nuclear testing,

dumping of wastes, and exploitation for food, minerals, oil and gas, and other resources. Given the current challenges, studies on the state of the marine environment have become more significant. There is now increasing recognition that oceans are finite, with fragile ecosystems and biodiversity under pressure from human activities, and climate and environmental changes. Yet, the benefits derived from the oceans have not been fully quantified as well as the environmental and societal impacts and costs of over-exploitation, pollution, and years of neglect. It has therefore become critical to understand that human activities, whether on land or on sea, have impacts, and each of our uses of oceans involves real or potential tradeoffs with other uses. This means we need a much better and more detailed understanding of the economic values of oceans and coastal and marine resources, and the state of ocean health underpinning the sustainable development of oceans and coasts.

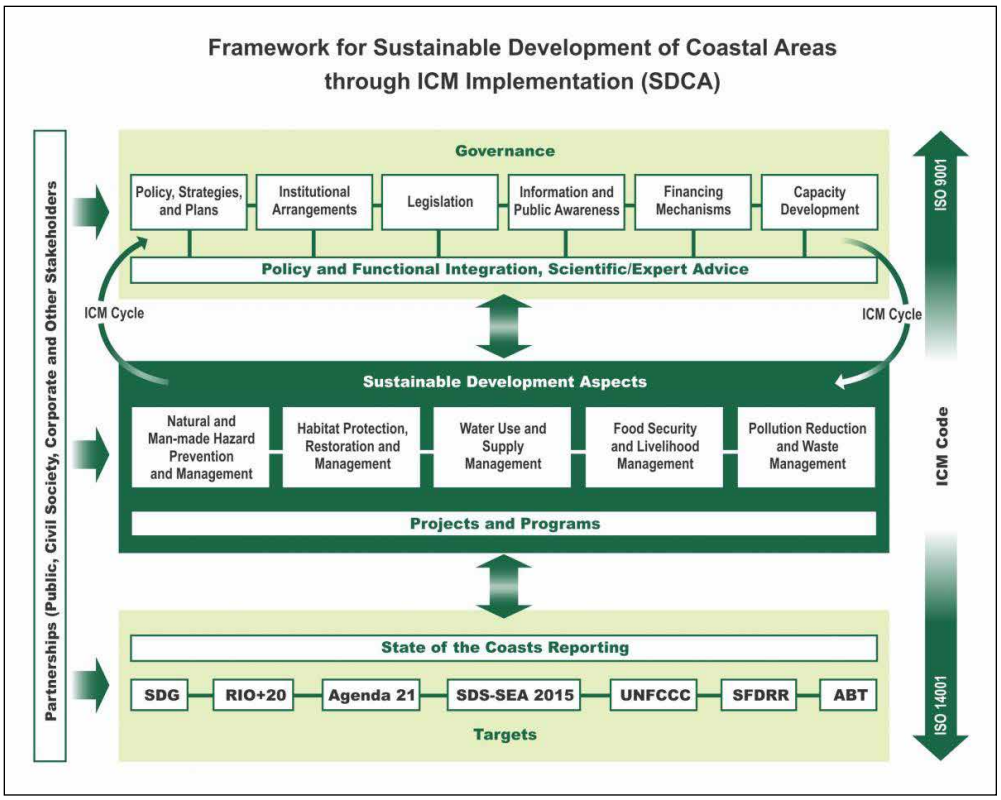
Within this context, the term "blue economy" has entered into the vocabulary of economic development in all parts of the world. But the meaning of "blue economy" is still evolving, with some emphasizing the possibilities of new ocean-based industries, such as renewable energy or bio-pharmaceuticals, and others emphasizing the need to transform the traditional ocean economy and the emerging ocean industries into a more sustainable and inclusive blue economy, conserving the oceanic natural capital and providing opportunities across society. The blue economy, as discussed during the East Asian Seas (EAS) Congress 2012, refers to a sustainable ocean-based economic model; one that employs environmentally-sound and innovative infrastructure, technologies, and practices, including institutional and financing arrangements, for meeting the goals of: (a) sustainable and inclusive development; (b) protecting our coasts and oceans, and reducing environmental risks and ecological scarcities; (c) addressing water, energy, and food security; (d) protecting the health, livelihoods, and welfare of the people in the coastal zone; and (e) fostering ecosystem-based climate change mitigation and adaptation measures.

All of the socioeconomic developments are taking place in a changing climate that is altering the physical properties of oceans that may dramatically shift the foundations of ocean and coastal economies. Though changes, such as sea-level rise and ocean acidification are becoming known, uncertainty still remains about the extent and timing with which these ocean changes will affect resources, coastal areas, and well-being.

1.2.4 What is Integrated Coastal Management?

ICM is a natural resource and environmental management framework which employs an integrative, holistic approach and an interactive planning process in addressing the complex management challenges in the coastal area. ICM helps governments to achieve social and economic development targets in a number of area through an integrated approach (see **Figure 1** – Sustainable Development Aspects).

Figure 1.1: Framework for Sustainable Development of Coastal Areas through ICM implementation.



Source: PEMSEA

The ultimate goal of ICM is to raise the efficiency and effectiveness of coastal governance in terms of its ability to achieve the sustainable use of coastal resources and of the services generated by the ecosystems in the coastal areas. By preserving the functional integrity of these natural resource systems and balancing the need for economic development, and through integrated planning, ICM aims to evaluate competing conflicts arising from multiple use of limited space and resources (Chua, 2006). ICM has been internationally recognized as key to sustainability by major conventions, such as Agenda 21, UNFCCC and, Convention on Biological Diversity (CBD).

Singapore is an island city state that is heavily dependent on its coastal and marine environment (CME), as well as its strategic location along a major sea lane. The island is a major transhipment hub for commercial shipping and is also one of the world's busiest ports. Its limited coastal and marine areas are densely populated and heavily used by various industries, including shipping, transport, petroleum and petrochemical manufacturing as well as non-industrial activities, such as residential development and recreation. These demands place Singapore's CME under constant pressure. To achieve sustainable development, this fragile environment needs to be carefully planned and managed in a holistic and integrated manner. Since 2009 Singapore adopted the ICM framework developed by PEMSEA and customised it to fit into its urban context. Such integration is key to Singapore becoming a model sustainable coastal city. [Refer to **Section 13.1.1** Integrated Urban Coastal Management (IUCM)]

1.3 Concept and Framework of the National SOC Report

The SOC report provides the description and assessment of the following:

- **Socioeconomic conditions:** population, economy, social features
- **Ocean economy:** gross value added of the ocean economy and contribution to national economy; valuation of ecosystem services; key ocean economic activities (contribution to income and employment, pressures and issues, response in terms of policies and best practices)
- **Developments in blue economy:** innovative and sustainable ocean economic activities; emerging industries; opportunities for investments and partnerships for blue economy development.
- **State of ocean health underpinning the blue economy:** natural conditions (oceanography and physical features of the seas and coasts); ecosystems and biodiversity; pressures and challenges (risks and threats from human activities, natural hazards, and climate change, impacts on the environment and communities).
- **Governance structure supporting blue economy development:**
  - *Institutional arrangements:*
    - Description of key policies, laws, and international agreements adopted that would address the pressures and threats to ocean health and ocean economy, and support blue economy development.
    - Supporting mechanisms (capacity development; research and development; financing, stakeholder participation; partnerships, etc.) for the implementation of these policies, laws, and international agreements.
  - *Sustainable development strategy and actions:* ocean and coastal management, fisheries management, ecosystem and biodiversity conservation, marine protected areas, pollution reduction, natural hazard management and climate change response to achieve the SDG 14 targets, SDS-SEA targets, other international commitments, and national targets to ensure ocean health and sustainable blue economy.
  - *Driving forces for blue economy*
- **Conclusion and recommendations**

1.4 Methodology and Timeframe

Data for the SOC Report was collected through literature searches of published, unpublished and electronic materials from libraries, the Internet and the media. Consultancy reports - commissioned by government agencies - on projects such as coastal restoration, master plan development, and pollution were also utilised. The sources on coastal and marine habitats from National Parks Board (NParks), research institutions and universities were extensively drawn upon. Most substantially, information was compiled from agencies themselves via information sharing at meetings and e-mail correspondences. The collection, compilation and drafting of the report were carried out within one year, with data not older than five years ago (i.e. since 2012).

1.5 Caveats and Limitations

This report represents the first initial assessment of the state of oceans and coasts of Singapore as performed under the SOC Reporting Mechanism. As this report follows the common approach that was provided by PEMSEA in assessing the blue economy across the region, there were some instances where factors explored in the original outline were not applicable in Singapore's unique urban context. The lack of disaggregated data on economic activities or industries, and studies on valuation of ecosystem services made it difficult to get an estimate of the ocean economy.

PART 1

THE SEAS AND PEOPLE OF SINGAPORE

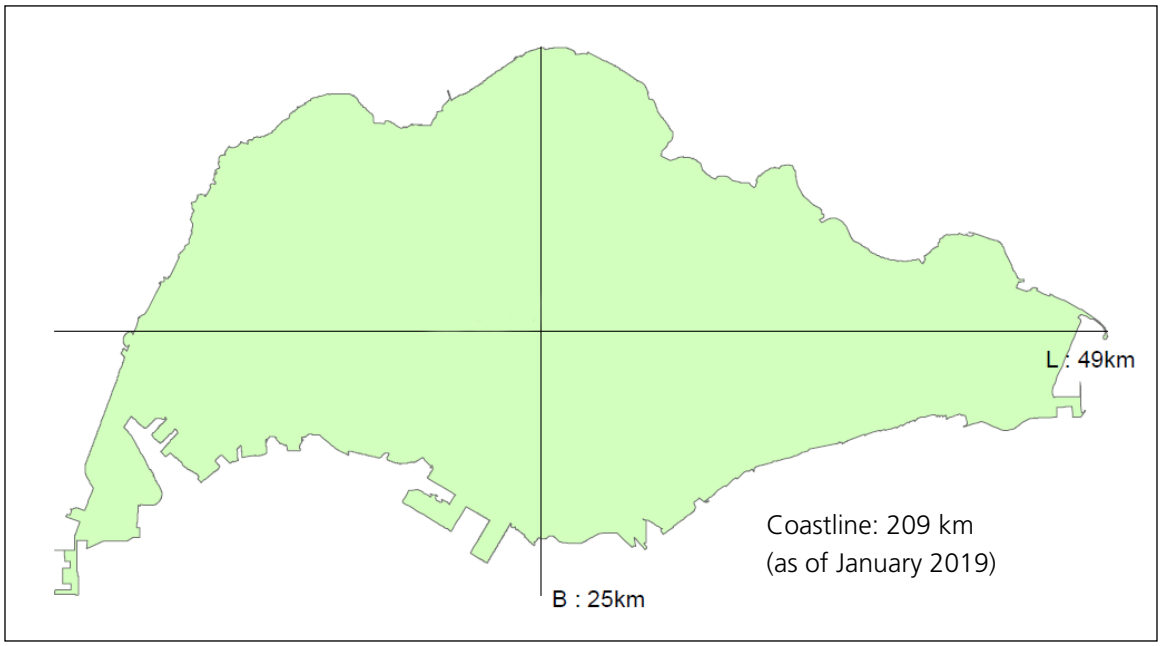
2 Singapore as an Island Nation

2.1 Geography

Singapore is a small, heavily urbanised, island-state in Southeast Asia situated at the southern tip of the Malayan Peninsula between Malaysia and Indonesia. It is located between latitudes 1°09'N and 1°29'N and longitudes 103°3'E and 104°25'E, approximately 137 kilometers (km) north of the equator.

Singapore consists of one main island and over 60 smaller islands and islets, with a total land area of approximately 719.9 square kilometers (km^2) by end 2017 including offshore islands (Department of Statistics, 2018). After Singapore Island itself, the subsequent largest islands are Pulau Tekong Besar to the northeast (25.5 km^2), Pulau Ubin (10.2 km^2), and Sentosa (5 km^2). The main island (mainland) of Singapore measures 49 km (30.4 miles) from east to west and 25 km (15.5 miles) from north to south (**Figure 2.1**). The coastline as of January 2019 is 209 km (Singapore Land Authority).

Figure 2.1: Length, Width, and Coastline of Singapore.

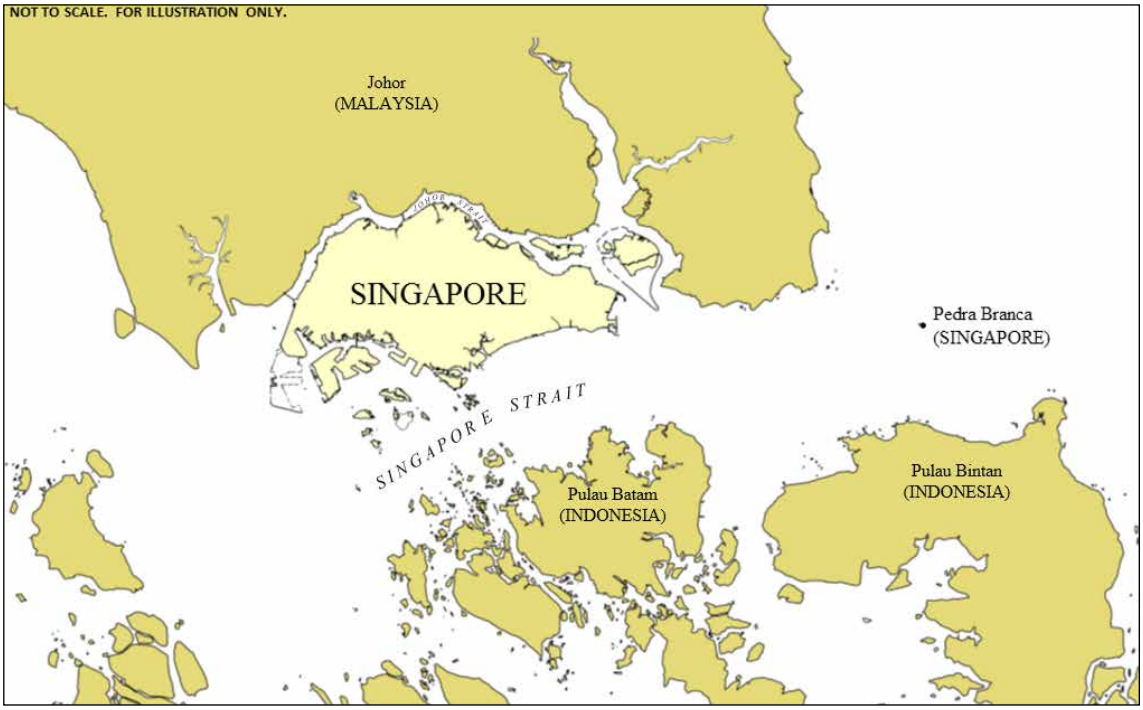


Source: Singapore Land Authority.

The shape of the coastline together with the adjacent deep waters give rise to Singapore's natural harbour, in particular at the mouth of the Singapore River on the southern coast of mainland Singapore.

Located between the Indian Ocean and the South China Sea, mainland Singapore is bordered on the north by the narrow Johore Strait, which separates it from Peninsular Malaysia, and on the south by the Singapore Strait (**Figure 2.2**). Biogeographically, Singapore is enclosed between two of the largest marine ecoregions[1] of the world, the Western Indo-Pacific and Central Indo-Pacific regions (Spalding, et al., 2007) and additionally sits near the coral triangle.

Figure 2.2: Map of Singapore.



Source: MPA

2.2 The People of Singapore

Population size, structure and changes have important implications for production, investment and consumption activities as well as community development, social networks and kinship ties. A good understanding of demographic forces and emerging trends driving environmental changes is useful for policy makers, planners, businesses and the academia.

The Singapore Department of Statistics compiles, monitors, and analyses Singapore's population statistics and indicators in detail. The annual report on Population Trends puts together different aspects of demographic statistics. *Population Trends, 2016* is the twelfth edition of the annual series.

[1] Marine ecoregions (ecological region): are areas of relatively homogenous species composition, clearly distinct from adjacent systems. The species composition is likely to be determined by the predominance of a small number of ecosystems and/or a distinct suite of oceanographic or topographic features. (Spalding et al., 2007)

2.2.1 Demography

2.2.1.1 Key Demographic Indicators

Largely, total population growth rates in Singapore have remained relatively low and stable over a 3-year time period. As of end of June 2017, total population of Singapore was 5.61 million, an increase of 1.3 per cent from previous year's period. This figure comprises of resident population (citizen and permanent residents) and non-resident population. Please see **Table 2.1** for detailed demographic indicators.

Table 2.1: Key Demographic Indicators, 1970-2016.

Indicator	1970	1980	1990	2000	2010	2015	2016
Total Population[2] ('000)	**2,074.5**	**2,413.9**	**3,047.1**	**4,027.9**	**5,076.7**	**5,535.0**	**5,607.3**
Resident Population ('000)	**2,013.6**	**2,282.1**	**2,735.9**	**3,273.4**	**3,771.7**	**3,902.7**	**3,933.6**
Singapore Citizens ('000)	1,874.8	2,194.3	2,623.7	2,985.9	3,230.7	3,375.0	3,408.9
Permanent Residents ('000)	138.8	87.8	112.1	287.5	541.0	527.7	524.6
Non-resident Population ('000)						1,632.3	1,673.7
Population Density[3] (Per km^2)	3,538	3,907	4,814	5,900	7,146	7,697	7,797
Sex Ratio[4] (Males per 1,000 females)	1,049	1,032	1,027	998	974	965	963
Median Age1 (Years)	19.5	24.4	29.8	34.0	37.4	39.6	40.0
Old age support ratio (Per person aged 65 years & over)							
Persons aged 15 – 64 years	17.0	13.8	11.8	9.9	8.2	6.2	5.8
Persons aged 20 – 64 years	13.5	11.3	10.5	9.0	7.4	5.7	5.4
Proportion of Singles Among Residents Aged 30 – 34 Years[5] (%)							
Males	21.5	21.3	34.0	30.7	37.1	37.5	N.A.
Females	9.6	16.6	20.9	19.5	25.1	25.5	N.A.
Educational Attainment							
Highest Qualification Attained of Residents Aged 25 Years & Over[6] (%)	N.A.	100.0	100.0	100.0	100.0	100.0	N.A.
Below Secondary	N.A.	83.1	63.3	45.3	34.5	29.1	N.A.
Secondary	N.A.	9.5	23.6	24.0	19.0	18.9	N.A.
Post-Secondary (Non-Tertiary)	N.A.	4.7	4.7	8.9	9.5	9.1	N.A.
Diploma & Professional Qualification	N.A.		3.6	9.8	13.3	14.7	N.A.

[2] Total population comprises Singapore residents (i.e. Singapore citizens and permanent residents) and non-residents. Data for 1970 and 1980 are based on de facto concept (i.e. the person is present in the country when enumerated at the reference period). Data from 1990 onwards are based on de jure concept (i.e. the person's place of usual residence). Data from 2003 onwards exclude residents who have been away from Singapore for a continuous period of 12 months or longer as at the reference period.

[3] Prior to 2003, data are based on Singapore's land area as at end-December. From 2003 onwards, data are based on Singapore's land area as at end-June.

[4] Data refer to resident population.

[5] Data refer to resident population, except for 1970 which refer to total population.

[6] Data pertain to residents who are not attending educational institutions as full-time students. The data include those who are upgrading their qualifications through part-time courses while working.

Table 2.1: Key Demographic Indicator, 1970-2016. (cont.)

Population	1970	1980	1990	2000	2010	2015	2016
University	N.A.	2.7	4.7	12.1	23.7	28.2	N.A.
Mean Years of Schooling Among Residents Aged 25 Years & Over12 (Years)	N.A.	4.7	6.6	8.6	10.1	10.7	N.A.
Males	N.A.	5.6	7.3	9.2	10.6	11.2	N.A.
Females	N.A.	3.7	5.9	8.1	9.7	10.3	N.A.

Source: Department of Statistics – Population Trends Report 2016.

Singapore's citizen population grew 1.0 per cent from 2015, with 3.41 million citizens as of end June 2016 attributable to citizen births and a calibrated approach to immigration. Citizen births reached highs of the decade, at 33,725 births giving a resident total fertility rate[7] of 1.24. The citizen population continues to age, with the proportion aged 65 and above standing at 13.7 per cent compared with 13.1 per cent in previous period. The citizen median age 41.0 years compared to 40.7 years in previous period. Citizen old-age support ratio[8] 4.7 compared to 4.9. The permanent resident population remained relatively stable at 0.52 million. Non-resident population grew by 2.5 per cent, due to stronger growth in the number of Foreign Domestic Workers (FDWs) and dependants of Singapore who are on long-term visit passes, totalled 1.67 million (including dependants, international students and individuals here to work).

Overall total population growth has remained relatively stable at about 1.2% to 1.3%, which has been the growth rate seen over the past three years (2014 - 2017). See **Table 2.2** below:

Table 2.2: Singapore Population Size and Growth by Residential Status.

Population	Number ('000)					Average Annual Growth[1] (%)				
	Total Population	Singapore Residents			Non-Residents	Total Population	Singapore Residents			Non-Residents
		Total	Citizens	PRs			Total	Citizens	PRs	
1990	3,047.1	2,735.9	2,623.7	112.1	311.3	2.3[2]	1.7[2]	1.7[2]	2.3[2]	9.0
2000	4,027.9	3,273.4	2,985.9	287.5	754.5	2.8	1.8	1.3	9.9	9.3
2010	5,076.7	3,771.7	3,230.7	541.0	1,305.0	1.8	1.0	0.9	1.5	4.1
2011	5,183.7	3,789.3	3,257.2	532.0	1,394.4	2.1	0.5	0.8	-1.7	6.9
2012	5,312.4	3,818.2	3,285.1	533.1	1,494.2	2.5	0.8	0.9	0.2	7.2
2013	5,399.2	3,844.8	3,313.5	531.2	1,554.4	1.6	0.7	0.9	-0.3	4.0
2014	5,469.7	3,870.7	3,343.0	527.7	1,599.0	1.3	0.7	0.9	-0.7	2.9
2015	5,535.0	3,902.7	3,375.0	527.7	1,632.3	1.2	0.8	1.0	-	2.1
2016	5,607.3	3,933.6	3,408.9	524.6	1,673.7	1.3	0.8	1.0	-0.6	2.5

Note: (a) "-" denotes nil or neglible:
(b) Data from 2003 onwards exclude residents who have been away from Singapore for a continuous period of 12 months or longer as at the reference period.

[1] For 1990 and 2000, growth rate refers to the annualised change over the last ten years. From 2010 onwards, growth rate refers to the change over the previous year.

[2] Growth rate is computed using population estimates based on de facto concept (i.e, the person is present in the country when enumerated at the reference period.)

Source: Department of Statistic

[7] Total fertility rate refers to the average number of children who would be born per female, if all females live through their childbearing years of 15-49 and bear children according to a given set of age-specific fertility rates.

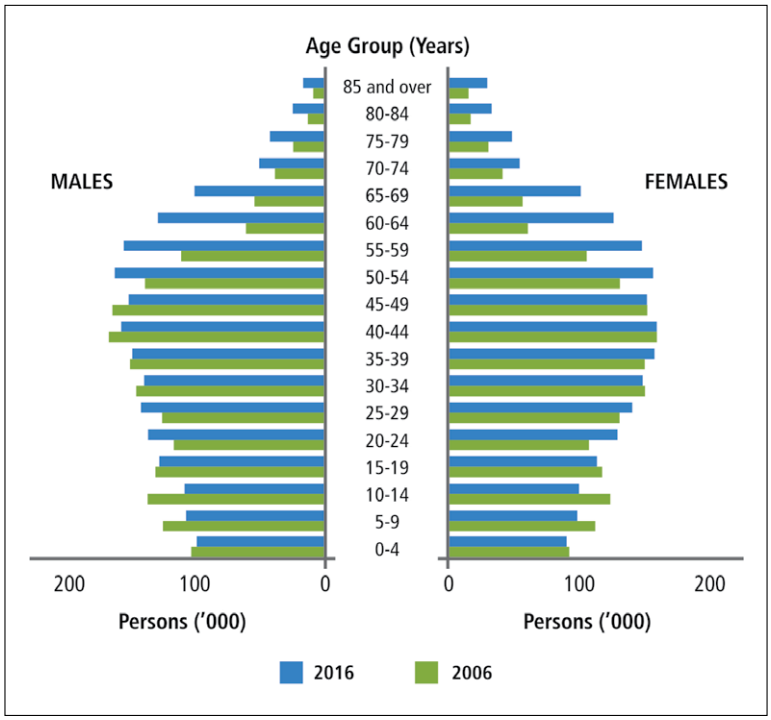
[8] The old-age support ratio refers to the number of persons aged 20-64 years per person aged 65 years and over.

Population density (calculated as total population per square kilometre) has seen a sharp increase from the 1960s figure of 2,831, to 3,538 in 1970, 5,900 in 2000, to the present day figure of 7,797 people per km^2 in 2016. In general, it has risen between one per cent and 4.5 per cent annually from 2007 to 2016, and stagnated in 2017 for the first time in a decade at 7,796, dipping slightly from 7,797 in 2016.

2.2.1.2 Age-Sex Structure

Median age of the resident population continues to rise from 40.0 years old at end-June 2016 to 40.5 years at end-June 2017 (**Figure 2.3**).

Figure 2.3: Age pyramid of residential population.



Source: Department of Statistic

Residents aged 65 years and over made up 13.0 per cent of the residential population in 2017, 0.6 per cent higher compared to 2016 (Department of Statistics, 2017).

The sex ratio also known as gender ratio, is the ratio of males to females in a population. For Singapore, this number has been steadily decreasing from 1,049 in 1970s, dipping below 1000 for the first time in 2000, to the current figure of 963 males per 1000 females in 2016.

2.2.1.3 Age-Dependency Ratio

The age-dependency ratio relates to the number is the ratio of dependents (aged below 15 years, and 65 years and older) compared to the working-age population (i.e. those aged between 15-64 years).

This is used to measure the pressure on a productive population. A high dependency ratio can cause serious problems for a country if a large proportion of a government's expenditure needs to be allocated for education, health and social security (e.g. pensions), which are most used by the two extreme age categories of the population spectrum.

The peak of 90 and above, were seen from 1960-1963, this halved by 1982 where it hit 45.3. Over the past decade, this ratio has been fluctuating between the maximum of 38.5 seen in 2006, dipping to a minimum of 35.3 in 2011 before increasing steadily to37.4 in 2015 and then 38.0 per 100 population aged 15-64 years in 2016.

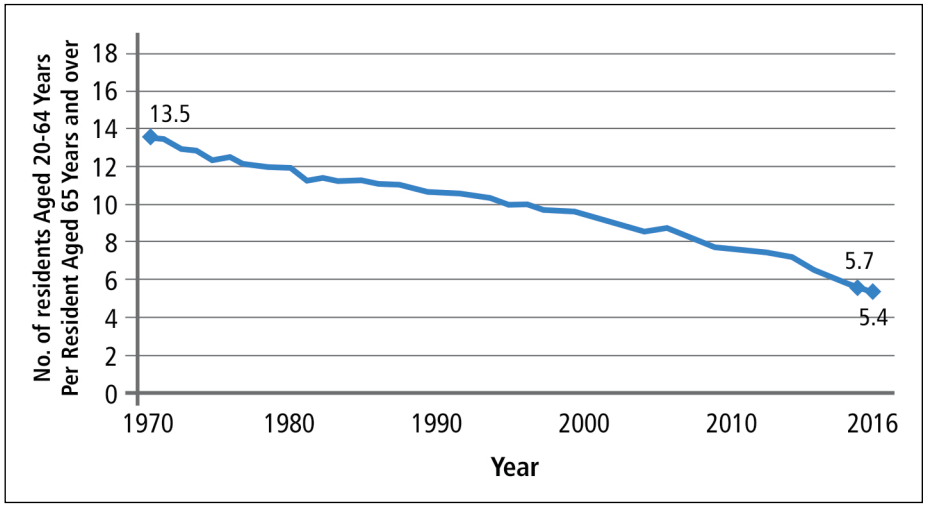
Old-Age Support Ratio

The old-age support ratio relates to the portion of the population who are capable of providing economic support to the portion of the older people who may be dependent on others' support. Computed as the ratio of the working-age population (aged 20-64 years) per person aged 65 years and over.

Over the past decades, we observe a continuous decline in this indicator, as we see an ageing resident population. Other factors that has influenced this downward trend include rising life expectancies and declining birth rates.

As of end-June 2017 there were 5.1 residents aged 20-64 years for each resident aged 65 years and over. Where in 1970, the ratio was 13.5, this has decreased by 60% and as of June 2016, the ratio stood at 5.4 residents aged 20-64 years for each resident aged 65 years and over (**Figure 2.4**), a further drop from 5.7 in 2015 (Department of Statistics, 2017).

Figure 2.4: Residential Old-age Support Ratio.

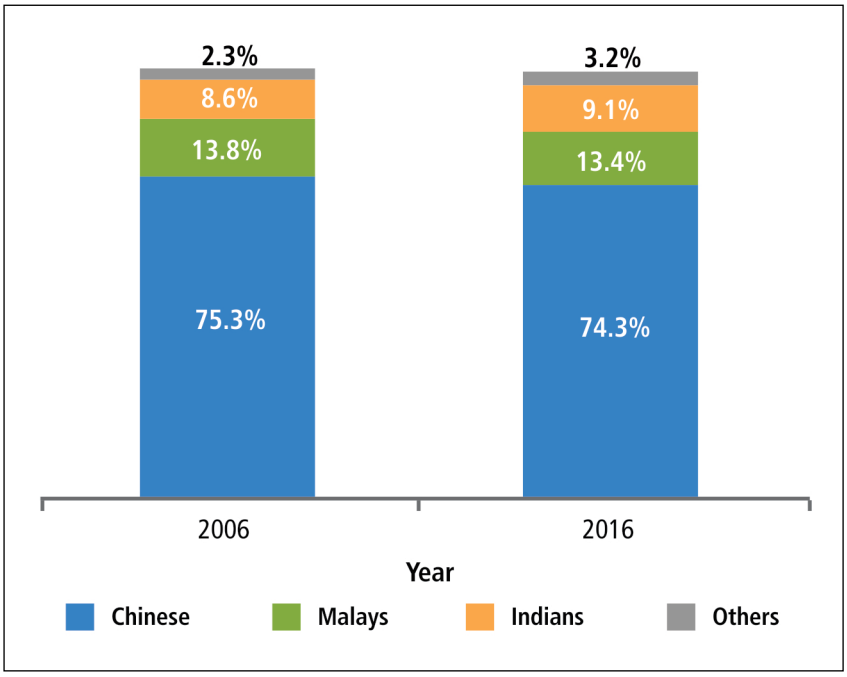


Note: For 1971-1979, data refer to total population.

2.2.1.4 Ethnic Composition, Languages and Religions of Singapore

As at end-June 2016, Chinese formed 74.3 per cent of the resident population, followed by the Malays and Indians at 13.4 per cent and 9.1 per cent respectively (**Figure 2.5**) making up most of Singapore's population (Strategy Group, 2017).

Figure 2.5: Ethnic composition of resident population.



Officially there are four languages in Singapore as well. The languages are Malay, English, Chinese and Tamil, with Malay being the national language (Mahbubani, 2014). However, English is the main working language. Singaporeans are educated to be bilingual whereby English is the main language of study, with their own mother tongue also being taught - Chinese, Malay or Tamil (Ministry of Education, 2010).

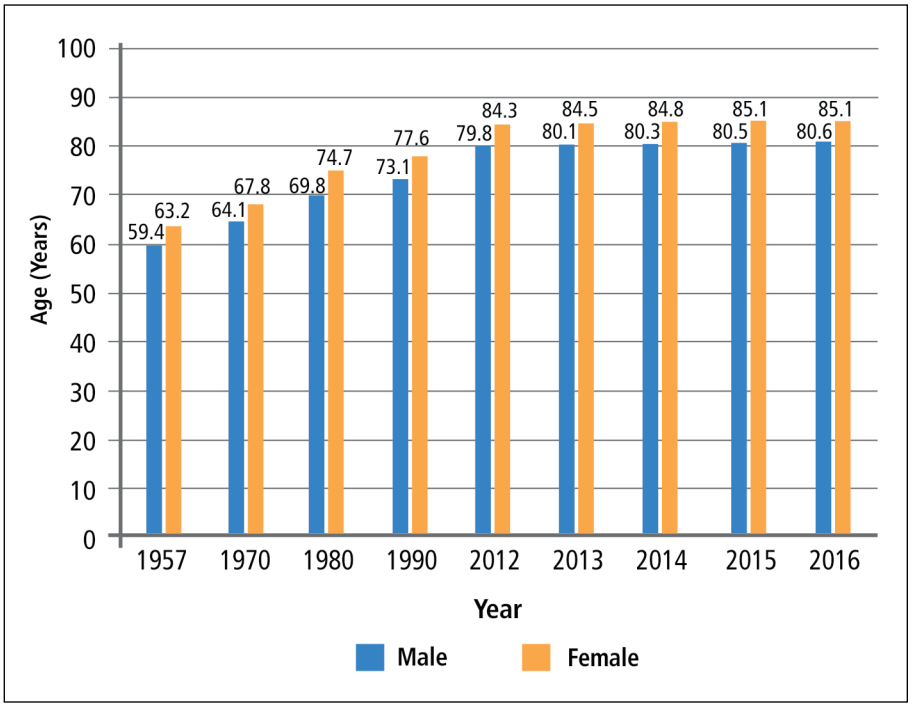
The most common religions within the population are Buddhism, Christianity, Islam, Taoism and Hinduism, amongst others.

2.2.2 Health

a. Life Expectancy[9]

Life expectancy has increased continuously. As of 2016, is at 85.1 years in female and 80.6 years in male population. See **Figure 2.6** for more details.

Figure 2.6: Expectancy at Birth.



Source: Department of Statistics

b. Top 10 Diseases[10]

Table 2.3: Top 10 Diseases.

	2014	2015	2016
Total No. of Deaths	**13,393**	**19,862**	**20,017**
% of Total Deaths			
1. **Cancer** (ICD_{10} : C_{00}-C_{97})	29.4	29.7	29.6
2. **Pneumonia** (ICD_{10} : J_{12}-J_{18})	19.0	19.4	19.3
3. **Ischaemic heart disease** (ICD_{10} : I_{20}-I_{25})	16.0	16.7	17.0

[9] According to Department of Statistics, 2018.
[10] According to Ministry of Health (MOH), 2016.

Table 2.3: Top 10 diseases. (cont.)

		2014	2015	2016
4.	**Cerebrovascular diseases (including stroke)** (ICD_{10} : I_{60}-I_{69})	8.4	6.8	6.6
5.	**External causes of morbidity and mortality** (V_{01} : Y_{89})	4.7	4.5	4.4
6.	**Hypertensive diseases (including hypertensive heart disease)** (IC10 : I_{10}-I_{15})	3.6	3.9	4.0
7.	**Urinary tract infection** (ICD_{10} : $N_{39.0}$)	2.6	2.2	2.3
8.	**Nephritis, nephrotic syndrome and nephrosis** (ICD_{10} : N_{00}-N_{07}, N_{17}-N_{19}, N_{25}-N_{27})	2.0	2.3	1.9
9.	**Other heart diseases** (ICD_{10} : I_{00}-I_{09}, I_{26}-I_{51})	1.9	2.2	1.9
10.	**Diabetes mellitus (including stroke)** (ICD_{10} : E_{10}-E_{14})	1.4	1.3	1.7

Source: Ministry of Health

c. Top Food-borne/Waterborne Diseases[11]

Top diseases caused by water contaminated with toxins associated with bacterial growth in the food, bacterial, viral or parasitic agents, toxins produced by harmful algal species or present in specific fish species or heavy metals and other organic compounds.

1. Acute Diarrhoeal Illness
2. Campylobacteriosis
3. Cholera
4. Enteric Fevers (Typhoid and Paratyphoid)
5. Hepatitis A
6. Hepatitis E
7. Salmonellosis
8. Food Poisoning

2.2.3 Literacy and Education

a. Literacy rate

According to United Nations Educational, Scientific and Cultural Organisation (UNESCO) Adult literacy rate is defined as percentage of population aged 15 years and over who can both read and

[11] According to Ministry of Health (MOH), 2016.

write with understanding a short simple statement on his/her everyday life. Generally, 'literacy' also encompasses 'numeracy', the ability to make simple arithmetic calculations. Adult illiteracy is defined as the percentage of the population aged 15 years and over who cannot both read and write with understanding a short simple statement on his/her everyday life.[12]

2.2.4 Human Development Index

The Human development Index (HDI) is a composite statistic developed by the Pakistani's economist Mahbub ul Haq for the United Nation Development Programme (UNDP) and derived from a composite index of (a) life expectancy, (b) education, and (c) per capita income indicators, which are used to rank countries on these three dimensions of human development. A country scores higher on the HDI when lifespan is higher, education level is higher, and the GNI per capita is higher (Jahan, 2016).

Singapore's HDI value of 0.932 in 2017 put the country at 9th position out of 189 countries and territories according to UNDP (2018). Between 1990 and 2015, the nation's HDI increased by 28.8 per cent, from 0.718 to 0.925 – attributed to life expectancy at birth increasing by 7.2 years, mean years of schooling increasing by 5.8 years, and expected years of schooling increasing by 4.8 years, while GNI per capita increased by about 127.8 per cent.

In 2017, life expectancy at birth was 83.2 years; mean year of schooling was 11.5 years; amd GNI per capita (2011 PPP$) was $82,503 (UNDP, 2018) (**Table 2.4**).

Table 2.4: Singapore's Human Development Indices.

	Life expectancy at birth	Expected years of schooling	Mean years of schooling	GNI per capita (2011 PPP$)	HDI value
1990	76.0	10.6	5.8	33,996	0.718
1995	77.4	11.6	7.3	45,228	0.773
2000	78.3	12.7	8.9	51,367	0.819
2005	80.2	13.9	10.5	57,709	0.868
2010	81.9	15.2	11.2	71,681	0.909
2015	82.8	16.1	11.5	78,742	0.929
2016	83.0	16.1	11.5	78,427	0.930
2017	83.2	16.2	11.5	82,503	0.932

Source: UNDP. 2018. Human Development Indices and Indicators: 2018 Statistical Update. (Accessed from http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/SGP.pdf)

[12] According to http://www.Uis.unesco.org/en/glossary-term/adult-literacy-rate.

2.2.5 Access to Solid Waste Management Infrastructure

NEA plans, develops and manages Singapore's waste management system. An efficient waste collection and disposal system is critical, given Singapore's limited land area and densely populated living environment.

In the 1960s and 1970s, waste was disposed of in various landfills around the island. However, in the late 1970s, NEA adopted waste-to-energy (WTE) incineration to reduce waste volume by 90% and reduce landfill space required. The first WTE plant was commissioned in 1979 and today there are four WTE plants located at Tuas and Senoko. Singapore's offshore landfill, Semakau Landfill, receives incineration ash, as well as non-incinerable waste via the Tuas Marine Transfer Station.

NEA's responsibilities include the licensing and regulation of solid waste collection, and ensuring that all waste is collected for proper disposal/recycling and do not end up in water courses leading to the seas and oceans.

[Refer to **Section 12.2** Pollution Reduction and Environmental Protection, **Subsections 12.2.1** Solid Waste Management Measures; and **12.2.2** Wastewater management facilities]

2.2.6 Access to Safe Water Supply, Safely Managed Sanitation Services and Wastewater Reuse

Based on the Environmental Performance Index (EPI) (Athanasoglou, et al., 2014) Singapore ranks joint first for the core issue - Water and Sanitation –scoring 100 out of 100 for both access to drinking water and sanitation.

While Singapore is widely recognised for its universal access to affordable and high quality potable water, this was not always the case. Water has always been an existential issue for Singapore. In the 1960s, Singapore was dependent on two sources of water: water from local catchments, and imported water from Johor, Malaysia. Since then, to meet our water needs, Singapore has developed a strategy based on what is locally referred to as "The Four National Taps":

1. Rainfall collected from water catchment areas and stored in reservoirs
2. Imported water
3. Water reuse – the NEWater Initiative
4. Seawater desalination

As a small island with limited land for water storage, Singapore needed to build and diversify our water sources to meet growing demands. To allow us to capture as much rainwater as possible, we expanded our local catchment areas to two-thirds of Singapore's land area by cleaning and damming rivers.

NEWater, or Singapore's brand of ultra-clean high-grade reclaimed water, is the pillar of our water sustainability. By enabling the use of every drop of water more than once, NEWater multiplies our potential water supply. We also desalinate water from the sea. Both NEWater and desalinated water are not dependent on rainfall and are thus more weather resilient. They help us mitigate the impact weather uncertainties and increase our water security.

In addition, through the development and application of innovative technologies, Singapore has put in place measures to ensure water safety. PUB monitors and tests all the water that it manages for over 300 different water quality parameters, exceeding the requirements stipulated under any international[13] drinking water regulation.

[Refer to **Section 8.1** Drivers of Future Growth, Innovations and Sustainability, **Subsection 8.1.1** Background to Singapore's Sustainable Water Story]

2.3 The Economy of Singapore

Singapore is an export-oriented economy that is highly reliant on international trade. Extensive industrialisation in the 1960s fuelled the nation's development, with the main driver of growth being manufacturing. In the early 1970s, Singapore joined the ranks as one of Asia's newly industrialising countries; whereby manufacturing and services sectors still prevail as the twin pillars of Singapore's high value-added economy.

2.3.1 Gross Domestic Product

Singapore's annual gross domestic product (GDP) growth rate from the 1960s to the 1990s has averaged about 8%, which is more than double that of the OECD average of 3.3%. Over the period from 2000 to 2010, the GDP nearly doubled from S$163 billion to S$304 billion. (**Table 2.5**) Real GDP per capita also rose rapidly at a compounded rate of nearly 12% p.a., while inflation and unemployment rates averaged less than 2% p.a. and 3% p.a. respectively over this period.[14]

In 2017, the economy expanded by 3.6%, an improvement from 2016 where overall growth measured 2.4% (In 2015, real economic growth was 2.2%).

Nominal GDP increased to $447.3 billion in 2017, as compared to $427.9 billion in 2016 (measured at current market prices). Real GDP was $422.7 billion and $407.9 billion for 2017 and 2016, respectively (measured at 2010 prices).

[13] For example, the World Health Organization's drinking water guidelines.
[14] (Monetary Authority of Singapore (MAS) n.d.)

Table 2.5: GDP, in millions, at 2010 market prices, by industry (Singapore Standard Industrial Classification 2015).

Variables	1960	1970	1980	1990	2000	2010	2015	2016
Gross Domestic Product (At 2010 Market Prices)	**7,609**	**18,405**	**43,805**	**92,146**	**183,379**	**322,361**	**398,369**	**407,918**
Goods Producing Industries:	**1,675**	**5,448**	**13,228**	**23,845**	**49,550**	**84,230**	**94,672**	**97,718**
Manufacturing	927	3,338	9,410	18,416	37,412	65,040	69,671	72,249
Construction	321	1,482	2,584	3,624	8,888	14,221	19,537	19,915
Utilities	132	353	819	1,566	3,098	4,851	5,334	5,425
Other Goods Industries	192	296	387	235	164	118	131	129
Services Producing Industries:	**4,772**	**10,323**	**25,141**	**56,335**	**112,372**	**208,683**	**272,030**	**275,973**
Wholesale and Retail Trade	1,768	3,786	6,990	12,660	27,620	58,449	75,776	76,514
Transportation and Storage	627	1,191	4,388	9,522	17,568	25,423	30,627	31,023
Accommodation and Food Services	266	578	1,508	2,846	4,384	5,921	7,151	7,423
Information and Communications	30	62	337	1,315	5,530	11,073	14,906	15,445
Finance and Insurance	155	595	2,574	8,848	15,286	33,154	51,735	52,557
Business Services	1,297	3,974	5,969	12,290	22,190	42,119	54,019	53,861
Other Services Industries	1,500	2,814	5,102	9,683	19,398	32,544	37,815	39,149
Ownership Of Dwellings	**319**	**816**	**1,507**	**6,112**	**9,531**	**11,514**	**13,301**	**14,010**
Gross Value Added At Basic Prices	**6,877**	**16,764**	**40,468**	**85,175**	**171,087**	**304,428**	**380,002**	**387,701**
Add: Taxes On Products	970	2,067	3,707	7,690	12,999	17,933	18,367	20,218

Source: Department of Statistics

Gross value added (GVA) was S$419.0 billion in 2017, S$401.4 billion in 2016, $393.8 billion in 2015.

The per capita GDP (in current prices) was S$76,697 for 2017 and S$76,318 for 2016. The Gross National Income (GNI) per capita (in current prices) was S$76,863 for 2017, S$72,376 for 2016, S$72,682 for 2015. (See **Table 2.6**)

Table 2.6: Nominal per capital GNI and per capita GDP at current market price.

Variables	1960	1970	1980	1990	2000	2010	2015	2016
Per Capita GNI (S$)	1,334	2,860	10,165	22,907	40,767	63,137	72,682	72,376
Per Capita GDP (S$)	1,310	2,832	10,714	23,139	41,018	63,498	75,533	76,318
Per Capita GNI (US$)	436	934	4,747	12,638	23,648	46,305	52,867	52,389
Per Capita GDP (US$)	428	925	5,004	12,766	23,794	46,570	54,941	55,243

Source: Department of Statistics

Table 2.7: Macroeconomic Indicators.

Variables	2010	2011	2012	2013	2014	2015	2016	2017
Gross national income or GNI (constant 2010 US$)	235,076,347,635	245,299,836,858	251,345,051,153	265,097,339,940	279,313,746,498	281,542,731,210	284,079,055,536	299,107,293,966
GNI per capita (constant 2010 US$)	46,305	47,321	47,313	49,100	51,065	50,866	50,663	53,295
GNI per capita, PPP (constant 2011 international $)	71,681	73,255	73,241	76,008	79,051	78,742	78,427	82,503
Gross domestic product or GDP (constant 2010 US$)	236,421,782,178	251,436,156,949	261,703,043,638	275,078,914,558	285,762,669,600	292,166,776,678	299,170,077,008	309,995,672,901
Real GDP growth (annual %)	15.24	6.35	4.08	5.11	3.88	2.24	2.40	3.62
Real GDP per capita (constant 2010 US$)	46,569.68	48,505.26	49,262.33	50,948.45	52,244.44	52,785.31	53,353.84	55,235.51
Unemployment, total (% of total labor force) (national estimate)	2.07	1.87	1.79	1.71	1.69	1.69	1.80	
Inflation, consumer prices (annual %)	2.82	5.25	4.58	2.36	1.02	(0.52)	(0.53)	0.58
Population	5,076,732	5,183,688	5,312,437	5,399,162	5,469,724	5,535,002	5,607,283	5,612,253
Population growth (annual %)	1.77	2.08	2.45	1.62	1.30	1.19	1.30	0.09
Population, % male (% of total)	49	49	49	49	49	49	49	49
Population, male	2,505,008	2,557,228	2,621,068	2,664,765	2,700,649	2,733,768	2,770,103	2,773,000
Population, female (% of total)	51	51	51	51	51	51	51	51
Population, female	2,571,724	2,626,460	2,691,369	2,734,397	2,769,075	2,801,234	2,837,180	2,839,253

2.3 2 Unemployment Rate

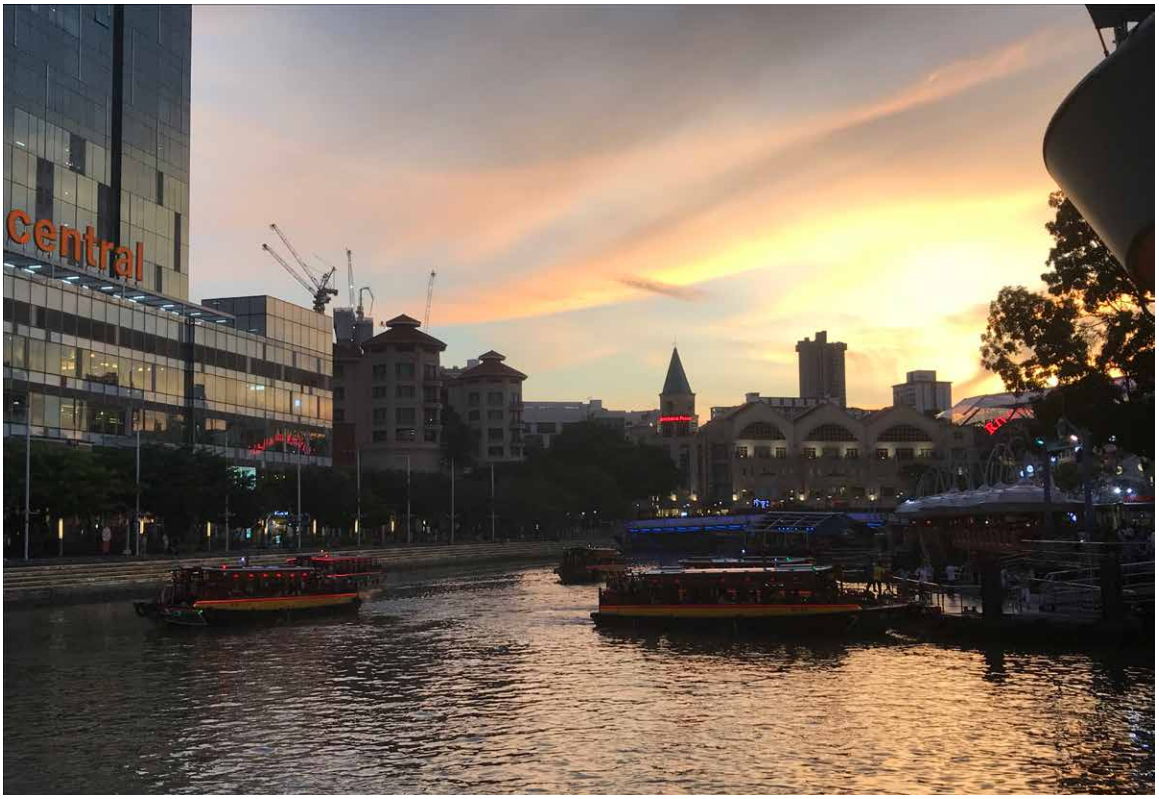
The unemployment rate refers to the unemployed as a percentage of the labour force (also known as the economically active population).

Singapore's unemployment rate averaged 2.44 per cent from 1986 until 2018, reaching an all-time high of 6 per cent in the first quarter of 1986 and a record low of 1.40 per cent in the second quarter of 1990.

Currently unemployment stands at 2.1 per cent in 2016, which is down from the high rate of 3 per cent during the decade right after the global financial crisis of 2008. This is largely due to an export-led rebound in the manufacturing sector – which makes up one-fifth of the economy – Singapore's GDP gained momentum in the last quarter of 2016.

2.3.3 Major Exports and Imports

Singapore's primary exports for commodities were machinery and equipment (including electronics), consumer goods, pharmaceuticals and other chemicals and mineral fuels. While Singapore's major imports are commodities, such as machinery and equipment, mineral fuels, chemicals, foodstuffs and consumer goods (Enterprise Singapore, n.d.).



PART 2

HARNESSING THE OCEANS

3 Ocean Economy

Oceans provide an extensive range of natural assets and resources – natural capital from which humans derive a wide variety of ecosystem services that make life possible and upon which human activities rely.

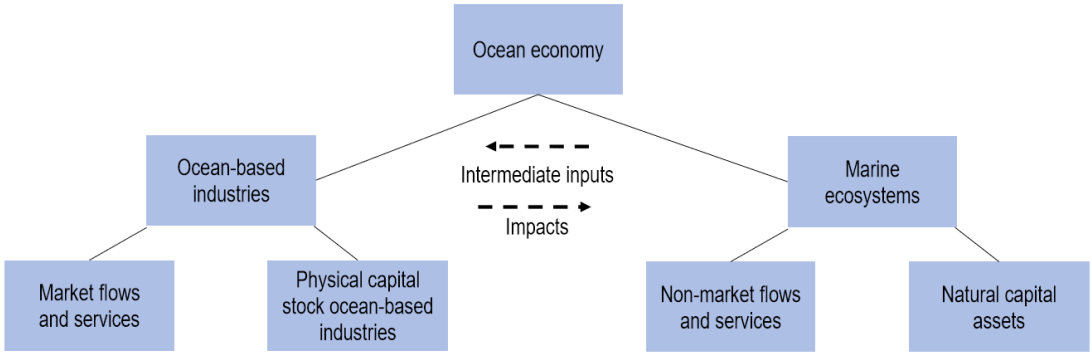
The entire ocean economy is measured as the sum of: (a) the economic activities with dependence on the ocean and coastal and marine resources, and (b) natural assets, goods and services of marine ecosystems upon which these industries depend on, and people rely on for food, income, livelihood, recreation, shoreline protection, etc. (**Figure 3.1**)

The ocean economic activities can be measured using the System of National Accounts (SNA), and include:

- *ocean-based activities*, such as fisheries, marine tourism, shipping, oil and gas, ocean energy, etc.;
- *ocean-related activities*: (a) those that use products from the ocean (e.g., seafood processing, marine biotechnology, salt); (b) produce products and services for the ocean-based activities (e.g., ports, ship-building, communication, maritime insurance); (c) marine education, and research and development; and (d) government agencies with direct maritime responsibilities (e.g., navy, coast guard, marine environmental protection, etc.).

The ocean also provides services that are not usually quantified and captured in the national income accounts, such as *regulating services* (e.g., carbon storage, shoreline protection, waste assimilation, nutrient cycling), *supporting services* (e.g., habitat, nursery), and *cultural services*.

Figure 3.1: Ocean Economy.



Source: OECD (2016), The Ocean Economy in 2030, http://dx.doi.org/10.1787/9789264251724-en.

3.1 Key Ocean Economic Activities

Singapore's maritime industry is a key pillar of Singapore's economy. Made up of shipping, port, maritime services and offshore & marine engineering sectors, Singapore's maritime industry contributes 7% of Singapore's Gross Domestic Product (GDP) and employs over 170,000 people.

Chapter 4 to 7 discuss details of key ocean economic activities.

3.2 Coastal and Marine Ecosystem Services

Whilst there have been various studies conducted on ecosystem services – particularly for the mangrove and coral reef habitats in Singapore – quantifying the economic, social, and cultural value of Singapore's environmental assets (i.e. "Natural Capital") has been identified as a gap in knowledge for Singapore's CME. With the ever increasing demand for marine and coastal resources as Singapore's coastal zone continues to develop, the status of the CME is currently undergoing assessment on a national level with a new project funded by government with the aim of informing future policy and urban development.

3.2.1 National Natural Capital Project[15]

The Natural Capital Singapore project was initiated on the 1st January 2018 to conduct the first national assessment for Singapore of the natural capital provided by ecosystem services, and the first assessment for a tropical, heavily urbanised country. By quantifying Singapore's Natural Capital, this 3-year project will help government agencies and other stakeholders to assess the trade-offs between urban development and environmental concerns, and to make more informed policy and management decisions. Led by the Singapore-ETH Centre and Department of Geography at NUS, the project brings together a multi-disciplinary team from ETH Zurich, NUS, Nanyang Technological University (NTU), Singapore-MIT Alliance for Research and Technology (SMART) and NParks.

The assessment will provide the first national-scale baseline of the status of Singapore's ecosystem and the first estimate of their societal and economic values. The project has three key objectives. First, in consultation with key stakeholders from multiple agencies, the team will create a Natural Capital Assessment (NCA) framework suited to Singapore's unique urban context. This first objective includes identifying key habitats in Singapore and charting the services they provide to residents. Methods for mapping habitats and services at appropriate spatial scales will also be developed.

Second, based on the framework, an NCA will be conducted on both terrestrial, and coastal and marine ecosystems. With regards to coastal and marine habitats in particular, this includes but is not limited to mangrove forests, seagrass, coral reefs, beaches and open water estuarine habitats, alongside artificial marine habitats such as coastal defence structures.

[15] http://www.naturalcapital.sg.

The way that a society values nature is very context dependent and is related to the socio-political and economic climate of the country as well as the culture, age and life experiences of residents. Care therefore must be taken in comparing or transferring values obtained from studies in temperate regions and even studies within tropical regions but from countries with different social and economic characteristics.

Third, with data from the NCA, the team will develop an interactive decision support tool that will help a wide range of government agencies to assess the impacts of future plans on Singapore's ecosystem services, and therefore its citizens. With respect to the marine environment such a tool might support planning for marine protected areas, management of climate change risks and design of marine infrastructure.

3.2.2 Prior Studies of Ecosystem Services in Singapore

Most studies that have been conducted, which attempt to apply monetary valuation techniques to shed light on the value and services provided by various ecosystems in Singapore – focus on terrestrial systems. For the coastal and marine systems, the available information can be extracted from the studies listed below.

3.2.2.1. Studies of Mangroves

On average, the total annual economic value of mangrove has been estimated at more than US$9,000 per hectare per year (Costanza, et al., 1997) However this figure is variable when comparing national estimates (Wells, et al., 2006). There is emerging scientific evidence that mangroves are important for the well-being of coral reefs and even the ocean's biogeochemical cycle with regards to its sources of marine dissolved organic carbon (Dittmar, et al., 2006).

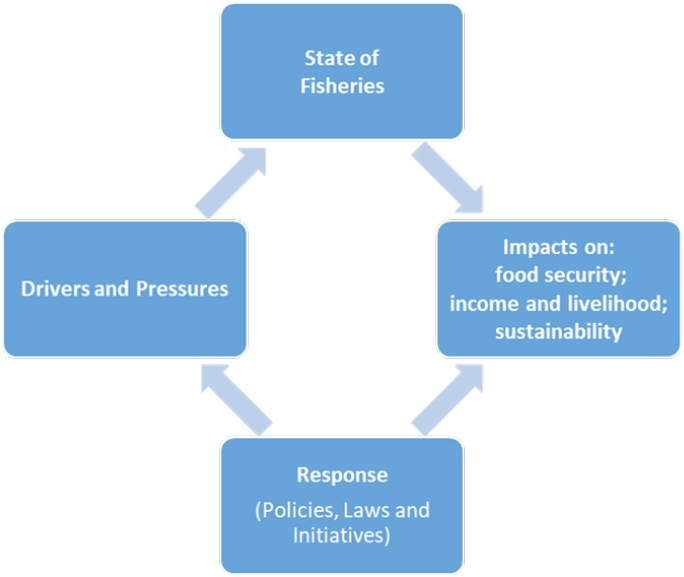
Regarding the carbon sequestration and storage, mangroves in Singapore store more than 450,000 tons of carbon across the nation (Friess, 2016). Mangrove in Singapore are significant barrier to attenuate wave energy from storm (Lee, 2017) and trap suspended sediments and pollutants (Hasan, et al., 2015).

Singapore's remaining mangroves also provide important extrinsic and intrinsic cultural ecosystem services to the local population such as recreational, educational, aesthetic, heritage and spiritual value (Thiagarajah, et al., 2015). Besides that, Singapore's mangroves are a rich source of biodiversity, containing 35 true mangroves species. A number of invertebrate species new to science was first to described from Singapore's mangroves, including crabs and species from Coleoptera, Isopoda and lepidoptera (Friess, et al., 2012).[Refer to **Section 10.1** Mangrove Habitats]

3.2.2.2 Studies of Coral Reefs

The roles and values of coral reefs in carbon sinks, tourism, attraction, shoreline protectors, fishery resources and research potential of the coral reefs in the straits of Malacca and Singapore compound to a value of US$563 million (Burke, et al., 2002).

4 Fisheries and Aquaculture



4.1 Fishery Resources and Fish Stocks

Singapore has a small commercial fishing fleet of seven offshore vessels and one inshore vessel, all of which are less than 24m in length. All commercial fishing vessels in Singapore are licenced to conduct fishing activities within Singapore waters and are Singapore-owned and operated. Singapore also has a high-seas plying fish carrier that receives transhipment of fish from foreign flagged fishing vessels operating in Regional Fisheries Management Organisations (RFMOs)-managed waters. All fish caught by Singapore's fishing vessels are consumed domestically. About 1,235 tonnes of wild caught fish was harvested from Singapore waters by the local commercial fleet in 2016. Singapore fishing industry receives no government subsidies for the conducting of fishing activities.

4.2 Aquaculture (fish, crustaceans, molluscs, etc.)

The main bulk of foodfish production comes from coastal farming in floating net cages along the Strait of Johor. There are currently 114 coastal fish farms (figures as of June 2018). Common marine foodfish species that are cultured include Seabass (*Lates calcarifer*), groupers (*Epinephelus spp.*), snappers (*Lutjanus spp.*), milkfish (*Chanos chanos*) and mullet (*Mugil spp.*). Green mussel (*Perna viridis*) forms the bulk of shellfish production in Singapore.

4.3 Fisheries Production (fish, crustaceans, molluscs, etc.)

Fisheries production and export figures for years 2013 to 2017 are shown in **Table 4.1**.

Table 4.1: Fisheries and Aquaculture Production and Export for 2013-2017.

Variables	1960	1970	1980	1990	2000
Wild Caught Seafood (Tonnes)	1,644	1,434	1,264	1,235	1,108
Aquaculture Production (Tonnes)	5,132	4,945	6,431	5,587	5,390
Export of Seafood (Live, chilled and frozen) (Tonnes)	25,985	16,335	22,328	19,128	15,925

Source: Agri-Food and Veterinary Authority of Singapore (AVA).

4.4 Fish Ports

Singapore has two fish ports providing 24-hour service daily to foreign and local fishing vessels for bunkering, discharging and transhipment of fish. Both ports enforce the Wholesome Meat and Fish Act and its subsidiary legislation, and the Fisheries Act and its subsidiary legislation.

Apart from locally caught seafood, the two fishery ports handled 14% of Singapore's imported seafood in 2017.

4.4.1 Jurong Fishery Port (JFP)

JFP started operations in 1969 and has a land area of 5.1ha. It serves as a docking and bunkering base for foreign fishing vessels operating in the Indian and Pacific Oceans and foreign fish carriers from Indonesia and Malaysia, and is also the marketing and distribution centre for fresh fish on the island.

Fishing vessels and fish carrier boats calling at JFP unload their catch for wholesale or re-export, either through 103 AVA-tenanted fish merchants at JFP or through exporters and processing plants. Fish sold at JFP are also imported by sea, land and air from various countries such as Indonesia, Malaysia, Thailand, Australia, Bangladesh, China, India, Myanmar, Taiwan, and Vietnam.

4.4.2 Senoko Fishery Port (SFP)

Situated in the north of Singapore, SFP has an area of 3.24ha. The port began operations in September 1997 and serves as a home base for the local fishing fleet of the seven offshore and one inshore fishing vessels.

There are 25 AVA-tenanted fish merchants based at SFP, handling about 15,000 tonnes of fish per annum. About half of this comprises supply landed by local fish farms, while the rest of the fish are imported.

4.5 Contribution to Food Security

Singaporeans consume about 21kg of seafood yearly, and in 2017, Singapore consumed a total of 120,013 tonnes. Of which, local seafood production accounts for about 4 per cent of local seafood consumption.

4.6 Sustainability: Pressures and Response

4.6.1 Fisheries

There is limited fishing pressure and capacity in Singapore due to the small fishing fleet. Commercial fishing vessels and the type of fishing gear used are licenced to be renewed annually. Locations for commercial fishing activity are monitored and shared by the fishing vessel masters. Moreover, all seafood caught on Singapore's commercial fishing vessels are recorded and monitored.

As a significant transhipment hub, Singapore plays a central role as a trading and distribution hub for fishery products. Internationally, Singapore cooperates with RFMOs through their Catch Documentation Scheme (CDS) for our trade in RFMO fish species to ensure that they do not come from illegal, unreported, and unregulated (IUU) fishing – a fishing activity which has emerged as a food security challenge.

Singapore has been a signatory to the Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated Fishing in the Region (RPOA-IUU) since 2007. The RPOA-IUU is a voluntary instrument whose objective is to enhance and strengthen fisheries management in the region, in order to sustain fisheries and marine resources and to optimise the benefits of adopting responsible fishing practices.

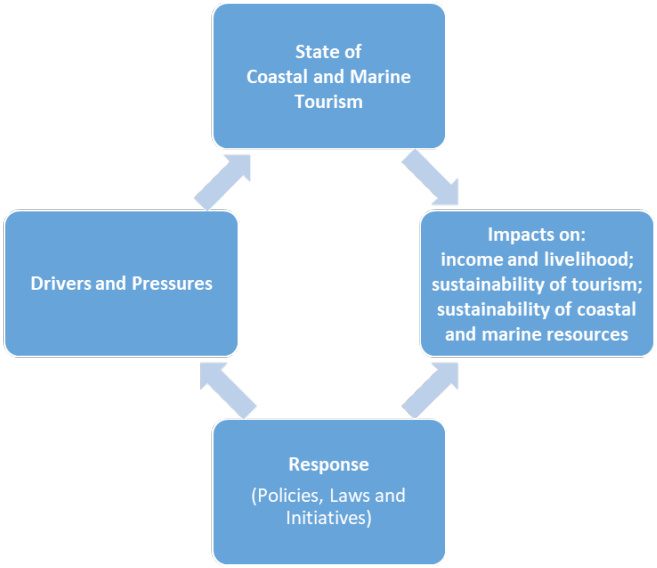
4.6.2 Aquaculture

The main concerns facing farms today, are the threats from harmful algal blooms (HAB) and climate change. For HABs, a multi-pronged approach was established to help the industry mitigate its effects. This includes working with research institutions to better understand local HAB species, training farms to develop contingency plans to reduce environmental stressors and close monitoring of water quality. For longer–term solutions, which would also negate effects from oil spills and climate change, coastal farms are also encouraged to adopt the Closed Containment Aquaculture Systems as effective and bio-secure production methods. [Refer to **Section 8.2** Innovative and Sustainable Economic Activities, **Subsection 8.2.1** Sustainable Aquaculture Inputs and Production Systems]

4.6.3 Response

To improve the standard and sustainability of the aquaculture industry, AVA launched the Good Aquaculture Practice for Fish Farming (GAP-FF) scheme in 2014. GAP-FF is a set of guidelines which were developed with reference to internationally recognised standards and adapted to ensure they are relevant to the local farming industry. The objective of the GAP-FF scheme is to promote responsible management practices in food fish farming as well as to provide assurance to both retailers and consumers by setting the benchmark for the production of safe and quality fish.

5 Marine and Coastal Tourism



Singapore has transformed from a humble trading post to a major player in the global tourism arena for its world-class attractions, rich heritage and innovative infrastructure.

Being a highly urbanised, land-scarce island nation, many of the attractions located along the coast are viewed in a very different light from coastal and marine tourism in the traditional sense. Nevertheless, characteristic of most tropical islands; Singapore still retains a few stretches of picturesque sandy beaches, where visitors can enjoy a day out by the shore. Most of these pockets of sand and sea can be divided in two broad clusters – the beaches located on Sentosa Island; and the east coast beaches, the largest of which is East Coast Park, a dedicated recreational beach park built on reclaimed land with a man-made beach protected by breakwaters.

The vision of our founding fathers – to establish Singapore as a garden city, with recreational spaces, world-class attractions and skyscrapers set amid lush greenery, "A City in a Garden" – has not only necessitated careful and stringent planning, but has also resulted in an unconventional slant on coastal tourism for Singapore.

5.1 Top Tourist Destinations

5.1.1 Marina Bay and Greater Southern Waterfront[16]

The 360-ha (890-acre) Marina Bay, located just to the east of the downtown district, in the central area of Singapore, was one of Singapore's boldest urban transformation projects to date. It is envisioned as a vibrant 24/7 environmentally-friendly, mixed-use precinct designated for living, working and playing along prime waterfront land. Beyond enhancing Singapore's city skyline, Marina Bay was designed with sustainability in mind, adopting environmentally-sustainable strategies and technologies in its development:

- Marina Reservoir serves as a freshwater reservoir that contributes up to 10 per cent of local water supply.
- The diverse land uses planned offers both residents and workers greater access to amenities, reducing possible long distance travelling.
- A common services tunnel is seen as a novel way of locating all utility services like electrical and telecommunication cables and water pipes in the same underground network, allowing for easier maintenance and upgrading with minimal disruptive road excavations.
- The waterfront promenade was designed as a well-shaded environment, with lush tree planting for pedestrians, with elements of water features including to cool ambient temperature and adding to the pleasant walking experience.

5.1.1.1 Marina Barrage[17]

Built at the confluence of five rivers, across the mouth of the 350m-wide Marina Channel, the Marina Barrage was officially opened in 2008. The project marked another milestone in Singapore's water story, and won the American Academy of Environmental Engineers (AAEE) Superior Achievement Award in 2009. Besides its functional features of aiding water storage and flood control, the Marina Barrage was also designed as an ideal recreational space, providing a rooftop park popular for picnics, kite-flying or taking in the sunset views.

Constructed based on three-fold benefits of: water supply, flood control and a lifestyle attraction, the S$256 million project commissioned by PUB,[18] turned Marina and Kallang Basin into a new downtown freshwater Marina Reservoir, creating Singapore's fifteenth reservoir. The Marina catchment area is one of the island's largest, most urbanised catchment, encompassing almost one sixth the size of Singapore, or 10,000ha. Combined with Punggol and Serangoon reservoirs, Marina Reservoir has increased Singapore's water catchment areas from half to two-thirds of Singapore's land area.

The barrage forms part of a comprehensive flood control scheme, aimed at alleviating flooding in the low-lying areas in the city like Chinatown, Boat Quay, Jalan Besar and Geylang. During heavy

16 See https://www.ura.gov.sg/-/media/corporate/Singapore-City-Gallery/Worksheets/Marina-Bay-Gardens-by-the-Bay.
17 https://www.pub.gov.sg/marinabarrage/aboutmarinabarrage
18 See PUB Annual Report, 2008

rain, the series of nine crest gates are activated to release excess stormwater into the sea when tide is low. During high tide, giant pumps are utilised to drain excess stormwater into the sea.

As the water level is kept constant all year round, rendering it unaffected by the tides and therefore ideal for all kinds of recreational water activities such as boating, kayaking and dragon-boating.

The facility is also an achievement in Singapore's efforts to go green. Demonstrating how sustainable energy technology can be incorporated into the building design, the Solar Park is one of the largest collections of 405 solar panels in Singapore and supplements the daytime electricity required for operations in the barrage. Generating 76,000kWh electricity per annum, the barrage won the Green Mark Platinum Infrastructure Award; with green principles being applied in all aspects of design, construction and operation that utilises energy and water efficiently, whilst minimising waste generated.

5.1.1.2 Marina Bay Sands®[19]

Marina Bay Sands® (MBS) is an integrated resort (IR) combining a hotel, casino, retail mall, convention facilities, and entertainment venues, such as theatres, nightclubs and a museum. The sprawling 570,000 m^2 complex - operated by Las Vegas Sands (LVS) Corp - dominates the entire Bayfront area, putting its definitive stamp on the Singapore skyline since its opening in 2010. A bold architectural statement and feat of engineering; the aesthetic design of MBS includes the iconic lotus-shaped ArtScience Museum™ against the backdrop of three 55-storey hotel towers and a 12,400sq m SkyPark® impressively cantilevered on top of the three towers.

5.1.1.3 The Gardens by the Bay[20]

Conceptualised in 2005, The Gardens by the Bay was a crucial component in boosting Singapore's reputation as a Garden City and complementing the government's vision of a "City in a Garden". The three public gardens occupy 101 ha plot of land, positioned right by the water's edge, and promoted as the nation's showpiece of horticulture and garden artistry. The largest of the three gardens, Bay South opened in 2012.

The Gardens by the Bay were originally envisioned by NParks to contend with that of the iconic green spaces like Central Park in New York and London's Kew Gardens, and become a defining feature of Singapore's desire to become a global city. Singapore needed a new public green space in the city area, as the famous Singapore Botanic Gardens was overstretched by leisure, research and academic usage. Horticultural recreation was to be Gardens by the Bay's focus, while the Botanic Gardens would be used mainly to education, conservation and research.

The main attractions include the two huge futuristic structures – The Flower Dome and the Cloud Forest conservatories –and the striking silhouettes cast by the Supertree Grove and the aerial walkway.

[19] See eresources.nlb.gov.sg/infopedia/articles/SIP_1607_2011-11-01.html
[20] See eresources.nlb.gov.sg/infopedia/articles/SIP_2012-06-26_095923.html

5.1.2 Sentosa Island[21]

Sentosa is a leading leisure destination and Singapore's premier island resort getaway - located within 15 minutes from the central business and shopping districts – receives over six million visitors a year. The island resort is managed by Sentosa Development Corporation (SDC, a statutory board under the Ministry of Trade and Industry), which works with various stakeholders in overseeing property investments, attractions development, operation of the various leisure offerings, and management of the residential precinct on the island.

The 500-hectare island resort is home to an exciting array of themed attractions, award-winning spa retreats, lush rainforests, golden sandy beaches, resort accommodations, world-renowned golf courses, a deep-water yachting marina and luxurious residences – making Sentosa a vibrant island resort for business and leisure. In March 2004, as part of a resort development plan for Sentosa and the southern islands, the Ministry of Trade and Industry conducted a study on the economic, tourism and social aspects of having a casino in the island resort. Singapore's first integrated resort, Resorts World Sentosa, which operates Southeast Asia's first Universal Studios theme park, is located on Sentosa.

Situated on the eastern end of Sentosa Island is Sentosa Cove, an exclusive oceanfront and residential enclave bustling with some 2,000 homes, romantic quayside restaurants, retail and specialty shops. The Island is also home to Sentosa Golf Club and its two acclaimed golf courses, The Serapong and The New Tanjong, which have hosted various international golf competitions.

5.1.2.1 SEA Aquarium

S.E.A. Aquarium, home to more than 100,000 marine animals of over 1,000 species, across into 50 different habitats. S.E.A. Aquarium does both educational and conservational projects. For conservational works, the Guardians of the S.E.A.A. is the conservation group of the aquarium. The group supports conservation research, education and public engagement efforts by bringing together a community of enthusiasts and organisations collaborating with S.E.A. Aquarium to protect the marine environment. The aquarium also provides educational service to people of all ages, and enables the public to get up close with marine life, providing them the opportunity to learn more about the wildlife.

5.1.3 Singapore Zoo[22]

Originally located in the botanic gardens, Singapore's first zoo was established in 1875 at the suggestion of then Governor Sir Henry Ord. Due to the lack of funds, upkeep of the zoo as well as high animal mortality rates, let to the zoo's closure in 1905. In late 1969, the government permitted the formation of a public limited company, Singapore Zoological Gardens, to establish and operate a zoo.

[21] See eresources.nlb.gov.sg/infopedia/articles/SIP_247_2005-01-20.html
[22] See eresources.nlb.gov.sg/infopedia/articles/SIP_403_2005-01-09.html

The contribution of S$9 million was donated by the government towards the zoo's development cost and set aside 1.05 km^2 of land for the project.

The Singapore Zoo was officially opened in 1973, extending into the Seletar Reservoir and situated on 0.3 km^2 (70 acres) of land, the zoo adopted some of the most advanced open concept zoo designs of the 1970s.

The zoo had an initial collection of about 300 animals housed in some 50 enclosures. Although the focus was on animals from the Southeast Asian region, there were also animals sourced from other parts of the world. The popularity of Singapore Zoo quickly gained, and welcomed its one-millionth visitor on 13 November 1974, less than two years after it opened to the public.

A series of major revamps took place after 2000. The free-ranging orang-utan habitat opened in April 2006 for visitors to get up close and personal with the orang-utans, and in 2007, the new Splash Amphitheatre was constructed. Introducing a new Splash Safari Show, which premiered on 26 May 2007. Following the opening of the Amphitheater, the Sumatran orang-utan exhibit was then opened on July 2007, as well as the completion of a new and much larger sun bear exhibit. The Rainforest Kidzworld open on 14 November 2008 in the former Children's World Animal Land. The S$8-million Frozen Tundra resembling the arctic Habitat – which house Inuka - the polar bear - was opened to the public on 29 May 2013.

5.1.4 Night Safari and River Safari[23]

Following the successful development of the Singapore Zoo, the Night Safari was established in 1994. It was the world's first night zoo, allowing visitors to observe nocturnal animals in a natural habitat. The Singapore Zoo, along with the Night Safari and the Jurong Bird Park, are managed by Wildlife Reserves Singapore (WRS), a holding company that was formed on 1 August 2000. The River Safari, a river-themed wildlife park, has a pair of giant pandas, which were Singapore's first pair of pandas. They were officially added to the park in February 2014.

The Night Safari is 35 ha, attracts more than 1.1 million visitors yearly, and is located in Mandai, adjacent to the Singapore Zoo and Upper Seletar Reservoir. It houses over 130 animal species and more than 2,500 animals. The Night Safari, was split into seven geographical zones, which can be explored both on foot and on tram. The safari consisted of: Himalayan Foothills, Indian subcontinent, Equatorial Africa, Indo-Malayan region, Asian Riverine Forest, Nepalese River Valley and Burmese Hillside.

The Night Safari took an open concept approach, to mimic natural environment. To contain the animals the Night Safari relies on more natural barriers - like cattle grids, instead of bars and grills that surround the entire park, delimiting animal movement. Nettings, plants, concealed wires and water moats are also utilised as natural barriers.

[23] See eresources.nlb.gov.sg/infopedia/articles/SIP_1039_2010-03-18.html

5.1.5 Singapore Botanic Garden[24]

Conceptualisation of a national garden started in 1822 when Sir Stamford Raffles, the founder of modern Singapore and a keen naturalist, developed the first 'Botanical and Experimental Garden' at Fort Canning. In 1859, the 82-ha Gardens was founded and laid out in the English Landscape Movement style by an Agri-Horticultural society. The Gardens was soon handed over to the British colonial government (in 1874), and a series of Kew-trained botanists saw the Gardens develop into an important botanical institute over the following decades. Currently, the Singapore Botanic Garden is managed by NParks.

The Gardens played an important role in establishing agricultural development in Singapore and the region in its early years. One of the earliest and most important successes was the introduction, experimentation and promotion of Para Rubber (*Hevea brasiliensis*) a major crop that brought profit to the Southeast Asian region in the early 20th century. The garden also manages breeding and hybridisation of orchids since 1928 using in vitro techniques in its laboratories. In contemporary times, the Gardens also played a key role in Singapore's Garden City programme through the continual introduction of plants of horticultural and botanical interest.

The Gardens became a UNESCO World Heritage Site at the 39th session of the World Heritage Committee (WHC) in 2015. The Gardens is the first and only tropical botanic garden on the UNESCO's World Heritage List. It is the first in Asia and the third botanic gardens inscribed in the world following Orto botanico di Padova in Italy, and the Royal Botanic Gardens, Kew in England.

5.2 Major Tourist Destinations and Attractions in Coastal and Marine Areas

5.2.1 Singapore as a "Garden City" and Nature and Parks

The Garden City was envisioned by the then Prime Minister, Mr. Lee Kuan Yew, as a strategy that started in 1960s, to attract foreign investors as well as to make the environment more pleasant. The garden city concept was incorporated in the Urban Redevelopment Agency's (URA) first *1971 Concept Plan* to guide the development of Singapore. A Garden City Action Committee (GCAC) was established in 1973 to ensure allocation of land for parks and open spaces.

NParks is the agency responsible for maintaining and enhancing the greenery of the City in a Garden. NParks manages the four Nature Reserves (3,347 ha), over 400 parks and the park connector network (2,792 ha), with an overall total area of around 15,570 ha (National Parks Board, 2017). NParks promotes community engagement with a range of recreational activities and offerings, with the ultimate objective of encouraging

[24] See eresources.nlb.gov.sg/infopedia/articles/SIP_545_2005-01-24.html

conservation of Singapore's urban greenery and biological diversity through proper management of parks and nature reserves, and a special significance in helping to retain our national heritage.

Of the three categories of parks – regional parks, neighbourhood parks, and greenways or park connectors – the following section addresses the main coastal parks and key coastal areas designated for leisure and provide opportunity for recreation. (**Table 5.1**)

Table 5.1: Coastal Parks and Coastal Nature Reserves, Singapore.

Park and Nature Reserve	2009 Area (ha)	Total Area (ha)	2016 Area (ha)	Total Area (ha)
Nature Reserve		185.07		219.19
Labrador Nature Reserve	20.46		25.88	
Sungei Buloh Wetland Reserve	164.61		193.31	
Coastal Park		470.04		519.23
Admiralty Park	25.67		25.67	
Changi Beach Park	31.11		28.52	
East Coast Park	209.60		242.42	
Pasir Ris Park	73.02		73.39	
Pasir Ris Town Park	12.76		12.36	
West Coast Park	50.00		50.00	
Kranji Reservoir Park and Nature Trail	47.00		60.07	
Sembawang Park	15.48		15.58	
Woodlands Waterfront Park	5.40		11.22	
Island		693.09		742.13
Coney Island	46.64		50.00	
Pulau Ubin Recreation Area	647.26		692.13	
Park with a Sea View		160.67		168.65
HortPark	23.50		24.57	
Kent Ridge Park	46.52		48.40	
Mount Faber Park	56.46		58.80	
Telok Blangah Hill Park	34.19		36.88	
Lower Riverine Park		4.81		5.16
Kallang Riverside Park	4.81		5.16	
Coastal Park in Central Area		19.31		19.35
Esplanade Park	2.40		2.40	
Marina Promenade	15.21		15.21	
War Memorial Park	1.64		1.74	
Waterboat House Garden	0.06			
Marine Park				
Sisters' Islands Marine Park			47.68	47.68
All parks		**1,533.80**		**1,721.39**

Source: NParks Annual Report 2016/2017.

5.2.1.1 Labrador Nature Reserve (LNR)[25]

Labrador was originally gazetted as a nature reserve under the old *Nature Reserves Ordinance*. More recently, the coastal secondary vegetation and the rocky shore have been gazetted as a Nature Reserve since 2002. The reserve is located on the southern coast of Singapore. It includes a large hill, which is covered by secondary forest. Labrador Nature Reserve consists of 10ha of gazetted nature reserve, and 11ha of managed parkland. Fronting the 30 m high cliff sides, the 100 m Labrador beach is the only rocky shore left on mainland Singapore. The beach is a mixture of rocks, mud, and patches of coral growth. It has representatives of several major intertidal ecosystems: natural rocky shore, seagrass areas, coral rubble and coral reefs.

The waterfront of the reserve has been developed into a park, and encircles the shore to include the foreshores of Berlayar Creek. This 11-ha park built surrounding the gazetted reserve area creates additional recreational opportunities for visitors to LNR. On the 4-m wide promenade, large shelters, barbeque pits, and benches cater to families and organized group outings. The refurbished jetty extending out to the sea is popular with anglers. The waterfront as well as lookouts built on the hill offer picturesque views of the sea. A boutique hotel, spa and restaurants are also located within the park.

The Reserve is also rich in history with many historical sites of WWII bunkers and other relics. The history trail captures the history of the fort and the war where visitors can view a casemate (war bunker) and tunnels in the Reserve.

5.2.1.2 Sungei Buloh Wetlands Reserve (SBWR)[26]

A group of avid birdwatchers from the then Malayan Nature Society (Singapore Branch) stumbled upon Sungei Buloh in 1986 and wrote a proposal to the government for its conservation. Sungei Buloh is an 87-ha wetland site, and was designated as a nature park in 1989 and developed in consultation with the Wildfowl & Wetlands Trust from United Kingdom, Jurong Bird Park, Worldwide Fund for Nature, and the Nature Society. It was officially opened in1993, and 2018 marks the 25th anniversary of Sungei Buloh.

On 1 January 2002, 130 ha of Sungei Buloh was officially gazetted as a nature reserve. To reflect its status, Sungei Buloh was renamed Sungei Buloh Wetland Reserve (SBWR). The reserve merged several pockets of natural wetland areas around Sungei Buloh, including the Lim Chu Kang mangroves, Kranji Reservoir Park and Kranji marshes to form a natural

[25] See https://www.nparks.gov.sg/gardens-parks-and-nature/parks-and-nature-reserves/labrador-nature-reserve
[26] See https://www.nparks.gov.sg/-/media/nparks-real-content/learning/learning-journeys/guided-walks/diy-guided-walks/sungei-buloh/diy-trail-gu

corridor for more strategic mangrove and wildlife conservation. Kranji Reservoir Park is linked to the Sungei Buloh Wetland Reserve via the Kranji Nature Trail that was opened in September 2003.

SBWR coastal area was previously occupied by abandoned prawn ponds. Now the reserve is covered mostly by mangroves and several freshwater ponds. At low tide, wide stretches of mudflats lie exposed, and the myriads of crabs, shellfish and worms attracted flocks of birds including migratory shorebirds, such as sandpipers and plovers, which make their annual crossing down south to escape the cold winters of the Siberian tundra. SBWR is recognised as an internationally important site for migratory birds, and the certification was presented by Wetlands International to mark its formal entry into the East-Asian Australasian Shorebird Site Network. This migratory network includes Australia's Kakadu National Park, Hong Kong's Mai Po and Japan's Yatsu Tidal Flats.

In 2003, SBWR also became Singapore's first ASEAN Heritage Park. Subsequently, the area has increased to 202ha, encompassing mangroves, mudflats, ponds and forests; providing an even larger sanctuary for the flora and fauna that inhabit it. The expansion – which included a new visitor centre and new trails for visitors to explore, located along Kranji Way making it more easily accessible by public transport - was zoned into four activity areas, with the core of the wetlands retained for conservation and research while the fringes will be enhanced for different levels of recreational use.

5.2.1.3 Pulau Ubin[27]

Situated just off the northeast coast of Singapore, in the Straits of Johor, this 10.2 km^2 island is home to Singapore's last village (or kampong); as well as Chek Jawa Wetlands, which is one of Singapore's richest ecosystems. Pulau Ubin translates as "Granite Island" and it was the granite mining that originally supported a few thousand settlers back in the 1960s, and supplied the local construction industry.

Much of the original vegetation was felled for the cultivation of rubber and crops like coffee, pineapple, coconut and jasmine. Today the abandoned granite quarries linger as scenic relics of Ubin's history, and much of the forests and grasslands have regenerated. Ubin retains much of its unspoilt and rustic charm, as one of the last rural areas to be found in Singapore.

Pulau Ubin is one the 20 Nature Areas designated under URA's Parks and Waterbodies Plan. The island was once a cluster of five smaller islets separated by tidal rivers. The building of bunds for prawn farming merged these islets into a single island. Today, much

[27] See https://www/nparks.gov.sg/news/2008/7/pulau-ubin

of the forests and grasslands have regenerated to cover up the land cleared. The island now offers nature lovers the option of exploring one of the many trails by means of a leisurely hike; or the more adventurous have the choice of renting mountain bikes to cruise across the rugged terrain. Ubin is also home to the Ketam Mountain Bike Park, an 8-km trail, which was built in 2007 for more serious mountain bikers.

The island was identified by BirdLife international as forming part of the Ubin-Khatib Important Bird Area (IBA), which supports significant numbers of migratory and resident birds, some of which are threatened species.

a. Chek Jawa

A quiet cape located on the eastern tip of Pulau Ubin, Chek Jawa is one of Singapore's richest ecosystems still left intact. It is a unique natural area covering an approximate 100 ha area. Here, six major habitats convene – sandy beach, rocky beach, seagrass lagoon, coral rubble, mangroves, and coastal forest – creating a melting point for biodiversity.

Chek Jawa was originally slated for redevelopment in 2000, however, its natural attractions were uncovered, and as soon as this came to light, thousands of visitors flocked to visit this wetland treasure. Appeals from nature lovers and general public led to a review of the reclamation plans. After careful consideration from all the public submissions and extensive consultations with scientific experts and relevant government agencies, it was announced in 2001 that reclamation works would be deferred for as long as Pulau Ubin was not required for development.

In 2001, NParks took over the management of the area, and conducts free guided tours. Facilities for visitors opened in 2007, and featured a visitor centre, viewing jetty, 1.1-km boardwalk through mangroves, and 20-m Jejwai Tower providing panoramic views.

b. Ubin Living Lab (ULL)

The Ubin Living Lab (ULL) is an integrated facility for field studies, education and research, and community outreach. Located at the south-west of Pulau Ubin, it features facilities to support programmes for organised groups. Future phases of the ULL include the planning and implementation of pilot projects for sustainable design and practices in potable water supply, waste management, electrical power supply, as well as green buildings.

5.2.1.4 Sisters' Islands Marine Park (SIMP)[28]

Consisting of two islands – Pulau Subar Laut (Big Sister) and Pulau Subar Darat (Little Sister) islands, which are separated by a narrow channel - Sisters' Islands were declared Singapore's first Marine Park in 2014. Located 9 km from the mainland, and spanning an area of about 40 ha, it encompasses the western reefs of both St John's Island and Pulau Tekukor. The marine park was established as a platform for outreach, educational, conservation and research activities related to Singapore's native marine biodiversity. The location was chosen due to its variety of habitats including coral reefs, sandy shores and seagrass areas.

The marine park enables Singaporeans to have a first-hand experience of the rich biodiversity which are usually submerged and inaccessible to most people. The Marine Park Public Gallery on St John's Island opened in 2015 to complement outreach programmes like the intertidal guided walks conducted at SIMP. The public gallery showcases the rich coral reefs, which support an ecosystem inhabited by rare and endangered species of seahorses, clams, sponges and other marine life in Singapore's waters and includes a 3D diorama of its dive trails –which were open as part of the Marine Conservation Action Plan. [Refer to **Section 12.1** Ecosystem and Biodiversity Conservation, and **Subsection 13.3.4.3** Marine Conservation Action Plan (MCAP) for more details]

Following a one-year feasibility study, NParks announced in 2016 the new conservation, research, outreach and educational plans. A boardwalk, intertidal pool, and a floating pontoon will be sensitively established and completed in progressive phases between 2017 – 2019. The *Plant-A-Coral, Seed-A-Reef* programme was also launched in 2016. It is a community outreach initiative by the Garden City Fund, providing opportunities for the community to contribute to habitat enhancement efforts in the Marine Park.

Small Sisters' Island serves as a dedicated site for marine conservation research work, with facilities to promote species recovery and habitat enhancement in the hope of providing better knowledge and understanding of Singapore's existing marine habitats and biodiversity. Marine scientists and researchers are given opportunities to conduct a wide range of studies and regular monitoring on Singapore's marine environment. Restoration activities, such as a coastal plant conservation area, reef enhancement units, and nurseries for iconic marine organisms, are also part of the efforts carried out at the Marine Park. NParks will also set up Singapore's first turtle hatchery, an in situ facility capable of receiving, nurturing and hatching rescued turtle eggs assessed to be at risk in other coastal areas in a bid to increase their survivability.

[28] See https://www.nparks.gov.sg/gardens-parks-and-nature/parks-and-nature-reserves/sisters-islands-marine-park

5.2.1.5 Coney Island[29]

A 50 ha Coney Island Park located off the northern coast of Punggol, houses a wide variety of habitats, including coastal forests, grasslands, mangroves, and casuarina woodlands. It is a sanctuary for a diverse range of Singapore's flora and fauna, some of which are critically endangered, and a popular spot for bird-watching.

5.2.1.6 East Coast Park (ECP)[30]

Located on the south-eastern coast of Singapore, ECP being the largest coastal park occupying a total land area of 185ha and with a 15km coastline, is also regarded as a flagship park. Built entirely on reclaimed land, East Coast Park was opened in the 1970s.

Today, it is managed with the theme "Recreation for All", offering a wide range of sports, dining and recreational facilities. Besides the typical park facilities like jogging/ cycling paths and barbeque pits, other facilities like bowling alleys, volleyball courts, holiday chalets, restaurants and a hawker centre can all be found in the park. Sporting opportunities such as cycling, in-line skating, cable skiing and water sporting activities as well as an Xtreme SkatePark, are also available. With its numerous facilities and activities, East Coast Park is one of the most heavily utilised parks in Singapore, attracting more than 7.5 million visitors a year.

5.2.2 Southern Islands of Singapore

Southern Islands refer to a group of island under URA's planning area consisting of a collection of islands: Kusu Island, Pulau Seringat, Larazus Island, St John's Island, Pulau Tekukor, Sentosa and Sisters' Islands, which are all situated in the Singapore Straits. The islands cover a total land area of approximately 5.58 km^2 and were originally administered by SDC from 1976 to 2017. Presently, Singapore Land Authority (SLA) manages– Kusu Island, St John's Island and Lazarus Island, whilst NParks oversees Sister's Islands Marine Park [Refer to Section 5.1.2 Sentosa Island and Section 5.2.1.4 Sisters' Islands Marine Park (SIMP)]. SDC continues to manage Sentosa Island.

Initially, about 15 years of planning and close to $300 million was spent for reclamation and infrastructure works, which were completed in 2006, in order to prepare them for future developments. STB announced plans in 2006 that by 2015, the southern islands would be turned into a tourist attraction. In April 2007, STB announced development would be put on hold (Boo, 2006). SLA confirmed there are no immediate plans to redevelop the Southern Islands, which were zoned for sports and recreation or open space under the URA Master Plan 2014 (Tan, 2017).

[29] See https://www.nparks.gov.sg/gardens-parks-and-nature/parks-and-nature-reserves/coney-island-park
[30] See https://www.nparks.gov.sg/gardens-parks-and-nature/parks-and-nature-reserves/east-coast-park

The islands are accessible by public ferry from Marine South Pier and popular for day trips, offering recreation activities like – beach picnics, swimming, sailing, scuba diving, snorkelling and fishing.

5.2.2.1 Kusu Island

Located 5.6km from Singapore's mainland, Kusu Island translates as Tortoise/Turtle Island, and as the name suggests, is home to a large number of tortoises, most of which are found at tortoise sanctuary. Offering a good mix of local heritage and beach activities, the island attracts thousands of pilgrims who flock annually to the Chinese temple and three Malay shrines (keramat).

5.2.2.2 St. John's Island, Pulau Seringat and Lazarus Island

Previously known as Pulau Sekijang Bendara, St John's Island is approximately 44 ha wide, and 6.5 km away from the main island of Singapore. Formerly used as a quarantine station and penal settlement, the island now serves as a recreational island with facilities like chalets, campsite, swimming lagoon, beaches, picnic grounds, trekking routes, and soccer fields. The natural shore of the island is home to some corals and reef life, which made it a suitable place for the Tropical Marine Science Institute (TMSI) to set up its coastal facility there: NParks hosts their Marine Park Public Gallery, and AVA also has their Marine Aquaculture Centre on the island.

As part of the Singapore Tourism Board's (STB) plan to develop the other Southern Islands as a tourist attraction, land reclamation commenced in 2000, creating a sand bank linking Pulau Seringat and Lazarus Island and forming a lagoon. Pulau Seringat now formed part of the extended Lazarus Island, with an 800m stretch of beach, and over 1,000 coconut trees were planted to enhance the island feel.

A causeway was built connecting Lazarus Island to St. John's Island to improve connectivity between the islands and making it more accessible to visitors.

5.3 Contribution to Income and Livelihood

5.3.1 Overview of the Tourism Sector

The statistics on tourism are provided for the whole of Singapore and do not differentiate between those patronising coastal tourism facilities and establishments from others that do not.

Table 5.2 provides data on tourist arrivals for the period 2012 – 2016. In 1964, when the Board was formed, Singapore welcomed a mere 90,000 visitors, in 2007 that number passed the 10 million mark. Due to uncertain global economic situation, tourism numbers dipped in 2009 as are tourism receipts showing a decline of 19 per cent from the previous year. Singapore's International Visitor Arrivals (IVA) in 2016 increased 7.7 per cent to 16.4 million. Tourism receipts (TR) in 2016 recorded S$25.7 billion.

Table 5.2: Tourism Statistics, Singapore, 2012-2016.

Year	Visitor arrivals (mil)	Visitor days (mil)	Tourism receipts ($bil)
2012	14.5	51	23.1
2013	15.6	54	23.5
2014	15.1	56	23.6
2015	15.2	55	21.8
2016	16.4	56	25.7

Note: STB has reviewed and revised their methodology for data collection and computation of tourism receipts so as to better capture tourism performance. On 12 February 2018, Tourism Receipts from 2016 onwards have been updated based on the revised methodology. Comparison of TR data from 2016 onwards against TR data between 2007 and 2015 is not recommended.
Source: STB Annual Report, 2016

5.3.2 Singapore's Cruise Tourism

5.3.2.1 Cruise Industry Performance

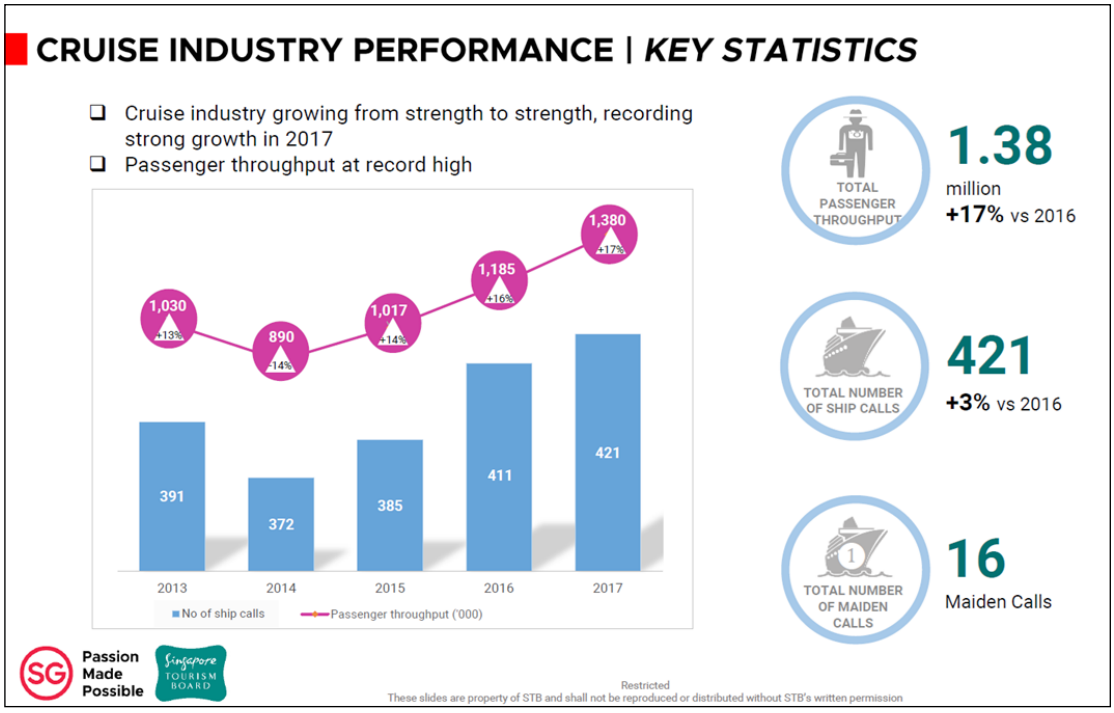
Singapore's cruise industry directly contributed S$706 million to the nation's economy in 2016, marking a 36 per cent rise from 2010 (Singapore Tourism Board, 2016/2017). This figure excludes the indirect spending on land by establishments specifically catering to cruise tourists. Singapore's 2017 cruise throughput is 1.38million (+17%); 421 ship calls (+3%). Data for the period 2010 – 2017 can be seen in **Table 5.3**.

Table 5.3: Total Cruise Passenger Throughput and Ship Calls for 2010 – 2017.

Year	Cruise Passenger Throughput (million)	Ship Calls
2010	1.014	640
2011	0.942	394
2012	0.913	334
2013	1.030	391
2014	0.890	372
2015	1.017	385
2016	1.185	411
2017	1.380	421

Source: Singapore Tourism Board (STB).

Figure 5.1: Key Statistics for Cruise Industry Performance.



Source: STB

5.3.2.2 Regional Developments for the Industry

Singapore hopes to benefit from a rise in cruise tourism, after the joint *ASEAN Declaration on Cruise Tourism*, led by Singapore – the ASEAN lead coordinator for cruise development – was officially adopted at the ASEAN Tourism Forum in January 2018 in Chiang Mai, Thailand. This marks another milestone in ASEAN's ongoing efforts to transform Southeast Asia into a vibrant cruising destination.

The Declaration also outlines ASEAN's commitment to further develop cruise tourism in the region by improving the clarity of cruise policies and regulations, increasing efficiency in administration processes, as well as refining business practices to be fairer and more responsible. Moving ASEAN, a step closer towards achieving its vision of becoming a thriving cruise hub, expanding connectivity within Southeast Asia and driving strong economic contribution to new port-of-calls and their communities. A rise in cruise tourism is expected to spur further advancements in port and destination infrastructure, catalyse ship deployments and spin off benefits for local tourism industries and stakeholders across the region. With these developments, the region has the potential to generate growth of up to 4.5 million passengers cruising in Southeast Asia by 2035 (Singapore Tourism Board, 2017), a ten-fold increase from 2016.

5.3.2.3 Cruise Terminals in Singapore

Currently, Singapore has two cruise terminals, Singapore Cruise Centre at Harbourfront, and the Marina Bay Cruise Centre Singapore. [Refer to related **Section 6.9** Marina / Ports for Recreation and Tourism for more details on each terminal]

5.3.3 Sentosa

The **Table 5.4** below shows the total visitorship of Sentosa from 2006-2016. The influx of tourist in 2010 was due to the completion of The Resorts World Sentosa in February 2010.

Table 5.4: Total visitors in 2006 – 2016 and Total Island Gross Revenue for Sentosa from 2008 - 2016.

Year	Total Visitors	Total Island Gross Revenue (S$M)
FY2006	5,678,975	-
FY2007	6,125,169	-
FY2008	6,133,856	320
FY2009	7,832,434	291
FY2010	19,087,332	674
FY2011	19,009,008	929
FY2012	20,452,613	1,026
FY2013	18,649,672	1,158
FY2014	19,371,843	1,170
FY2015	19,508,739	1,171
FY2016	19,266,163	1,175

Notes:
1. SDC Financial Year runs from April to March.
2. Total Visitorship saw a spike in FY2010 when Resorts World Sentosa opened in February 2010.
3. The local to tourist visitorship ratio has varied over the years. Currently, the ratio is about one local to three tourist visitors.
4. The Total Island Gross Revenue (TIGR) measures the spending by all visitors to Sentosa (excluding casino revenue).

5.4 Sustainability: Pressures and Response

The UN World Tourism Organisation (UNWTO), designated 2017 as the International Year of Sustainability of Tourism for Development, which aims to support a change in policies, business practices and consumer behaviour towards a more sustainable tourism sector and contribute to the SDGs in the context of the 2030 Agenda for Sustainable Development. The campaign promotes tourism's role in the following key areas:

1. Inclusive and sustainable economic growth
2. Social inclusiveness, employment and poverty reduction
3. Resource efficiency, environmental protection and climate change
4. Cultural values, diversity and heritage
5. Mutual understanding, peace and security.

With the continued exponential growth of tourism across the globe – an average of 5 per cent a year since 2010, generating an average 17 million extra arrivals a year – at this projected pace of growth, international tourists are expected to surpass 1.8 billion by 2030 (UNWTO, 2011). Sustainability of this increase, is at the forefront of many government agencies.

In Singapore's urban context, multiple agencies work together to ensure the tight management of any potential impacts of mass tourism for the small island nation. While STB is responsible for sustainable tourism at the national level; other agencies responsible for the planning and management of sustainable resources in Singapore include the URA, SDC, NParks and the National Heritage Board (NHB).

Furthermore, aspects of environmental protection relating to tourism, in terms of creating and enforcing environmentally sensitive polices, lie under the purview of the Ministry of Environment and Water Resources (MEWR), together with its two statutory boards, NEA and the Public Utilities Board (PUB). MPA is the lead agency responsible for the protection of the marine environment from ship-based sources of pollution and enforcement of the requirements of the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL Convention) in Singapore waters.

5.4.1 Singapore's Tourism Development Story[31]

In the 1980s, STPB launched the S$1-billion *Tourism Product Development Plan*, which called for the preservation of our historic districts including Chinatown and our colonial hub, and to revitalise the Singapore River.

[31] See eresources.nlb.gov.sg/infopedia/articles/SIP_31_2005-01-31.html

On 11 January 2005, Minister for Trade and Industry, Mr Lim Hng Kiang, unveiled the Board's bold targets to triple tourism receipts to S$30 billion, double visitor arrivals to 17 million, and create an additional 100,000 jobs in the services sector by 2015. A S$2-billion Tourism Development Fund was set up to meet these targets.

In February 2003, STB reviewed its strategies and resource allocation to place more emphasis on growth areas and to raise our presence in China and India. The Board re-organised its internal structure, and formed eight strategic tourism units each with specific targets in growth sectors. One significant decision was to build the two IRs with supporting attractions around Marina Bay – a move that has transformed the shape and image of our city's waterfront skyline and image.

Other targets include the provision of recreation facilities for the masses as part of the programme for a clean and green Singapore with more recent emphasis on creating a liveable city. The Board sought proposals for recreation proposals. STB also supported the upgrading of coastal parks for recreation and the promotion of water sports in coastal portions of rivers and reservoirs.

STB works closely with URA for allocating suitable waterfront land including the prime locations in the Marina South district. Development plans for the area took into account the need for greater ease of access by way of roads, bridges and MRT lines that would merge seamlessly with the existing central business district.

In support of the efforts of STB, and as part of the *Master Plan 2008*, URA unveiled a new island-wide *Leisure Plan* that showcases a diverse range of leisure opportunities for people of all ages to enjoy. Among the list of attractions are those with coastal locations. The Leisure Plan builds on the previous Parks & Waterbodies and Identity plans developed by URA in 2002 (**Figure 5.2**). The key highlights of the Leisure Plan included:

- Tripling the existing park connector network from 100 km today to 360 km
- Developing a first-ever 150-km round-island route for people to stroll, jog or cycle around the entire country
- Expanding the park connector network with seven loops and five links
- Increasing Singapore's green spaces by adding more park spaces from about 3,300 hectares today to 4,200 hectares; more parks will offer a greater variety of experiences for all
- The Kranji & Lim Chu Kang area is the newest leisure destination identified. It offers the potential of becoming a unique countryside destination close to nature. There will be new park lands and agri-tainment attractions, enhancements to existing attractions, for example, Sungei Buloh and Kranji Reservoir, and greater access to the nature areas, the waterfront and the farms.

Figure 5.2: URA's Leisure Plan as Part of the Master Plan 2008.

Source: URA, http://www.ura.gov.sg/myendearinghome/funthings/funthings_leisurehsp_text.html.

Sustainable tourism is covered by STB's larger, strategic framework called the *Tourism 21 Blueprint*. This framework specifically addresses the creation of thematic zones, community-based tourism development, and development of nature-based tourism.

Given the limited natural vegetation resources available in Singapore, the Nature Conservation Working Committee of the *Singapore Green Plan* decided that eco-tourism should not be promoted indiscriminately. Consequently, STB's marketing efforts on the niche market, targets the cultivation of the educational market segment. This will ultimately lead to the development of a new generation of visitors, with better appreciation of nature and culture.

Whilst there is no explicit legislation on sustainable tourism, STB has identified the following areas as major programmes in effect to promote sustainable tourism:

- Developmental programmes;
- Ethnic thematic areas (enhancement of cultural heritage zones);
- Agro-tourism (development of farm tourism); and
- Rustic charms and nature trail (development of nature-based tourism).

Training programmes include tour guides courses, and marketing programmes an educational market segment. Eco-tourism and nature-based tourism are promoted by low impact tour activities in farms, and by a programme as well as nature-based activities for the Sungei Buloh Nature Reserve and Pulau Ubin.

5.4.2 Case Study: Sentosa on Sustainable Island Development

Sentosa Island was designated by the Singapore Government in the early 1970s to be a key tourism and leisure destination for the country. The Singapore Development Corporation (SDC) was set up as the master planner and place manager for the island. Sustainable development of the island is done through a combination of careful land use planning and responsible operations. SDC strives to develop the resort island as a leading leisure and tourism destination in sustainable manner. The *Sentosa Sustainability Plan* was thus developed to: (1) Minimise the island's carbon footprint; (2) Conserve its flora and fauna; (3) Develop itself as a hub for green projects; and (4) Adopt responsible environmental standards and business practices (SDC, 2016).

5.4.2.1 Careful planning and land use

As developments intensify over the decades, two nature areas on the island have been protected and kept off-limits to development. The coastal fort at the western tip of the island and the surrounding forests and coast have also been left untouched. Developments are concentrated along the coastline and clustered to optimise land use.

SDC's conservation policy is to **maintain 60% of Sentosa Island as green and open spaces**. This is done through stringent land use conditions for our own development projects and those undertaken by private developers. Satellite imaging is used regularly to monitor the extent of vegetation cover on the island and the biodiversity in the forests and sea is monitored with the help of independent nature groups and consultants. SDC employs an in-house arborist and landscaping team to monitor the heritage trees. Energy consumption, water and air quality are also tracked.

5.4.2.2 Nature and heritage conservation and protection

Under the *Sentosa Development Corporation Act*, it is an offence to poach wildlife or cut the trees on the island. There are 26 heritage trees on Sentosa, the densest concentration of heritage trees in the country. These trees are of botanical and historical significance, and are recognised and protected by NParks. Similarly, there are 16 buildings which were given the conservation status by URA in 2004. These buildings were built by the British between the 1880s and 1930s to accommodate garrisons for the coastal defence of the island and the harbour. They are also historically significant.

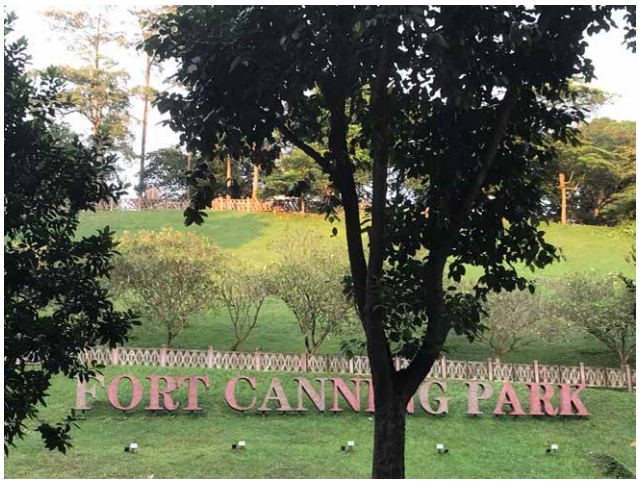
5.4.2.3 Vehicular traffic management

Measures are in place to help reduce vehicular traffic. To encourage carpooling, vehicles entering via the causeway bridge are charged an admission rate regardless of the number of people in the vehicle. Other modes of entry via the electric train, ropeway cable car and the pedestrian boardwalk have been introduced and priced affordably to provide an environmental-friendly way of entering the island.

5.4.2.4 Resource use and management

Numerous measures to reduce electricity and water consumption, such as using energy-efficient (LED or T5 fluorescent) lights and with motion-sensor capability, have been progressively introduced. Several building water points are retrofitted with water-saving devices that are certified as water-efficient by PUB.

SDC believes in a balanced approach between development and conservation. Sentosa offers many differentiated leisure products within a compact area, and nature and heritage co-exist alongside state-of-the-art leisure offerings. The island generates approximately 17,000 job opportunities. It remains accessible to the underprivileged as throughout the year, charity and welfare groups can enter the island for free for their own recreational outings. Furthermore, SDC and the businesses on the island collaborate on the annual Sentosa Gives community-giving week, whereby children from disadvantaged backgrounds are hosted for a free day of fun on the island.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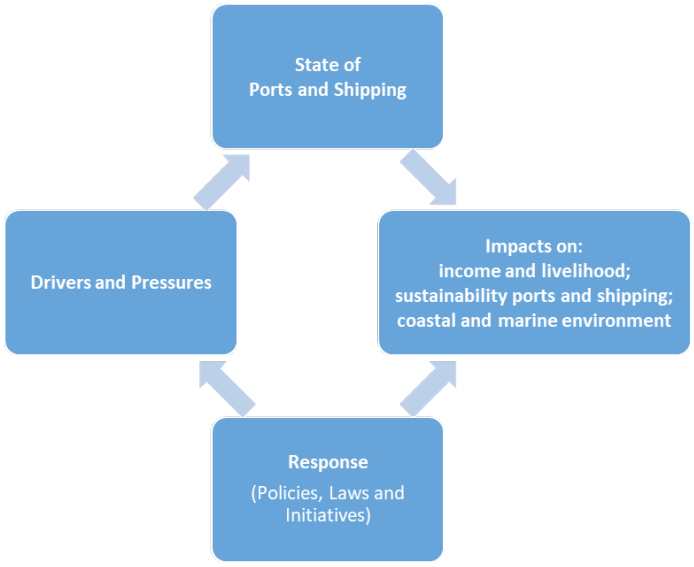
6 Ports and Shipping



6.1 Navigational Lanes and Shipping Traffic

6.1.1 Navigational Lanes

A ships' routeing system for the Straits of Malacca and Singapore (which includes Traffic Separation Schemes (TSS), Precautionary Areas, deep water routes etc.) and the "Rules for Vessels Navigating through the Straits of Malacca and Singapore" (or simply, "the Rules") have been adopted by IMO, as proposed by Indonesia, Malaysia and Singapore.

Vessels crossing the TSS and Precautionary Areas in the Singapore Strait are also recommended to display the night signals consisting of three all-round green lights in a vertical line.[32]

6.1.2 Ship Reporting

The IMO has adopted the Mandatory Ship Reporting System in the Straits of Malacca and Singapore (STRAITREP), as proposed by Indonesia, Malaysia and Singapore. Applicable vessels within the operational area of STRAITREP are to comply with the requirements of STRAITREP.

[32] Singapore Port Marine Circulars No. 04 of 2013, 2013.

6.1.3 Shipping Traffic

For figures on shipping traffic in the Port of Singapore, please refer to Section 6.3: Port Performance Indicators.

6.1.4 Vessel Traffic Information System

MPA's Vessel Traffic Information System (VTIS) allows the tracking of vessels' movements in the port waters and Singapore Strait in real time. It integrates information from various sources such as radar, Automatic Identification System (AIS), Maritime Communication System, Closed Circuit Television System (CCTV) and ship databases into one system to communicate and monitor vessels' movements. The VTIS enables MPA to provide timely information and advice to help vessels transit safely through the Singapore Strait, as well as manage traffic within our port waters.

6.2 Major Ports

6.2.1 The Port of Singapore

The Port of Singapore includes terminals located at Tanjong Pagar, Keppel, Brani, Pasir Panjang, Sembawang and Jurong. They can accommodate all types of vessels, including container ships, bulk carriers, ro-ro ships, cargo freighters and coasters.

The terminals are managed by two commercial port operators, PSA Singapore Terminals, which manages the major share of container handling in Singapore, and Jurong Port Pte Ltd, which is Singapore's main bulk and conventional cargo terminal operator.

6.2.2 PSA Singapore Terminals

PSA Singapore Terminals operates four container terminals with a total of 67 berths at Tanjong Pagar, Keppel, Brani, and Pasir Panjang as one seamless and integrated facility. Its newest terminal, Pasir Panjang Terminal (PPT) can handle mega container vessels of 13,000 twenty-foot equivalent units (TEUs) or more. The Phase 3 and 4 expansion of PPT was opened in 2015 – this increased PSA's total port capacity by about 50% to 50 million TEUs, thereby strengthening Singapore's position as the world's largest transhipment hub. PSA will also spend about S$3.5 billion in best-in-class infrastructure and the latest port technology. For example, there will be automated container yard and unmanned rail-mounted gantry cranes supported by intelligent systems (PSA, nd).

Currently, a new port is being developed at Tuas. The port leases for the terminals at Tanjong Pagar, Keppel and Brani are due to expire in 2027, and all container port activities will be eventually consolidated at the upcoming Tuas port. The consolidation at Tuas is expected to increase efficiency in port operations due to the elimination of inter-terminals haulage.

There are also plans to incorporate more automation, intelligent control systems, and sustainable technologies into the new Tuas terminals. Some key innovations will include unmanned vehicles, such as automated yard cranes, drones, data analytics and driverless trucks for port transport (PSA, nd). The development of Tuas Terminal comprises four phases targeted for completion in 2040. Phase 1 of the development entails the construction of a new port terminal with 20 deep-water berths having a total capacity of 20 million TEUs per annum. Phase 1 is currently on schedule and will be completed by 2021. The new Tuas Terminal will be opened progressively from 2021 onwards. When fully completed, Tuas Terminal will have a total capacity of up to 65 million TEUs, thereby catering to the future projected growth in container handling demand.

6.2.3 Jurong Port

Jurong Port is a multi-purpose port and the main bulk and conventional cargo gateway for Singapore and the region. The port handles steel products, cement, project cargo and copper slag, among others, using an extensive network of pipelines and conveyor systems for speedy and environmentally-friendly discharge and loading. It operates the world's largest common user cement terminal, handling more than 90% of Singapore's bulk cement imports and driving the local construction industry. It is also accredited by the London Metal Exchange as an ideal storage and transhipment hub for companies dealing in metals, such as steel and tin ingots. Besides the main terminal, Jurong Port operates the Offshore Marine Centre, a multiuser waterfront facility providing port services to companies engaged in fabrication of marine and offshore equipment. Jurong Port also has two separate Lighter Terminals for vessel crafts to deliver spares and provisions to ships calling at Singapore.[33]

6.3 Port Performance Indicators

Please refer to **Table 6.1** below for the Port of Singapore's Performance for period of 2010 – 2017 (MPA, 2016).

Table 6.1: Port Performance Indications in 2017.

Indicators	2017	2016	2015	2014	2013	2012	2011	2010
Vessel arrival tonnage (>75 GT) (in billions of gross tonnes)	2.80	2.66	2.50	2.37	2.33	2.25	2.12	1.92
Vessel calls (>75 GT) (in thousands of calls)	214	209	201	199	201	189	186	183
	33.7	30.9	30.9	33.9	32.6	31.6	29.9	28.4
Cargo throughput (in millions of tonnes)	627.7	593.3	575.8	581.3	559.6	538.0	531.2	503.3
Tonnage of ships under the Singapore flag (in millions of gross tonnes)	88.8	88.0	86.3	82.2	73.6	65.0	57.3	48.8
Volume of bunkers sold (in millions of tonnes)	50.6	48.6	45.2	42.4	42.7	42.7	43.2	40.9

Source: MPA, 2016.

[33] See http://www.jp.com.sg.

6.4 Contribution to Income and Livelihood

Singapore's maritime industry is a key pillar of Singapore's economy. Made up of shipping, port, maritime services and offshore and marine engineering sectors, Singapore's maritime industry contributes 7% of Singapore's Gross Domestic Product (GDP) and employs over 170,000 people. MPA, in partnership with the industry, unions and other government agencies, developed and launched the Sea Transport Industry Transformation Map (ITM) in January 2018. The Sea Transport ITM builds upon MPA's strategic long-term plans to develop Singapore's next-generation port and strengthen the international maritime centre, with an aim to grow the sector's value added by SGD$4.5 billion and create more than 5,000 good jobs by 2025.

6.5 Aids to Navigation

The Hydrographic Department of MPA manages the operation and maintenance of five lighthouses and a few hundred beacons, navigational buoys and mooring buoys. An integrated wireless monitoring system is employed to ensure that the lanterns of the lighthouses are operational. It also operates a Differential Global Positioning System (DGPS) broadcast service so as to enhance navigational safety in our port waters and the Singapore Strait. MPA also ensures accurate charting of our waters and the timely distribution of updated hydrographic information to enable ships to navigate safely in our busy waterways.

6.6 Port Reception Facilities for Garbage Collection

Singapore provides daily reception facilities from 0730 to 1730 hours for the collection of garbage from ships in the anchorages. Five garbage collection craft are deployed to pick up garbage from ships. No additional fees are collected from ships for disposal of garbage unless special requests to dispose garbage at a specific timing and location are made where S$900 will be charged.

6.7 Other Facilities

There are three public landing points in the Singapore port. The West Coast Pier services the public going to and from ships anchored at the western anchorages. The Marina South Pier caters to those going to and from the eastern anchorages, and the outlying islands. The Changi Point Ferry Terminal serves the public going to and from the outlying islands at the northern sector such as Pulau Ubin. These landing points are equipped with the following facilities: immigration and customs facilities, eating outlets and shops, and launch/ferry services.

6.8 Preparedness, Response and Co-operation

6.8.1 Marine Emergency Action Procedure

MPA has in place the *Marine Emergency Action Procedure* (MEAP) to deal with marine incidents effectively. To test and demonstrate Singapore's readiness to respond effectively to marine incidents, emergency exercises are conducted regularly. For example, MPA organises an annual Chemical Spill exercise, which is a multi-agency joint chemical spill exercise that includes the simulation of a chemical spill and responses to combat chemical pollution and test multi-agency responsiveness and co-operation. A full deployment exercise is conducted every alternate year, in conjunction with the biennial International Chemical and Oil Pollution Conference and Exhibition (ICOPCE) organised by MPA. Otherwise, a tabletop exercise is conducted instead. Such exercises help ensure the effective implementation of marine contingency plans and readiness of personnel in responding to incidents, should prevention fail.

Further, as a supplement to the MEAP, there is the *Oil Spill Contingency Plan*. The aim of the Plan is to respond effectively in the shortest possible time to stop the discharge of oil and contain the spill so as to minimise the impact of the oil spill as well as to minimise the amount washed ashore.
In dealing with incidents involving bulk chemicals, hazardous and noxious substances (HNS), carried by ship at sea and at terminals, MPA has developed the *Chemical Contingency Plan* (Marine), which is also a supplement to the MEAP. It is jointly implemented with government agencies.

As the impact of oil spills may be transboundary, there is also a *Standard Operating Procedure for Joint Oil Spill Combat in the Straits of Malacca and Singapore* (SOP) set by the Revolving Fund Committee, comprising the littoral States of Indonesia, Malaysia and Singapore. The SOP, which was drawn up following the establishment of the Revolving Fund, covers areas, such as the response areas and division of responsibility among the littoral States, communication and information sharing procedures, inter-state assistance and reimbursement procedures. The objectives are to facilitate early information sharing and enable prompt and coordinated response to any oil spill incident.

6.8.2 Pollution from Ships

Singapore is party to all six Annexes of the IMO's MARPOL convention, the main international convention covering prevention of pollution of the marine environment by ships. There are six Annexes or categories of pollution covered by MARPOL: (i) oil, (ii) noxious liquid substances in bulk, (iii) harmful substances in packaged form, (iv) sewage, (v) garbage and (vi) air pollution.

In Singapore, MARPOL is implemented under the Prevention of Pollution of the Sea Act (PPSA) and its associated regulations, which provide powers to impose fines of up to $1 million or imprisonment

terms of up to two years, or both, for non-compliances with MARPOL. The regulations are applicable to (i) Singapore-registered ships wherever they may be; and (ii) foreign-registered ships in Singapore waters.

As a responsible flag state and port state, Singapore conducts inspections on both Singapore-registered ships and foreign-registered ships in our port to ensure that they comply with the regulations on garbage disposal into the sea and that anti-pollution measures are in place. Ships are also required to maintain garbage record and management plans for verification by inspectors. In our port, as part of our MARPOL obligations, Singapore provides daily reception facilities for garbage collection from ships. Please refer to the section on "Port reception facilities for garbage collection" in Section 6.5 for more details.

Further, our Port Inspectors patrol our port waters to ensure that ships in our port do not illegally discharge waste, oil, garbage and sewage. To enhance the effectiveness of our patrols, we leverage on technology such as drones. Enforcement action will be taken against vessels that infringe our regulations.

6.8.3 Ballast Water Management

Singapore has acceded to the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWMC) which came into force internationally on 8th September 2017. Like MARPOL, the BWMC is administered through the Prevention of Pollution of the Sea Act (PPSA). All applicable Singapore-registered ships of 400 gross tonnes and above (excluding floating platforms, floating storage units and floating production storage and offloading units) are required to carry the following on board:

- International Ballast Water Management Certificate (IBWMC);
- Ballast Water Management Plan (BWMP) approved by our Recognised Organisations (ROs) on behalf of MPA; and
- Ballast Water Record Book (BWRB).

As part of our BWMC obligations, Singapore is required to provide for ballast water sediment reception facilities in ports and terminals where the cleaning or repairs of ballast tanks occurs. Singapore is also obligated to notify mariners of areas under its jurisdiction where ships should not uptake ballast water due to known conditions, such as outbreaks, infestations, toxic algal blooms, etc. MPA, upon receipt of such updates from relevant agencies, will issue such notifications.

6.8.4 Piracy and Armed Robbery Against Ships

Singapore is one of the founding members of the Regional Co-operation Agreement on Combating Piracy and Armed Robbery Against Ships in Asia (ReCAAP), the first regional government-to-government initiative to promote co-operation against piracy and armed robbery against ships

in Asia. Singapore also hosts the ReCAAP Information Sharing Centre (ISC) that was established in 2006. The objectives of ReCAAP ISC include exchanging information among Contracting Parties on incidents of piracy and sea robbery in Asia, capacity building and fostering greater co-operation amongst ReCAAP members and the maritime community to tackle piracy and armed robbery against ships in Asia.

In addition, together with Indonesia, Malaysia and Thailand, Singapore continues to conduct co-ordinated sea and air maritime security patrols of the Malacca and Singapore Straits. In the fight against regional piracy and armed robbery against ships, Singapore actively and regularly engages the shipping community to encourage the use of recommended practices for protection against piracy for merchant vessels operating in piracy-prone areas. In conjunction with ReCAAP ISC and the industry, anti-piracy events that promote dialogue between governments, maritime law enforcement agencies, relevant international organisations, and the maritime industry are also regularly organised.

As part of Singapore's contributions to international counter-piracy efforts, Singapore hosted the following events:

- **Meeting of Anti-Piracy Contact Points and Workshop on Piracy and Armed Robbery against Ships, 11-12 January 2017**. Singapore MPA and the ReCAAP ISC co-organised this inaugural Meeting and Workshop bringing together anti-piracy contact points and reporting centres from Africa, Asia, and Europe, as well as international bodies like the IMO, and industry participants. The event allowed participants to exchange best practices on information sharing, and, deepened ties and communications among anti-piracy contact points to enable more effective information sharing. The 2-day event was well attended by about 55 participants from Africa, Asia and Europe, as well as approximately 133 industry representatives.
- **ReCAAP Capacity Building Executive Programme (CBEP), 27 September to 6 October 2017**. The 10-days CBEP, co-hosted in Singapore and Japan, was co-organised by the Ministry of Foreign Affairs Japan (MOFA) and MPA, in co-operation with the ReCAAP Information Sharing Centre (ISC). The CBEP was aimed at building capacity, enhancing information sharing and strengthening co-operation amongst the ASEAN ReCAAP member states, as well as Indonesia and Malaysia. Key topics covered under the CBEP were:
    - Trends and developments in piracy and armed robbery against ships in Asia
    - Best practices of information sharing
    - Best practices in the law enforcement and prosecution against piracy and armed robbery against ships
    - International laws and regulations related to piracy and armed robbery against ships
    - Emerging maritime threats such as cybersecurity and maritime terrorism

6.8.5 International Ship and Port Facility Security Code

Recognising the importance of enhancing maritime security, Singapore was among the first States in the world to fully comply with the IMO's International Ship and Port Facility Security (ISPS) Code in July 2004. A Statement of Compliance of a Port Facility (SoCPF) is issued to an ISPS-compliant port facility, and is valid for five years. The Designated Authority (DA) conducts a renewal verification (RV) for the port facility every five years. This verification shall ensure that the security system of the port facility fully complies with the applicable requirements of the ISPS Code and the approved security plan. The DA also conducts one intermediate verification (IV) between the second and third anniversary date of the certificate. The intermediate verification includes inspections and ensures that the security system remains satisfactory for the service for which the port facility is intended. In addition, the DA conducts an annual security audit on the port facility. There are currently 120 ISPS-compliant port facilities.

6.9 Marina / Ports for Recreation and Tourism

6.9.1 Singapore Cruise Centre Private Limited (SCCPL)

SCCPL manages and operates two regional ferry terminals: Harbourfront Ferry Terminal (HFT) and Tanah Merah Ferry Terminal (TMFT) and one cruise terminal.

6.9.1.1 Singapore Cruise Centre at Harbourfront

The Singapore Cruise centre at Harbourfront has two terminals, the International Passenger Terminal (IPT) and the Regional Ferry Terminal (RFT).

The IPT is the homeport of ships including Costa Crociere, as well as ships from Royal Caribbean International and Star Cruises. With two berth for ships to dock, CC01- 310m with depth alongside 12m and CC02 – 270m with depth alongside 11m. In 2010, 642 vessels that belong to 34 cruise lines. Cruise lines including well known cruise operators namely Cunard Line, Royal Caribbean International, Star Cruises, Costa Crociere, Princess Cruise Line, Crystal Cruises, Silversea Cruises, Regent Seven Sea Cruises, Holland America Line, P&O Cruises and Seabourn Cruise Line.

The RFT was built to serve regional ferry destinations to the South and West of Singapore, mainly to the Indonesian islands of Batam and Karimun.

6.9.1.2 Tanah Merah Ferry Terminal (TMFT)

TMFT has four berths that serve regional ferries traveling to destinations south and east of Singapore, namely the Indonesian islands of Batam and Bintan. In 2007, the terminal

underwent a S$3 million renovation to improve the space to better serve its passenger and customers.[34]

6.9.2 SATS-Creuers Cruise Services

A joint venture between SATS Ltd – Singapore's leading service provider to the needs of the aviation industry and a host of other businesses in hospitality, food, healthcare, freight and logistics – and Creuers del Port de Barcelona S.A. – a leading international cruise operator in Europe – operates Marina Bay Cruise Centre Singapore (MBCCS). With deep water, a large turning basin and no height restrictions, the terminal has the capacity to dock ships of up to 220,000 gross register tonnage, and measuring up to 360m in length with a hull draft of up to 11.5m. The cruise centre allows for the travel to international destinations, such as Australia, Brunei, Hong Kong, Indonesia, Malaysia, Thailand and Vietnam.

6.9.3 Marina South Pier

Marina South Pier is a public landing point operated by MPA. Located in Marina South, it is primarily used by small passenger launches and ferries for travel between the southern islands. Singapore Island Cruise provide transport for tourists and day-trippers to the southern islands such as Kusu and Saint John island. [Refer to related **Section 5.3.2** Singapore's Cruise Tourism]

[34] See https://www.singaporecruise.com.sg

7 Other Ocean Economic Activities

7.1 Offshore Oil and Gas

Singapore does not possess any offshore oil and gas resources. Despite not having any Oil and Gas (O&G) resources of its own, there are important and related activities, which are situated along the coasts; namely Singapore's Oil Refinery, and Oil and Gas (O&G) Equipment and Services industries.

Singapore is a leading O&G Equipment Services hub in Asia, and hosts over 3,000 established Marine and Offshore Engineering (M&OE) firms. In 2016, the industry contributed S$3.6 billion to Singapore's GDP, S$12.3 billion to total manufacturing output, and employed more than 23,000 locals (MTI, 2018).

The *M&OE Industry Transformation Map* (ITM) was launched in February 2018 at the Trade Association Hub, in conjunction with the Association of Singapore Maritime Industries (ASMI) with the clear aim of driving transformation and aid companies, including small and medium-sized enterprises (SMEs) to capture long-term growth opportunities in the industry. [Please refer to **Section 8.4.6** Marine & Offshore Engineering (M&OE) Industry Transformation Map (ITM) for cutting-edge R&D conducted for this sector and M&OE]

7.2 Ship-building

7.2.1 Location of Shipyards

Shipyards are mostly located at the Western part of Singapore. There are smaller operations located in other parts of Singapore.

7.2.1.1 Sembcorp Marine

Jurong Shipyard (now one of several facilities owned by Sembcorp) launched the national industry in 1963 as a joint venture between EDB and Ishikawajima-Harima Heavy Industries (IHI), and was Singapore's first commercial shipyard offering ship repair services.

Sembawang Shipyard was the second of Sembcorp Marine's yards, and commenced operations from the conversion of the unused naval base, the Royal Navy Dockyard in late 1968.

Located at Tuas View Extension, the Sembcorp Marine Tuas Boulevard Yard, will be an integrated, mega-shipyard that will eventually cover 206ha and service the global O&G and marine sectors. The 73.3-ha Phase I of the yard began in 2013 with four very large crude carrier (VLCC) drydocks with a total dry dock capacity of 1.55 million Dwt (deadweight tonnes). Phase II's marine operations began in 1Q 2017.

7.2.1.2 Keppel Offshore & Marine

In 2002 the offshore and marine business of Keppel was privatised, resulting in the integration of Keppel Shipyard with Keppel FELS and Keppel Singmarine to form the current Keppel Offshore & Marine group.

Keppel Shipyard was founded by Temasek Holdings in 1968, when Keppel Harbour was reclaimed from the British Royal Navy after their withdrawal from Singapore, and is currently a leader in the conversion of Floating Production Storage and Offloading (FPSOs), Floating Storage and Offloading, and Floating Storage and Re-gasification Units.

7.2.2 Production (quantity and value)[35]

The shipbuilding sector's manufacturing output in 2016 was S$13.1 billion.[36]

7.2.3 GVA and Contribution to the Total Economy

The shipbuilding sector had a total value added of S$3.8 billion in 2016, about 0.9% of Singapore's GDP.

7.2.4 Threats: Causes and Impacts

Uncertain oil prices

The sharp decline in oil prices from over US$115 per barrel in 2014 to less than US$28 in 2016 resulted in a severe downturn in the industry.

Oil prices are expected to remain uncertain in the future. While OPEC cuts have supported the rise in oil prices, US shale activities have had a capping effect on price gains. Uncertain oil prices will lead to caution to commit new capital expenditure, and hence offshore E&P spending may not recover in the near term.

However, there are signs of a gradual recovery, given the recent pickup in shale activity in the US.

[35] Values are calculated using aggregated total of the following SSICs: 1) Manufacture and repair of marine engine, 2) Manufacture and repair of oil rigs, 3) Manufacture and repair of other oilfield and gasfield machinery and equipment, and 4) Building of pleasure boats and sporting boats.

[36] 2016 GDP at Current Market Prices: S$428 billion.

7.2.5 Response

7.2.5.1 Enhancing Productivity

Improving Labour Productivity

Given price pressures, companies have been increasingly looking to improve productivity to keep costs down. As such, agencies have been supporting companies with their investments in automation and robotics in a bid to improve labour productivity.

7.2.5.2 Encouraging Innovation and R&D

7.2.5.2.1 Helping SMEs Develop Differentiating Capabilities

The government has supported many SMEs in innovation projects and efforts to embark on research activities.

7.2.5.2.2 Leveraging on TCOMS (Technology Centre for Offshore & Marine Singapore) as a national R&D Receptacle

TCOMS was established to serve as the national integrator for public-private R&D, and push the sector towards the development of next-generation systems.

TCOMS has various capabilities, such as the deep water ocean basic test facility, which is expected to be operational in Q1 2019. Other capabilities include a fabrication lab for model fabrication and sensor deployment, and the numerical simulation lab for coupled physical-numerical approach with a digital twin for developing and validating models. [Refer to **Section 13.5** Research and Development (R&D), **Subsection 13.5.3.3** The Technology Centre for Offshore and Marine Singapore (TCOMS)]

7.2.5.3 Aligning Jobs and Skills of Workers

7.2.5.3.1 Equipping Workforce with Skills for New Areas

A key strategy involves ensuring that the workforce has the necessary skills-sets to support the industry's foray into new growth areas and technologies such as LNG and renewables. As such, support has been provided to train engineers and workers in the design and engineering of new systems. [Refer to **Section 8.2.3** LNG Bunker Ready Port]

7.2.5.3.2 Strengthening SME's Human Resource Capabilities

The government also implemented various programmes to support SMEs in enhancing their HR capabilities.

7.3 Maritime Services

Singapore offers a comprehensive range of both technical and commercial maritime services, such as finance, broking, insurance, surveying, legal and arbitration services.

7.3.1 Marine Insurance Services

Besides the Lloyd's Asia platform, there are currently about 30 marine insurance players in Singapore offering both direct and reinsurance cover to all sectors of the maritime industry. Nine of the 13-member International Group Protection and Indemnity (P&I) Clubs have offices in Singapore, and these cover third-party liability risks. There are also some 60 licensed insurance brokers, including marine specialists in Singapore.

7.3.2 Shipping Finance

Singapore is home to more than 20 banks with shipping finance portfolios. Beyond bank lending, Singapore also offers alternative financing options, such as listings on the Singapore Exchange (SGX).

7.3.3 Maritime Legal and Arbitration Services

Singapore is a highly regarded arbitration centre for resolving maritime disputes, and houses some 30 law firms (both local and foreign) that engage in maritime practice. The Singapore Chamber of Maritime Arbitration (SCMA) serves to promote maritime arbitration and has an internationally renowned panel of arbitrators. Singapore's Admiralty Court adjudicates on disputes relating to ships, such as those arising out of collisions.

7.3.4 Shipbroking

Today, there are over 20 major shipbroking firms operating in Singapore. The Institute of Chartered Shipbrokers (ICS) – an internationally recognised professional body representing shipbrokers, managers and agents globally – operates a branch in Singapore. Other than the traditional core services of chartering and Sale & Purchase, Singapore-based shipbrokers offer value-added services, such as research, consultancy, and freight derivatives broking.


Maybank
HSBC

PART 3

DEVELOPMENTS IN BLUE ECONOMY

8 Blue Economy Initiatives

8.1 Drivers of Future Growth, Innovations and Sustainability

The notion of sustainable development has been around for many years. One of the most cited definitions is from the World Commission on Environment and Development Report (WCED 1987): "meeting the needs of the present without compromising the ability of future generations to meet their own needs". It is an ever-evolving concept, one that cannot be defined in precise terms but is context specific.

United Nations Conference on Sustainable Development (UNCSD or Rio+20) in 2012 took stock of the changes that occurred since the Earth Summit in 1992, providing substantive evidence for the effects of climate change and a clear vision of the path that the international community, national governments, partnerships must implement in a cohesive manner. On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development – endorsed by world leaders in September 2015 at an historic UN Summit – formally came into effect.

Singapore has the opportunity to play its part by acknowledging the importance of its environmental reserves and optimising its usage. While many sustainable development issues cannot be addressed in isolation, Singapore recognises the need for renewed commitment and enhanced partnerships from all stakeholders – including states, international financial institutions and civil society – in order to be able to achieve the requirements laid out in the United Nations' 2030 Agenda for Sustainable Development.

Singapore's approach to sustainable development are underpinned by two factors: pragmatism in governance and implementation, and partnerships to build capacity. Knowledge and learning are the building blocks for any sustainable society.

The following section discusses the drivers of sustainable growth and innovations in Singapore that also support blue economy development, and the plans or projects related to the achievement of the SDGs and SDS-SEA.

8.1.1 Singapore's Sustainable Water Story

Singapore has come a long way in achieving universal access to affordable and high quality water, as well as sanitation. At the point of independence in 1965, Singapore faced poor water and sanitation conditions. Singapore was also classified as being water scarce and ranked 170th out of 190 countries in terms of freshwater availability, according to the 1st UN World Water Development Report in 2002.

Singapore takes an integrated approach to water management. PUB is Singapore's National Water Agency and is a statutory board under the MEWR. As Singapore's water authority, PUB oversees the entire water cycle and optimises the use of Singapore's water resources by integrating the water supply, sewerage and drainage functions to close the water loop.

The integration of water and wastewater management has been conducive in tapping synergies and progressing water reuse. Given that Singapore has limited natural water resources and land to store rain, the country's journey towards water security is guided by long-term integrated planning, and pursuing economic growth while protecting the environment in a balanced way. As a result of early investment in sustainable development of water and sanitation infrastructure, Singapore has fulfilled all the targets under SDG 6 (Clean Water and Sanitation) and contributes to achieving SDG 14 (Life Below Water).

8.1.1.1 Increasing Pressure on Water, Energy and Natural Resources

As one of the most water-stressed countries in the world, Singapore faces increasing pressure to ensure that there is adequate water supply to meet the demand of the growing population and economy. Water demand in Singapore currently stands at around 430 million gallons per day (mgd), which is enough to fill 782 Olympic-sized swimming pools, and is split with homes consuming 45% and the non-domestic sector 55%. By 2060, Singapore's total water demand could almost double, with the non-domestic sector account for about 70%. As demand for water continues to increase, concomitant with population and economic growth, it is essential for Singapore to be forward-thinking in its planning and implementation of water infrastructure to secure adequate and affordable supply for the future generations. PUB has adopted a holistic approach to ensure adequate supply of water in Singapore: (i) Capture every drop of water, (ii) Reuse water endlessly, and (iii) Desalinate seawater.

8.1.1.2 Safe and Affordable Drinking Water

Being a small island with limited land for water storage, Singapore expanded its local catchment areas to two-thirds of Singapore's land area by cleaning and damming rivers

so that rainwater can be captured as much as possible. To safeguard the quality of the rainwater collected, there is strict enforcement actions against illegal discharges into the drains and inland waterbodies. The Active, Beautiful, Clean Waters (ABC Waters) Programme was also launched in 2006 to improve Singaporeans' appreciation of water, and be inspired to keep the waterways and reservoirs clean

NEWater, or Singapore's brand of ultra-clean high-grade reclaimed water, is the pillar of the country's water sustainability. By enabling the use of every drop of water more than once, NEWater multiplies the potential water supply. Singapore also desalinates water from the sea. NEWater is primarily supplied to industrial sectors, such as wafer fabrication parks, industrial estates and commercial buildings for industrial and cooling purposes.

Today, all used water in Singapore is collected and treated at water reclamation plants. The move towards a fully-sewered system, with 100% of the population served by modern sanitation, was initially motivated by early efforts to clean up Singapore's rivers, and ensure clean water in the urban water catchments. It subsequently facilitated the foray into water recycling, and closed the water loop.

As for desalination, it became a viable option as improvements in membrane technology brought down the cost significantly.

8.1.1.3 Efficient Water Use

For the domestic sector, the water efficiency labelling scheme (WELS) allows consumers to make informed decisions in purchasing more water-efficient products, by requiring suppliers to introduce water-efficient water fittings and appliances to the market. To complement WELS, minimum water efficiency standards for water fittings covered under WELS were also set. All new developments and existing premises undergoing renovation are required to install water fittings with at least a "1-tick" water efficiency rating. From April 2019 onwards, this requirement will be raised to at least "2-tick". PUB is also looking at leveraging technology to help consumers save more water, such as via smart shower devices, and automated meter readings.

As the bulk of water demand is expected to come from the non-domestic sector, PUB has in place extensive measures to encourage companies to use water efficiently. PUB requires large water users to submit water efficiency management plans annually, and recognises the top performers through the Water Efficiency Awards. To assist companies in improving their water efficiency, PUB supports their implementation of projects, such as water recycling through the Water Efficiency Fund, and the Industrial Water Solutions Demonstration Fund.

8.1.1.4 Public Awareness and Changing Consumption Growth and Patterns

Besides ensuring that water supply can meet demand, it is equally important to manage water demand so that it does not grow at an unsustainable rate.

PUB has adopted a three-pronged approach to water demand management:

- **Water pricing**: Water is priced to reflect its scarcity value and to encourage consumers to use it prudently. We do this by pegging the water price to the long-run marginal cost of producing water.
- **Mandatory requirements**: PUB has introduced mandatory measures to drive water conservation. These include mandatory labelling of water fittings and appliances to indicate their water efficiency levels to help consumers make informed purchasing decisions. Minimum water efficiency standards for water fittings and appliances are also put in place to phase out the least efficient products from the market. Businesses consuming 60,000 m3 or more water per year are required to prepare and submit water efficiency management plans to PUB annually. This requirement promotes the establishment of water management systems, which will help businesses and industries better understand and manage their water usage.
- **Public engagement**: PUB has initiated a wide range of public education and outreach programmes to internalise the water-saving mindset and effect behavioral change in the way water is used. For example, water rationing exercises are conducted in schools to raise student awareness of water as a precious resource.

8.1.1.5 Future Challenges/Opportunities

a. Climate Change Mitigation and Adaptation

Singapore has marked 2018 as the Year of Climate Action to focus attention on climate change, and raise the level of national consciousness around the need to take individual and collective action to fight climate change for a sustainable Singapore.

PUB invests in efforts to enhance flood resilience. PUB has taken a holistic approach to introduce flexibility and adaptability to Singapore's drainage system. Through the "Source-Pathway-Receptor" approach, measures are not only carried out along the Pathway (e.g. through widening and deepening of drains and canals), but also implemented at the Source where stormwater runoff is generated (e.g. through on-site detention), and at the Receptor where floods may occur (e.g. through platform levels, crest protection and flood barriers). This approach allows stormwater management to be addressed at all parts of the catchment, with building owners and developers playing a role in managing the impact of urban development on flood risks. Singapore will continue to build up its NEWater and

desalination capacities to supplement conventional water sources during dry spells to ensure that adequate drinking water can be provided for all. By 2020, Singapore will have completed three additional 30 mgd desalination plants built by HSL Constructor, Keppel Infrastructure and Tuas Power-ST Marine.

PUB is also committed to reducing our carbon footprint by reducing emissions, reducing energy usage and exploring alternative energy sources. For instance, besides installing solar panels at some of our land installations, PUB is also exploring the use of our raw water reservoirs' vast surface areas for floating solar photovoltaic (PV) systems to supply clean and renewable energy. In 2016, PUB launched a floating solar PV system test-bed to study its effect on the reservoir's evaporation, biodiversity and water quality. Building on the results of this test-bed, PUB is exploring the feasibility of deploying these systems at a larger scale.

b. The Use of Technology

It is therefore important for PUB to bring down desalination's energy use and cost, and ensure its long-term affordability. PUB is currently looking into other forms of technology to extract freshwater from seawater, and investments have been made to undertake research in biomimicry, as well as scaling up the use of electrodeionisation (EDI) technology, a method that uses an electric field to pull dissolved salts from water developed by Evoqua. Both methods are expected to lower the energy consumption for desalination. (Proper disposal or reuse of the brine produced during desalination must also be addressed to mitigate the environmental impacts.)

Singapore has also put in place measures to ensure water safety, leveraging on the development of innovative technologies. For instance, besides monitoring and testing all the water that it manages for over 300 different water quality parameters, exceeding the requirements stipulated under any international drinking water regulation, PUB has also deployed the Fish Activity Monitoring System and other online systems, which help to enhance the security of drinking water by providing 24/7 monitoring of water quality.

PUB is also working with industry partners to exploit the IT revolution to better leverage digital technologies for its operations. There are three key focus areas: (i) IoT/sensors, (ii) robotics/automation and (iii) data analytics.

In this regard, various solutions are being studied or piloted. For instance, PUB is developing a SMART Water Grid, a network of wireless sensors installed in water supply mains across Singapore, which functions as a real-time platform to monitor water pressure, flow and quality. The system provides decision support tools that helps in network management and

allows early detection of anomalous network occurrences, enhancing PUB's operations and the efficiency of water supply to consumers. This helps to minimise the losses of water due to leaks.

In addition, PUB is also testing the use of drones for sewer inspections, robotic "swans" for water quality monitoring of our reservoirs, as well as data analytic software to make sense of the data that is collected by the different sensors deployed for water supply, wastewater collection and drainage. Collectively, they enable PUB to make better decisions and ensure good water supply 24/7 to customers.

8.2 Innovative and Sustainable Ocean-related Economic Activities

8.2.1 Sustainable Aquaculture Inputs and Production Systems

Besides providing funding assistance [refer to **Section 10.3.2** Supporting and participating mechanisms – Fisheries], AVA also provides basic infrastructure and technical assistance to help the industry raise and sustain productivity. Specifically, AVA with research partners, conducts research and development (R&D) on breeding, improved nutrient, and genetic selection to raise farm productivity. Where applicable, these findings are shared with local farmers. Additional support is given by educating the public on the merits of choosing local produce through events, roadshows, promotions and digital outreach efforts.

8.2.1.1 Marine Aquaculture Centre (MAC)

The Marine Aquaculture Centre (MAC) was set up in 2003 to carry out R&D across the entire hatchery production process. It is also a key aquaculture research and trial facility for companies and research institutes to conduct controlled trials for fish nutrition studies, vaccine safety tests and evaluation of commercial products.

MAC's key R&D initiatives include the application of Recirculation Aquaculture Systems technology with the accompanying culture protocols for intensive fry production, the genetic improvement of the Asian seabass, captive breeding of new species and the development of closed containment systems for coastal fish farms. An example is the selective breeding project with Temasek Life Sciences Laboratory to develop fast-growing and good quality Asian seabass fry suitable for the local aquaculture industry. This project uses advanced molecular biotechnology, such as marker-assisted selection (MAS) technique, allowing desired traits to be selected more accurately and effectively, without any genetic modification. Besides faster growth, traits, such as disease resistance and higher nutritional value of meat content, were also selected for.

8.2.1.2 Climate Smart Aquaculture

Climate change results in more extreme weather patterns causing stress to farmed fish. Thus farmers have been adopting technologies, such as close containment systems to provide control over water quality parameters. As a result, a high level of bio-security can be maintained by reusing treated water compared to conventional culture systems, which are susceptible to disease outbreaks and the vagaries of the weather. As a result, such farms are able to achieve consistent hatchery production with good farm management practices.

Other farms have also invested in a real-time water quality monitoring system, which can be powered by solar energy. In the event of impending poor water conditions, the system will automatically send out alerts so that early precautions can be taken to safeguard fish stocks.

8.2.2 Sustainable Maritime Transport/Maritime Singapore Green Initiative (MSGI)

In 2011, to reduce the environmental impact of the maritime transport sector, the MPA pledged up to $100 million over 5 years to the MSGI. The MSGI essentially provides grants to maritime transport operators that work to reduce negative environmental impacts. The voluntary programmes were designed to recognise and incentivise maritime companies to adopt clean and green shipping practices and go beyond the International Maritime Organization (IMO) mandated requirements when it comes to sustainability. In 2016, following industry's support, enhancements were made to the Initiative and new programmes were added. The Initiative was also extended to 30 December 2019. With effect from 1 July 2016, the MSGI comprises the following five programmes:

- The **Green Ship Programme** provides incentives to Singapore-flagged ships for the reduction of carbon emissions through better energy efficiency design that is beyond what the IMO mandates. The same incentive is also extended to Singapore-flagged ships that install scrubbers or use LNG to reduce the emission of pollutants.
- The **Green Port Programme** aims to encourage ocean-going ships calling at the Port of Singapore to reduce the emission of pollutants like sulphur oxides and nitrogen oxides. MPA will reduce port dues by 25% for ocean-going vessels that burn clean fuels, LNG or use approved measures to control emissions for their entire port stay.
- The **Green Technology Programme** encourages local maritime companies to develop and adopt eco-friendly technologies that reduce the emission of pollutants. It offers a grant that covers up to half of the total qualifying cost to develop and adopt the green technologies.
- The **Green Awareness Programme** promotes environmental awareness as well as recognition of maritime companies at the forefront of sustainability efforts. This is done through seminars and workshops, and co-funding incentives to promote early sustainability reporting ahead of requirements of the Singapore Exchange (SGX).

- The **Green Energy Programme** promotes the adoption of cleaner and greener marine fuels and one focus area is the adoption of LNG fuel.

[Refer to **Annex A.3** for other details of MSGI]

8.2.3 LNG Bunker-ready Port

MPA intends for Singapore to become a cleaner and greener port by adopting liquefied natural gas (LNG) as one of the cleaner marine fuel solutions for the future.

To this end, MPA is working with the shipping industry to bolster Singapore's LNG bunkering capabilities to be an LNG bunker-ready port by 2020. This includes putting in place necessary infrastructure for the end-to-end LNG bunker supply chain, developing regulatory schemes and ensuring a sufficient supply. In 2017, MPA launched a three-year LNG bunkering pilot programme to test operational protocols for LNG bunkering operations in Singapore.

MPA is also working with ten other ports and maritime administrations to establish a network of LNG bunker-ready ports to enable LNG as marine fuel for global shipping.

To facilitate the trial and use of LNG as bunkers, MPA has:

- Appointed two LNG bunker suppliers, Pavilion Gas and FueLNG (Joint venture between Keppel and Shell) to fulfil end-to-end supply chain logistics for LNG bunkering operations;
- Allocated S$18 million to co-fund the building of nine LNG-fuelled vessels;
- Allocated S$6 million to co-fund the building of two LNG bunker vessels to conduct ship-to-ship LNG bunkering in Singapore;
- Co-funded around S$2 million to build the interim truck loading facility at Singapore LNG terminal to facilitate LNG bunkering operations via the truck-to-ship supply model;
- Introduced additional 10% port dues incentive for vessels, which employ LNG-fuelled harbour craft under the Green Port Programme, and waiver of craft dues for LNG-fuelled harbour craft since the start of 1 October 2017;
- Launched the Technical Reference (TR) 56 for LNG bunkering developed by SPRING, MPA and industry parties to provide a safe, efficient, sustainable and transparent technical framework for conducting LNG bunkering operations in Singapore; and
- Formed an LNG Port Focus Group comprising eleven members to establish a network of LNG bunker-ready ports along the Far East-Europe and Transpacific trade routes.

[Refer to **Section 8.4** Investment Opportunities]

8.2.4 Innovative Water Sources

[Refer to **Section 8.1.1** Background to Singapore's Water Story]

8.2.5 Eco-tourism

8.2.5.1 Mandai's eco-tourism hub[37]

The Mandai's eco-tourism hub has an estimated completion date of 2023. When completed, Mandai's eco-tourism hub is expected to attract more than 10 million visitors each year from the current 4.6 million visitors. This will generate a significant number of jobs in conservation research, tourism and hospitality.

Welcomed by the tourism industry, the development of the hub hopes to attract a growing number of ecotourists to Singapore. Developer Mandai Park Holdings (MPH) gave the assurance that the development will be done sensitively, and has taken steps to ensure this. As early as 2012, MPH engaged nature groups on plans to develop the area. MPH also voluntarily commissioned an Environment Impact Assessment (EIA). Following the completion of the EIA, the results of which were announced in July of 2016, the developer also agreed to make changes to development plans. Mitigation measures and monitoring plans have also been put in place.

8.2.5.2 Responsible diving[38]

To encourage a deeper appreciation for Singapore's marine biodiversity, NParks has developed Singapore's first dive trails located at Sisters' Islands Marine Park. The shallow and deep dive trails were established to showcase the variety of marine biodiversity and reef features. Divers will be guided through 20 stations marked by signs which will bring their attentions to the variety of marine life as well as messages on conservation and responsible diving. Some stations will also engage divers in simple biodiversity or water quality surveys as part of NParks' efforts to encourage participation in our Citizen Science programmes.

To protect marine biodiversity, the dive trail is planned for divers with relevant dive experience and a certification beyond entry level from reputable international training organisations. This certification can be obtained by signing up with certified dive centres. Divers are required to have logged at least 20 divers with one local dive within the past two years.

Dive windows will be made available based on the conditions of the marine habitat and suitable currents. To minimise damage to the reefs and prevent overcrowding, a maximum of eight divers are allowed for each trail at any given time.

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[37] See https://www.chanelnewsasia.com/news/singapore/new-mandai-eco-tourism-hub-to-feature-global-wildlife-create-job-7563720

[38] See https://www.nparks.gov.sg/gardens-parks-and-nature/parks-and-nature-reserves/sisters-islands-marine-park

To ensure dive safety while safeguarding the reef habitat, only dive operators that meet all necessary criteria and adhere to regulations established for the dive trials are approved to conduct the guided dives. A list of NParks' approved dive operators can be found on their website.

8.2.5.3 Nature tours and bird watching

There are now 18 licensed tourist guides specialising in nature, and at least three organisations that offer eco-tours in Singapore. In particular, outdoor adventure company, Asian Detours, has been leading mangrove kayaking and cycling trips in Pulau Ubin since 2010. The tours are accompanied by professional guides, who point out flora and fauna, and historical landmarks. Guided nature walks are also offered by private tour companies as well as public organisations. NParks conduct guided tours at many of its parks and gardens.

Singapore's parks and nature reserves are maintained to help facilitate the birds in creating the right homes. Many different species of birds can be found in various part of Singapore. In particular, Sungei Buloh Wetland Reserve is a wonderland for bird watching enthusiasts. During the migratory season between September and March, the Reserve functions as a significant stopover point for birds. Guided birdwatching tours and workshops are also organised.

8.3 Emergent Ocean Economic Activities

8.3.1 Clean Ships Manufacturing

With less than two years until the IMO MARPOL Annex VI global 0.5% fuel sulphur rule comes into effect, shipowners and operators are increasingly pressed for time to decide on which option to select to conform to regulations on emission reduction.

South-east Asia's first LNG Bunkering vessel is being built by Keppel Singmarine. Keppel Singmarine expects to complete construction on the dual-fuel LNG bunkering vessel in the third quarter of 2020. The vessel will be built to a proprietary of Keppel Offshore & Marine's ship design and development arm, Marine Technology Development, for greener and safer bunkering activities within the Singapore port. It will have a capacity of 7,500 m^3.[39] [Related to **Section 8.2.3** LNG Bunker Ready Port. Please also refer to **Section 8.4** Investment Opportunities]

8.3.2 Diversifying Water Supply - Desalination

Over the last 50 years Singapore has built up a robust and diversified supply of water under the "Four National Taps" strategy. Beyond developing the infrastructure for enhancing water collection yield from local catchments and the high-grade reclaimed NEWater; by virtue of being an island, surrounded by sea PUB have capitalised on this by turning on Singapore's fourth national tap - desalinated water in 2005.

Today, Singapore has three desalination plants, with two more in the pipeline to be completed by 2020. The current focus is on continued research on technological improvements that will reduce desalination's energy use and cost, and ensure its long-term sustainability. PUB is currently looking into other forms of technology to extract freshwater from seawater, and investments have been made to undertake research in biomimicry, as well as scaling up the use of electrodeionisation (EDI) technology, a method that uses an electric field to pull dissolved salts from water developed by Evoqua. Both methods are expected to lower the energy consumption for desalination.

8.3.3 Ocean Energy

The ocean is an enormous store of potential energy that can be harnessed in the pursuit for alternative means to satisfy energy demands.

[39] The Straits Times, 2018.

8.3.3.1 National Strategy

Singapore has significant interest in renewable energy as an emerging field, which needs to be closely studied and developed in tune to regional needs (SMI, 2014). Noteworthy milestones in Singapore's *Ocean Renewable Energy* (ORE) activities include the development of various marine renewable energy test bedding sites, and collaborative projects between academic research institutes and industry, all of which benefit from the support of public agencies.

Singapore has set a national target of reducing its greenhouse gas emissions intensity by 36% compared to 2005 levels by 2030. Singapore is also working towards stabilising its emissions with the aim of peaking around 2030 (Singapore Climate Action Plan, 2016). This makes improving energy efficiency as Singapore's key strategy to reduce greenhouse gas emissions, and plans have been made to expand the scope of current initiatives across all sectors especially the power generation sector (NCCS, MEWR & MND, 2016).

More than S$800 million public funding has been set aside by the Singapore government for research in energy, water, green buildings and addressing land scarcity of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015).

Ocean renewable energy has been identified as one of the prominent alternative energy by Energy Research Institute @ NTU (ERI@N) specifically towards remote coastal and islandic region as part of its strategic research interests.

Singapore, being a small city-state, develops its own solutions to address constraints in land and water resources by building partnerships between public agencies, academia and industries towards the country's sustainability agenda. An example of this is Singapore positioning itself as a "Living Laboratory" – "making its national urban infrastructure available to local and international companies who find it useful to develop, test, prove and showcase their solutions in a real-life urban environment that is also representative of many Asian cities" (EDB, 2015). This enables Singapore to harness the best technologies and industrial solutions from its partners.

8.3.3.2 Market Incentives

The *Green-e Renewable Energy Standard* for Singapore allows Green-e Energy certification of renewable energy products throughout Singapore, in order to accelerate the development of renewable generation and renewable electricity markets, and to provide consumers a meaningful mechanism through which they can express demand for renewable electricity (Green-e, 2017). Instead of subsidies, Singapore has taken proactive

steps to introduce regulatory enhancements to facilitate the entry of renewable energy when such technologies become commercially viable (EMA, 2017). The Government's support for renewables mainly comes in the form of funding for RD to develop capabilities within the industry.

8.3.3.3 Public Funding Programmes

More than S$800 million public funding has been set aside by the Singapore Government for research in energy, water, green buildings and addressing land scarcity, of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015).

Ocean renewable energy has been identified as one of the prominent alternative energy by Energy Research Institute @ NTU (ERI@N) specifically towards remote islands and coastal regions as part of its strategic research interests. The government also welcomes clean technology companies to use Singapore and its islands as a 'Living Lab' to testbed and demonstrate innovative solutions before scaling up for the rest of the world. In 2017, the Singapore Economic Development Board (EDB) secured investments from six clean energy companies worth $500 million for next five years (EDB, 2017).

8.3.3.4 Research and Development

ERI@N, supported mainly by the EDB, focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre of excellence for conducting advanced research, development and demonstration of innovative solutions, which have both regional and global impact. The Institute has considerable expertise and strength in areas of offshore energy, which includes wind, wave and tidal energy and complementary technologies, such as energy storage, micro grids, and smart energy systems, and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

ERI@N's Wind and Marine (W&M) research programme is aimed at improving the performance, lowering costs and accelerating deployment of offshore renewable technologies specific to the tropics, where unique technology challenges exist. It advances the technology development and commercialization through early collaboration with industry. It works closely with government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps and develop the appropriate technologies.

8.3.3.5 Technology Demonstration: Open Sea Test Sites

a. Sentosa – ERI@N Tidal Site

The Sentosa Tidal Test Site is a joint collaboration between SDC and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013).

Recent developments on the test site include the deployments of tidal turbines supported from the floating barges. Also, novel concepts, such as anti-biofouling coatings are being evaluated for better field performance. The power developed is used for electric lighting on the boardwalk.

b. Sentosa-ERI@N Tidal Test Site

The Sentosa Tidal Test Site is a joint collaboration between SDC and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to display tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013).

c. ERI@N Tidal Turbine System

In the interest of promoting sustainable energy solutions to achieve energy security with reduced carbon footprint in tropical regions, the Energy Research Institute at NTU (ERI@N) works with international partners in developing and test bedding tidal in stream energy systems for island conditions with micro grids architecture. Recent developments include the deployment of scaled tidal turbines supported from the floating barges.

This project is one of the pioneering tidal turbine deployment in Southeast Asia and may act as a model for smaller scale energy developments in coastal areas throughout Southeast Asia. This project also shows that successful deployment of ocean renewable energy technologies could be possible through regional and international collaboration with the involvement of academic and industrial partnership. The island micro grid is currently using diesel generators to power its operations. A hybrid renewable energy solution, including tidal energy, will improve the operations of the island in terms of having a cleaner and relatively cheaper energy source. The continued monitoring of the

deployed solution and of the project's impact to GPFT and PT BUMWI's locality will be a key in scaling up such initiatives. The present test bedding effort shows that a similar approach towards adoption of ocean renewable energy is achievable to empower Singapore's remote islands. Taking this inspiration, there is now some traction in developing similar projects in locations such as those in Indonesia, Vietnam, Malaysia, Myanmar, and the Philippines.

8.3.3.6 Operational Projects

Barge based floating tidal system

In the interest of promoting sustainable energy solutions to achieve energy security with reduced carbon footprint from tropical regions, ERI@N works with international partners in developing and test bedding tidal in stream energy systems for island conditions with micro grids architecture. Recent developments include the deployment of scaled tidal turbines supported from the floating barges.

8.3.3.7 Planned Deployments

a. Renewable Energy Integration Demonstrator-Singapore (REIDS)

REIDS aims to power Pulau Semakau - an island south of mainland Singapore, which serves as a landfill - purely via renewables, like ocean energy. First of its kind in the region, the hybrid micro grid will facilitate the development and commercialization of energy technologies suited for tropical conditions that will help address the growing demand for renewable energy technologies in Asia. REIDS will integrate multiple renewables and novel technologies, such as power-to-gas Technologies and smart hybrid grids, and enable the development of solutions suited for small islands, isolated villages, and emergency power supplies.

b. REIDS Onshore: Renewable energy towards remote islandic conditions

The REIDS onshore project aims to solve engineering, economic, environmental and societal energy transition challenges for off-grid communities. It customizes grid science towards remote islandic needs and integrates various renewables. Technologies deployed at the test bed include solar photovoltaic, wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc. Presently, work is in progress to make the island energy self-sufficient with its renewable sources. The Republic's largest wind turbine was unveiled at Semakau Island on 20th October 2017, marking the first time the renewable energy source is connected to the island's power grid. The turbine comes with three 10.5m long-span rotor blades that produce an electrical output rating of 100 KW.

c. REIDS Offshore: Marine energy resource

The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as Tropical Marine Energy Centre (TMEC), has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society), and seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and is expected to be completed by December 2017. During this project, the resource mapping methodologies are well utilized to identify the ocean energy potential of the southern islands of Singapore that have been identified from the MPA. Presently, an environmental impact assessment (EIA) for the test sites has been carried out to understand the impact of ocean energy system deployment on marine life and environment. The outcome of this project extended towards Singapore's guidelines and standards development by working with Spring Singapore to support local supply chain's marine energy resource mapping guidelines of new regions, such as our neighbouring region of Southeast Asia and other tropical islands and remote coastal regions. Overall, the present project aims to develop technologies and deployment methodology for meeting energy needs towards the remote island region.

d. Floating PV Systems

The Solar Energy Research Institute of Singapore (SERIS) at NUS is managing the world's largest floating photovoltaic (PV) test-bed at Tengeh Reservoir. A collaborative initiative spearheaded by Singapore EDB and PUB, the project team has conducted rigorous study on the technological feasibility and continued monitoring of the floating solar system performance to facilitate further deployment of large-scale floating PV systems on inland water bodies.

8.3.3.8 Relevant National Events

a. Workshop on Tidal Current Extractable Energy: Modelling, Verification and Validation

This workshop was organised and hosted by ERI@N, Singapore through teleconferencing on June, 2017. The main goal of this workshop is to prepare a Tidal Energy Resource Modelling Guideline report through the study of the various factors affecting the result of the simulations along with code-to-code comparisons.

As great multitude of tools and techniques are used to determine the amount of tidal resources and to quantify the resources available in different parts of the world, establishing a standard in extractable resource modelling can pave the way in promoting

the adoption of tidal energy among the various stakeholders, as it can provide confidence in the amount of available resources. International Tidal Energy Working Group is thus consequently formed and various research teams can conduct extractable resource studies to share their results and methodology, and work towards creating a standard report for modelling in harnessing tidal energy.

b. Workshop on Ocean Energy in Islandic Conditions

ERI@N conducted a workshop to discuss the opportunities and barriers to local adoption of ocean renewable energy in island and remote coastal areas of the Asian region from the perspective of various stakeholders and the possible solutions to address the challenge. It also tackled the crucial roles of the different stakeholders (academia, policy-makers, industry and end –users) that each has to play to contribute to the uptake of ocean renewable energy in Southeast Asia.

c. Asian Conference on Energy, Power and Transportation Electrification (ACEPT)

The second Asian Conference on Energy, Power and Transportation Electrification (ACEPT) was organized by Energy Research Institute @ NTU (ERI@N), as a part of Asia Clean Energy Summit (ACES), and was held in conjunction with Singapore International Energy Week (SIEW 2017) on October 2017. ACEPT 2017 cooperated with the Institute of Electrical and Electronics Engineers (IEEE) to bring together the world leading experts to present emerging topics on energy, power, and transportation electrification.

d. International Floating Solar Symposium (IFSS)

International Floating Solar Symposium was organised by Solar Energy Research Institute of Singapore (SERIS) as a part of Asia Clean Energy Summit (ACES) and was held in conjunction with Singapore International Energy Week (SIEW 2017) on October, 2017. It addresses the water-energy nexus through evaporation reduction and opens paths to ultra-low balance of system (BOS) costs. The fascination with scalability and market potential is palpable: New form factors were being discussed, and field tested and the young industry is charting its way through the options for electrical architectures and unfamiliar environmental considerations. Thus various industry players, innovators, developers and other stakeholders of floating solar were brought together.

8.3.4 Deep Sea Opportunities

Rapid progress being made in the development of deep sea technologies is opening up whole new sectors of ocean use and exploration.

8.3.4.1 Deep Sea Mining

The International Seabed Authority (ISA) – an organisation established by the UN's Law of the Sea Convention (UNCLOS), which organises, regulates and controls all mineral-related activity in the internal seabed area beyond national jurisdictions – began issuing the first licenses in 2001.

The authority granted Ocean Mineral Singapore Pte Ltd (OMS) the 15-year exploration contract for polymetallic nodules at a site within the Clarion-Clipperton Fracture Zone of the Pacific Ocean in July 2014. Work is still being concluded on a regulatory framework before mining can commence, OMS – a subsidiary of Keppel Corporation – will be conducting environmental studies and surveys for deposits in the approved area which is roughly 80 times the size of Singapore (58,000 km^2) in conjunction with the Keppel-NUS Corporate Laboratory.

In September 2017 Singapore hosted the fourth Asia-Pacific Deep Sea Mining Summit – as the international community move ever closer to mining the deep ocean floor, industry stakeholders from developing island nations and ocean regulators to commercial deep sea miners and subsea technology companies meet to learn more about the opportunities in this evolving space.

8.3.4.2 Deep Sea Exploration

An exploration team of 31 marine scientists and support staff, completed the 14-day, South Java Deep Sea Biodiversity Expedition (SJADES) in March 2018 - surveying the uncharted deep seas of the Sunda Strait, off the southern coast of West Java, Indonesia. The research team sampled 63 stations, at depths ranging from 500m – 2,000m, documenting a total of 800 species from over 200 families of sponges, jellyfish, molluscs, starfish, urchins, worms, crabs, prawns and fish amounting to more than 12,000 individual organisms. More than 12 new species of crustaceans were discovered and more than 40 new records for Indonesia.

Led by Professor Peter Ng, head of the Lee Kong Chian Natural History Museum of NUS, and Professor Dwi Listyo Rahayu, senior research scientist at the Research Centre for Oceanography of Indonesia Institute of Sciences, the endeavour is a demonstration of the collaborative spirit embodied in RISING50 – a celebration of 50 years of diplomatic relations between Singapore and Indonesia.

8.4 Investment Opportunities

The ocean's contribution to Singapore's economy, is one of considerable significance. As the country's economic relationship with the ocean is continuously evolving, so do the challenges as well as the opportunities that can be captured (discussed in **Sections 11.0** Key Challenges in a Dynamic Environment, **Section 7.0** Other Ocean Economic Activities, and **Section 8.0** Blue Economy Development).

Given the various blue economy initiatives that have been described in the aforementioned sections, the segment below aims to highlight/summarise a few of the key areas identified for potential growth and development within the blue economy for Singapore.

8.4.1 Food Security

8.4.1.1 Aquaculture Health and Nutrition Research and Aquaculture Systems Development

Fish disease and feed are one of the highest cost drivers in aquaculture. Tropical fish diseases are not well understood for some species and feed are not yet optimised. Hence, there are opportunities to deepen research capabilities to support animal health and nutrition research.

There are also opportunities to develop innovative aquaculture systems which are more manpower and space efficient. These opportunities would be more visible in the development of an integrated agri-food park to cluster a range of food, aquaculture and biosciences sectors to foster and encourage innovation.

8.4.2 Securing Singapore's Water Supply Through Diversification

8.4.2.1 Research and Development (R&D) Linked to Policy, Planning, and Other Applications

Singapore has seen significant investment in weather-resilient water sources by PUB into NEWater and desalinated water. NEWater is primarily supplied to industrial sectors such as wafer fabrication parks, industrial estates and commercial buildings for industrial and cooling purposes. As for desalination, it has become a viable option as improvements in membrane technology has brought down the cost significantly. Currently, Singapore has three desalination plants, with two more in the pipeline to be completed by 2020.

8.4.2.2 Capacity Development, Technology Transfer and Knowledge Management

Singapore also works closely with the international community in sharing its experience and know-how. PUB engages international organizations that work on water issues, such as UNESCO, the World Water Council, Global Water Partnership and the Asia Pacific Water Forum, and contributes actively to the discourse on sustainable urban water management. Singapore organises the Singapore International Water Week (SIWW), a global platform to share and co-create innovative water solutions. SIWW 2016 attracted over 21,000 participants from 125 countries and regions. In addition, the Lee Kuan Yew Water Prize, an international water prize, honours outstanding contributions by individuals or organisations towards solving the world's water challenges and the laureates' achievements in sustainable water solutions have made a difference to cities and people around the world. The 2018 SIWW which was held in July focused on advanced wastewater treatment and SMART water solutions and attracted more than 24,000 participants from 110 countries and regions.

8.4.2.3 Future Challenges/Opportunities - Use of Technology to Enhance Water Security and Weather Resilience

Conventional water sources –i.e. local catchments and imported water, face several threats, including weather uncertainties and pollution. Singapore is progressively building up other water supply sources, NEWater and desalinated water, ahead of demand to ensure the resilience of Singapore's water system in the long term. It is therefore important for PUB to bring down desalination's energy use and cost and environmental impacts, and ensure its long-term sustainability. PUB is currently looking into other forms of technology to extract freshwater from seawater, and investments have been made to undertake research in biomimicry, as well as scaling up the use of electrodeionisation (EDI) technology, a method that uses an electric field to pull dissolved salts from water developed by Evoqua. Both methods are expected to lower the energy consumption for desalination. Our Water, Our Future is a publication by PUB that sets out the water strategies and plans that will be undertaken over the next 50 years. Today, Singapore has three desalination plants, with two more in the pipeline that will be completed by 2020.

8.4.3 Investment Opportunities in Solid Waste and Plastic Waste Management

Investment opportunities include introducing efficient, cost-effective and innovative waste-to-energy/ resources solutions for waste streams such as e-waste, food waste, and packaging and plastic waste.

8.4.4 Marine Tourism/Cruise Tourism

For the cruise industry, the following green initiatives are emerging trends which could be considered for future investment:

i. **Shore power**: Develop a sub-station at cruise terminals so that cruise ships can use shore power from the terminal instead of using diesel engine to power their ships when berthed.
ii. **LNG provisioning**: Some new cruise ships use LNG as fuel instead of diesel. This is cleaner but more expensive, and requires costly retrofitting of the vessel for its use. To equip Singapore with the necessary infrastructure to provide LNG to such cruise ships is one of the areas for future investment.

8.4.5 Next Generation Port (NGP) 2030 Initiative

MPA will implement strategic changes in response to the upcoming challenges facing the industry. NGP 2030 is one such example, and envisions to allow Singapore's ports to utilise a new generation of technologies to increase efficiency and productivity, intensify land use in the port, improve safety and security and promote sustainability.

A major component of the NGP 2030 is the next generation Tuas Terminal, which will deploy advanced port technologies and have numerous automated systems.

8.4.6 Marine & Offshore Engineering (M&OE) Industry Transformation Map (ITM)

Developed by a multi-agency team, led by EDB, together with trade associations and chambers (TACs), unions and industry partners, the M&OE ITM charts the roadmap to drive transformation and help companies, including small and medium-sized enterprises (SMEs), capture long-term growth opportunities in the industry. Through the ITM, the M&OE industry is expected to have a value-added of S$5.8 billion and create around 1,500 new jobs by 2025.

These include SPRING Singapore's Bridging Loan (BL) and International Enterprise (IE) Singapore's enhanced Internationalisation Finance Scheme (IFS) to help Singapore-based M&OE companies finance their operations and bridge short-term cash flow gaps. Since 2016, the two schemes are administered in partnership with local financial institutions, and have catalysed nearly S$700 million in loans to more than 100 unique borrowers, 80% of whom are SMEs. ASMI, the Shipbuilding and Marine Engineering Employees' Union (SMEEU), Workforce Singapore (WSG), and EDB have also been supporting the reskilling of affected employees through Professional Conversion Programmes (PCPs) under WSG's Adapt and Grow initiative, so that they may be redeployed into new job roles or in the same or adjacent industries.

While it is critical to preserve core capabilities in the M&OE industry and ride through the downturn, Singapore must also be prepared to seize new opportunities on the horizon. The M&OE ITM has identified three key thrusts: (1) Preparing for the future through innovation and productivity improvements; (3) Pursuing new growth areas; and (3) Equipping Singaporeans with relevant skills.

8.4.6.1 Preparing for the Future through Innovation and Productivity Improvements

To ensure that our M&OE industry remains globally competitive, the Government is helping companies invest in advanced manufacturing. These include additive manufacturing, robotics and automation to improve productivity. As the global M&OE industry increasingly explores digital technologies to optimise its operations and generate new revenue streams, the Government will support companies in developing next-generation M&OE solutions that can enable remote monitoring, provide predictability and support decision-making.

The Government will also support companies' in-house research & development (R&D) initiatives and facilitate public-private R&D through research institutes, such as the Technology Centre for Offshore and Marine Singapore (TCOMS).

8.4.6.2 Pursuing New Growth Areas

Driven by the global transition to a low-carbon economy and increased alternative uses of Liquefied Natural Gas (LNG), global expenditure on LNG is expected to exceed US$280 billion by 20212. Similarly, on the back of heightened global focus on sustainability, the global offshore wind market is anticipated to exceed US$130 billion by 2023. These present opportunities for the M&OE industry to leverage its existing capabilities in building offshore structures and supporting offshore projects, to venture into these new areas.

The Government will help companies access these new business opportunities by connecting companies with relevant stakeholders and resources, and supporting business partnerships with companies in overseas markets.

8.4.6.3 Equipping Singaporeans with Relevant Skills

As M&OE companies intensify their transformation efforts and pursue new growth areas, Singaporeans must be well-prepared to take on the new and exciting job roles coming ahead.

The Skills Framework for Marine and Offshore was developed by SkillsFuture Singapore (SSG), WSG, EDB and SPRING Singapore, together with industry stakeholders, such as employers, industry associations, unions and education providers. The framework allows individuals to explore career advancement opportunities along or across seven career tracks, which include Design and Engineering; Quality Assurance and Quality Control; and Workplace Safety and Health. In total, it covers 29 job roles in the Marine & Offshore industry. It also provides key information on the industry, and identifies a total of 96 existing and emerging technical skills and competencies. The emerging skills and competencies include Additive Manufacturing, Robotics and Automation Application, and Green Ship Design.

SSG has also launched the Skills Future Series, which is a curated list of short and modular courses to reskill or upskill the workforce in emerging and priority skills areas required, such as Advanced Manufacturing and Data Analytics. Temasek Polytechnic will also implement two new SkillsFuture Earn and Learn Programmes (ELPs) in emerging and critical areas – Robotics and Automation and the Industrial Internet of Things – this year. In addition, the Institute of Technical Education (ITE) will offer its new Work-Learn Technical Diploma in M&OE this April.

Professionals, Managers, Executives and Technicians (PMETs) can tap on WSG's PCPs to be reskilled for job roles in the new growth areas, such as LNG. Since October 2016, more than 300 PMETs have been reskilled through the three PCPs for Marine Engineers, Assistant Engineers and Technicians.

PART 4

STATE OF OCEAN HEALTH UNDERPINNING THE BLUE ECONOMY

9 Oceanographic Features

9.1 Bathymetry and Hydrography

The seabed around mainland Singapore is highly irregular, with numerous islands and shoals dispersed throughout. Much of the coastal waters around mainland Singapore have an average depth of 30 m (98 feet) with some areas as deep as 80 m (262 feet) (Anon, n.d.). The currents and circulation in the water surrounding mainland Singapore are mainly tidally-driven and influenced by the coastlines of Singapore and its neighbours.

The Johor Strait, which lies along the northern coast of Singapore, is divided into two parts by the causeway linking Singapore and Malaysia. Water depths in the middle of the Johor Strait range between 10-20 m. The width of the Johor Strait varies from about 0.5 to 2 km including the tidal flats on either side (Chan, et al., 2006).

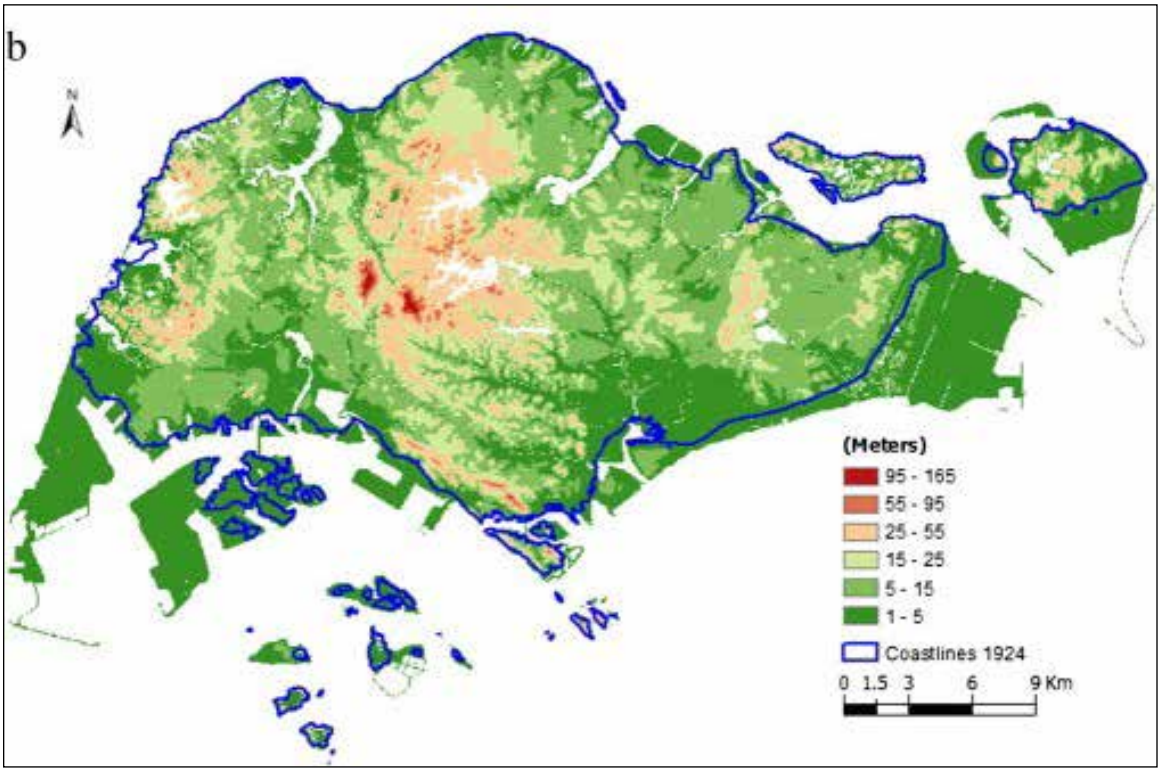
The Singapore Strait is bounded by mainland Singapore's and Peninsular Malaysia's southern coast on one side, and the northern coasts of Indonesia's Riau Islands on the other. The Malacca and Singapore Straits are connected to the Java Sea through Selat Durian, Selat Combol, Selat Riau, and several other minor straits between islands. The narrowest part of the Singapore Strait is about 5 km. Between mainland Singapore and Pulau Batam, the range is about 5 to 15 km (Chan, et al., 2006). Sections of Singapore Strait have very deep waters, exceeding 50 m, and a trench is found off St. John's Island. The axis of the trench lies in an east-west direction, and there are other areas below 60 m. These trenches were probably part of the channels of the valleys of the ancient river system which used to flow across Sundaland (Chia, et al., 1988).

9.2 Topography, Geology and Drainage

A low-lying island, much of the country lies only 15 m above the mean sea level; approximately 30 per cent of the island less than 5 m above the mean sea level. The topography of Singapore is shown in **Figure 9.1**. The relief of the main island reflects the influence of the underlying geological formations.

The highest elevation is located at Bukit Timah Hill at 166 m (540 ft), comprising igneous rock, whilst the lowest point is the Strait of Singapore at 0m. Much of coastal relief along the coastline of the mainland and on some offshore islands is characterised by flat reclaimed land (**Figure 9.1**).

Figure 9.1: Topography of Singapore 2012.



Source: Wang, et al., 2015.

Singapore can be geographically divided into three major terrains: (a) the central core – hilly area made of igneous rocks composed mainly of granite; (b) the western undulating area of sedimentary rocks (sand and mudstone), including the Southern Ridges; and (c) the flatter, eastern coastal area consisting of alluvium and sediment.

The existing habitats include terrestrial primary and secondary forests; open grasslands; and coastal habitats of freshwater swamps, mangroves, seagrass beds and coral reefs. Singapore currently has four legally-gazetted Nature Reserves, and another 20 administratively-protected Nature Areas that cover the majority of natural habitats within Singapore like primary dryland forest, tall secondary forest, freshwater swamps, rocky shores, mangroves, mudflats, seagrass beds and coral reefs.

The Singapore River, located within the central region of the island, is the principal river of Singapore, and measures 3.2 km in length from its mouth to Kim Seng Bridge (Savage, et al., 2004). It has been a historically important resource for almost 200 years, since the time of early settlers and traders. The Singapore River has five tributaries: Geylang, Kallang, Pelton, Rochor, and Whampoa rivers. Other small streams exist, some of which flow directly into the sea through mangrove swamps, lagoons, or broad estuaries. Several of the larger streams have been damned to form freshwater reservoirs. While Singapore has no natural lakes, there are 17 reservoirs (both coastal and inland) and water catchment areas, which have been created to fulfil some of Singapore's water supply requirements.

The complex pattern of drainage on Singapore Island is the result of heavy perennial rainfall acting on the weathered rocks of a varied terrain. The Island is divided into 40 drainage basins, the largest of which is Sungei (meaning river) Kranji-Pang Sua Basin, which is 68.12 km^2 and covers 12.5% of the total drainage area. The other large basins -- S. Seletar, S. Jurong, S. Kallang, S. Rochore, S. Serangoon and S. Geylang -- individually drain more than 16 km^2. Together, these seven basins cover 27% of the total drainage area.

9.3 Climate[40]

Singapore has a tropical climate, with relatively uniform temperature, abundant rainfall, and high humidity. The climate is characterised by two monsoon seasons separated by inter-monsoon periods. The Northeast Monsoon occurs from December to early March, and the Southwest Monsoon from June to September. The early part of the Northeast Monsoon season, in December and January, is the wetter period of the year when monsoon surges occur, which can bring prolonged heavy rain to Singapore. The later part of the Northeast Monsoon season from February to early March is normally much drier. Afternoon thunderstorms are common throughout the year, especially during the inter-monsoon periods from late March to May and October to November. Widespread heavy rain and gusty winds associated with Sumatra squalls also occur occasionally during the Southwest Monsoon season and inter-monsoon periods. Singapore's 1981-2010 long-term average daily temperature is 27.5°C, with an average daily maximum of 31.5°C and an average daily minimum of 24.7°C. The long-term average annual rainfall is 2,166mm.

The ambient air quality in Singapore is monitored by the National Environment Agency through the Telemetric Air Quality Monitoring and Management System. The system comprises remote air monitoring stations linked by wireless means to a data management system at the Environment Building.

9.4 Currents and Tides[41]

The Singapore coast is characterised by accumulation rather than erosion, much like other areas located in the humid tropics where low wave and tidal energy conditions prevail (Swan, 1971), which is further compounded by the uneven topography of the seafloor around Singapore.

Wave fetch is largely short and disrupted, and furthermore, the directions of maximum fetch rarely overlap with those of the strongest winds. Singapore's low-energy marine and coastal environment is a resultant factor from sheltering effect produced by the surrounding landmasses, as wave power is dissipated through refraction and obstruction by the shallow waters, islands,

[40] Meteorological Service Singapore
[41] Based on information provided from the Coastal Environmental Profile of Singapore

and reefs. The average breaker height is below 20cm (Chew, 1974) (Swan, 1971); whilst open-water waves, during storms caused by the southwest monsoon and swell from the South China Sea, can reach 1m in height. However, refraction and obstruction lessen their effects closer to shore (Wong, 1985) (Chew, et al., 1975) .

The Hydrographic Department of the Maritime and Port Authority of Singapore (MPA) monitors coastal tidal levels in real time through a network of 13 tide gauges covering Singapore and its offshore islands. Tidal data is used for predictions of tidal heights and streams, which are published in the Singapore Tide Tables.[42]

Information on tidal currents is available on the Digital Tidal Atlas[43], which includes information on the predicted speed and direction of the currents at anchorages at Sundog bunkering and Eastern bunkering. Information on the predicted tidal current for Singapore waters is also available commercially at info@Sea.[44]

9.4.1 Currents

The currents (or tidal streams) that circulate Singapore are referred to as monsoon currents, which are induced by the prevailing winds during the monsoons (Tham, 1973). During the northeast monsoon, which occurs from December to early March, there is a net transport of water from the South China Sea to the Singapore Strait. Whilst during the southwest monsoon from June to September, water from the Java Sea and Malacca Straits is transported through the Singapore Straits (Chan, et al., 2006).

Where wind-driven currents are dominant in the more exposed areas, such as South China Sea, the influence of the wind on the currents in the Singapore Strait is less significant in comparison with the more dominant influence of tidal forcing (Chan, et al., 2006). Generally, tidal streams at the western entrance of Singapore Strait flow in a south-southwest or north-northwest direction, while those at the eastern end flow in west-southwest or east-northeast direction.

Studies on current movement within the East Johor Strait and adjacent waters by Lim (Lim, 1984) exhibited very similar patterns of surface and near bottom tidal currents. During flood tide, water enters East Johor Strait from Kuala Johor, and the direction is reversed during ebb tide. Both the surface and near bottom tidal currents in Kuala Johor are stronger than those in East Johor Strait. Also, in both areas, the ebb flows were observed to be stronger, and the surface currents were stronger than the near bottom currents. Kuala Johor has a stronger residual current than East Johor Strait where the net current moves seawards at the upper layer and towards Johor

[42] The Singapore Tide Table is published annually. It can be purchased from chart distributors, see https://www.mpa.gov.sg/web/portal/home/media-centre/publications/singapore-tide-tables

[43] Please see http://www/marinet.mpa.gov.sg, 2018

[44] Info@Sea is a joint venture between MPA and its partners to provide dynamic tidal and current forecasts to ships. See more at http://www.infoatsea.com

Causeway near the bottom. This is in contrast to the surface and near bottom water in Kuala Johor which flows into Singapore Strait.

Lim's (Lim, 1984) investigation on the hydrological conditions in West Johor Strait showed that during the northeast monsoon, a branch of the southerly current in the South China Sea moves along the east coast of Peninsular Malaysia, and turns round the southern tip of the peninsula to move through Singapore Strait before entering the Strait of Malacca. During the Southwest monsoon, a northerly current from Java Sea passes into Singapore Strait and into the Strait of Malacca through the east coast of Sumatra and into the South China Sea. Thus, Singapore Strait receive water from South China Sea during the northeast monsoon, and from the Java Sea during the southwest monsoon (Rahman & Chia, 1977).

Tidal streams within Singapore Strait attain maximum velocity first at the eastern entrance, and then progressively farther westwards. Stream velocities range from 0.5-1.0 meters per second (ms^{-1}) in open water of Singapore Straits, up to 1.5-2 ms^{-1} in constricted channels between islands (Shankar, et al., 1996). Non-tidal currents that arise from prevailing winds can reach a maximum speed of 0.4 ms^{-1} during southwest monsoon.

9.4.2 Tidal Regime

The tides in Singapore result from those generated in the South China Sea and to a lesser extent those produced in the Indian Ocean. Generally semi-diurnal, they are characterized by two occurrences of both high and low waters within a lunar day; the second occurrence of high and low waters are of a lower range, where the difference in the heights of successive high and low waters - referred to as diurnal inequality. The rising tide moves westward, and the ebb tide, eastward.

The mean tidal range is around 2.5 m; maximum spring tide reaches about 3.0 m, while the range for neap tides reach 0.7 m (Shankar, et al., 1996). Observations reveal that spring or neap tides in Singapore Strait occur two days after the new/full moon or first/last quarter of the moon. The range of tide decreases gradually as movement progresses further eastward away from the Singapore Island. Diurnal range reaches a peak when the moon is farthest from the equator, and the tides occurring at such times (twice in a lunar month) are known as tropic tides.

The Singapore Regional Waters (SRW) is one of the more mixed tidal regions in the world. The complexity is brought about by a multitude of factors, such as the interaction of the Indian and Pacific Oceans with their respective mainly semi-diurnal and diurnal tide; intricate coastline geometry; the presence of landmasses/islands; and abrupt variations in bathymetry (Kurniawan, et al., 2011).

The average Mean Sea Level (MSL) of 1.555 m is determined at tidal gauge located at Victoria Dock (1935-1937) (Khoo, 2010), and experiences daily fluctuations, with changes in water density, wind and atmospheric pressure. While the monthly mean also varies, the change in yearly means in Singapore is marginal. As a result of the prevailing south-westerly winds, the monthly MSL is lower than the yearly

one during April to September, when the water mass is moved away from the land mass towards the South China Sea. Conversely, during November to January, the monthly MSL is higher, when winds of the northeast monsoon pile up the water at the south-western portion of the South China Sea (Chua & Lim, 1986).

9.5 Sea Surface Temperature (SST)

Throughout the year, sea surface temperature (SST) varies within a small range of not more than 4°C, with an annual pattern, which is influenced by the monsoons. During the northeast monsoon period, SST drops to its lowest in January, ranging between 27°C and 28°C. As the hot and dry season approaches in May, SST rises to a maximum of between 30°C and 31°C. From this peak, it then drops throughout the rest of the year with a slight increase in October in the inter-monsoon period between the southwest and the northeast monsoon (Tham, 1973).

Variation of SST throughout the year may be affected by yearly variation of the wind (monsoons), cloudiness and solar radiation. Largely, there is no significant temperature difference between surface and bottom depths due to the lack of stratification / highly vertical mixing of the water column in the southern waters (Tham, 1973).

9.6 Salinity

The salinity fluctuates twice annually, and is heavily affected by the monsoons. The salinity maxima reach as high as 32‰, which occur during the inter-monsoon period of March-April and October-November. Compared to the salinity maxima, which remain approximately the same value, the salinity minima do not (Chou & Chia, 1991).

These two salinity minima occur during December-January and July-August and coincide with the Northeast and Southwest monsoons periods. Due to the heavy rainfall of the monsoon season, water moving through the Singapore Straits are diluted. Water from the Java Sea moves up through the Berhala Strait during the southwest monsoon. The water from heavy rainfall discharge by the rivers dilutes the water along Sumatran coast. The diluted water body then flows eastwards towards Singapore, lowering the salinity to a minimum of 28.5‰. The other higher salinity minimum of 30‰ occurs during the northeast monsoon, when water enters the Singapore Straits from the South China Sea. This annual oscillatory pattern has been observed to be predictable, although the actual values of the two maxima and the two minima are likely to vary.

9.7 Availability of Nutrients

Singapore Strait's phosphate content as determined by Tham (Tham, 1953) during the post-war years of 1948 and 1949 showed that there was an annual pattern of variations, except from the months of June

to August. In January, March and November, peaks were observed. The maximum values in both years were recorded in January. During June to August period, other peaks were observed in the two years.

Due to the unusually high rainfall in the first quarter of 1948, very high values of phosphate were recorded. Tham demonstrated a close link between rainfall and phosphate content. The lower average value for 1949 coincided with the below-average rainfall of that year. Phosphorus compounds are washed into the sea through the river and higher content will be registered after heavy precipitation.

Besides phosphate, nitrates are also an important nutrient in water bodies. Nitrate analysis conducted by Khoo (Khoo, 1966) in Johor Straits indicated a range of 47.56 to 82.27 ppm with an annual pattern of variation like that of phosphate content. The nitrate content is lower than that of temperate water and is possibly due to the high level of phytoplankton in Singapore's perpetually warm waters.

In 2000 study (Gin, et al, 2000) of the Singapore Strait, overall chlorophyll concentrations were relatively low at about 1 to 3 micrograms per liter (μg L^{-1}), although local areas off the east coast and the Johor Strait showed episodic, elevated levels of chlorophyll ranging from 5 to 80 μg L^{-1}. In terms of nutrients, phosphate in the Singapore Strait ranged from non-detectable levels to 0.024 mg P per liter, nitrate + nitrite levels ranged from 0.005 to 0.078 mg N per liter, while ammonium ranged from non-detectable to 0.053 mg N per liter.

Presumably, nutrients are rapidly taken up by phytoplankton, which explains the generally low levels of nitrogen and phosphorus measured. There is also some seasonal variation in nutrients and chlorophyll due to the different monsoons. Another factor which could contribute to lower chlorophyll concentrations in the Singapore Strait is the reduction in light levels in nearshore coastal waters due to the higher turbidity generated from extensive land reclamation and construction activities along the north-east coastline and southern islands.

9.8 Marine Water Quality

The marine and coastal areas of Singapore are widely used for an array of industries comprising shipping, transportation, petroleum, and petrochemical manufacturing, in addition to non-industrial activities such as residential development and recreational usage. In Singapore water quality issues are managed on a multi-agency basis. At present, Singapore references the *ASEAN Marine Water Quality Criteria* (AMWQC) and *ASEAN Long-Term Goals* to benchmark our coastal and inland water quality. Individual agencies have also adopted guidelines for specific beneficial uses in line with those of international organisations. For example, NEA adopts the World Health Organization (WHO) Guidelines for recreational water quality at beaches and fresh water bodies to assess the suitability of recreational waters for primary contact activities. Given Singapore's limited water resources, it is critical that water pollution and quality are carefully monitored and regulated.

The Pollution Control Department (PCD) of NEA regularly monitors the water quality of various inland water bodies and coastal areas. Water quality in various rivers, streams and ponds in both water and

non-water catchment areas are regularly monitored and analysed for levels of dissolved oxygen (DO), biochemical oxygen demand (BOD), and total suspended solids (TSS). The water quality of the catchment and non-catchment areas remained good in 2017, and monitoring data are shown in **Table 9.1**.

Table 9.1: Monitoring Result of Inland Waters.

Parameters Monitored		Water Catchment Streams (% of time)	Non-water catchment rivers/streams (% of time)
Dissolved Oxygen (>2mg/L)	2016	99%	95%
	2017	97%	100%
Biochemical Oxygen Demand (<10mg/L)	2016	97%	92%
	2017	98%	95%
Total Suspended Solids (<200mg/L)	2016	100%	95%
	2017	100%	98%

Source: NEA

Regular water samples are also collected from various sampling points along the Straits of Johor and the Straits of Singapore. The water samples are analysed for physical, chemical and microbiological parameters. The monitoring results for Enterococcus counts under the coastal water quality monitoring programme are shown in **Table 9.2** below.

Table 9.2: Monitoring Results of Coastal Waters.

Parameters Monitored		Straits of Johor East (% of time)	Straits of Johor West (% of time)	Straits of Singapore (% of time)
Enterococcus Count (<200 per 100 ml)	2016	98%	97%	98%
	2017	97%	94%	100%

Source: NEA

In 2014, a real-time continuous water quality monitoring system for the coastal waters of Singapore was commissioned. The monitoring system comprises eight buoy-based stations equipped with sensors to monitor key water quality parameters. Data collected from the eight buoys is transmitted real-time to an Operational Management System (OMS), which processes and manages the data. Furthermore, the OMS incorporates water quality models for the forecasting of water quality, backtracking, and determining coastal areas affected by oil or chemical spill incidents.

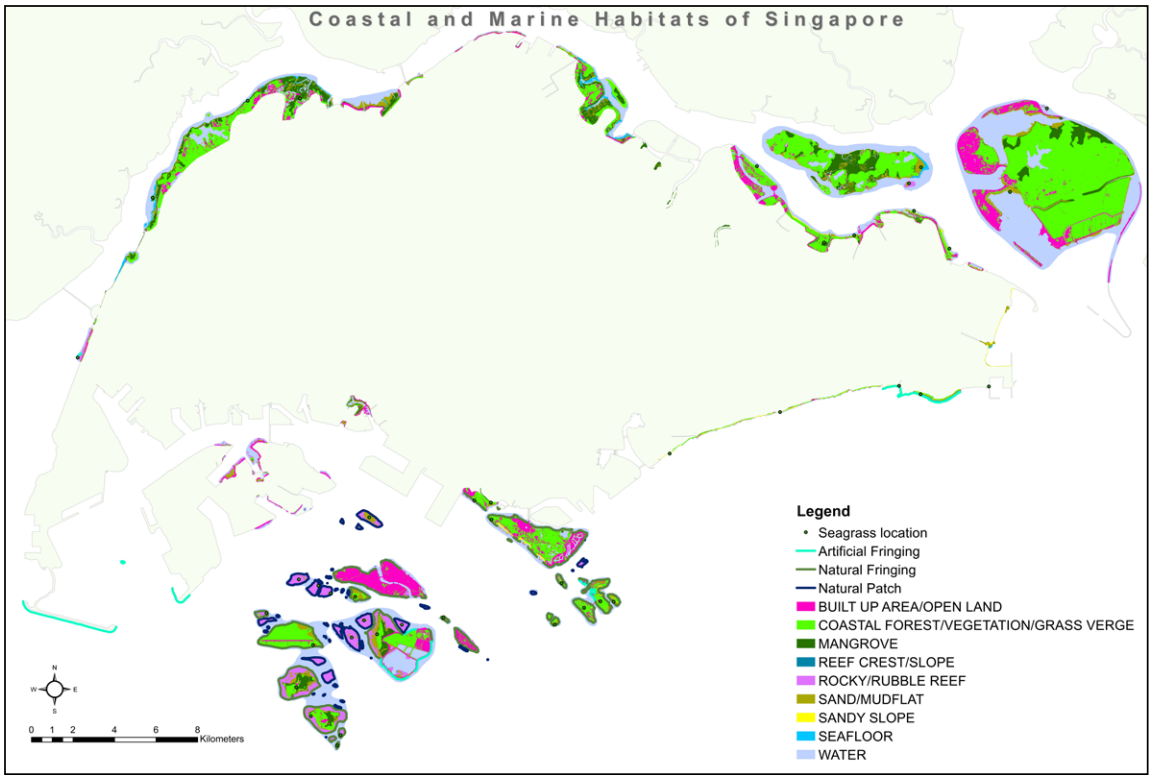
NEA also introduced new water quality guidelines in 2008. The guidelines were developed based on the World Health Organisation's water quality guidelines for recreational use. Under the guidelines, primary contact activity is only allowed when the 95th percentile Enterococcus bacteria counts in the beach water do not exceed 200 counts per 100ml. Under the annual water quality review carried out in 2017, all seven beaches (Sentosa Island, Seletar Island, Sembawang Park, Changi, East Coast Park, Pasir Ris and Punggol) monitored by NEA have met the guidelines and were graded as "Good".

10 Coastal and Marine Habitats

Located within the Sundaland biodiversity hotspot, Singapore has a rich array of native biodiversity in numerous habitats ranging from dryland forest, tall secondary forest, freshwater swamps, rocky shores, mangroves, mudflats, seagrass beds to coral reefs.

The main coastal and marine habitats in Singapore occur in the supra-tidal, intertidal and subtidal zones. **Figure 10.1** is a map showing the distribution and location of these coastal and marine habitats.

Figure 10.1: Coastal and Marine Habitats of Singapore.



Source: NParks

Singapore's waters support a good number of marine biodiversity. The northern shores and northern offshore islands are where the largest patches of mangrove forest are found. The northern shores are also characterized by vast area of sand and mudflats since it receives sediments from small rivers in Singapore and from Sungai Johor and Sungai Pulai. In the south lies sandy beaches, and

reef dominating habitats. Particularly patch reefs and fringing reefs are the common features of the southern islands. Seagrass meadows are also found in many intertidal areas both north and south of the coasts. Man-made habitats such as lagoons and seawalls also contribute towards biodiversity in Singapore's urban context. Please see the summary of Singapore's coastal and marine habitats in **Table 10.1**.

The fast pace at which development occurs in coastal cities inevitably places great strain on many coastal ecosystems. Under the tremendous stress imposed on our natural environment - a result of intensive developments arising from population growth, industrialisation and expansion of shipping and port activities - there has been a loss of natural habitats in the entire country with consequent loss of biodiversity [Refer to **Section 11.2** Anthropogenic Issues, Subsection **11.2.1** Urbanisation, Land reclamation, and Development in Coastal and Marine Areas]. This segment will look at the status of key marine habitats in Singapore - namely mangrove habitats, subtidal habitats, and intertidal habitats - including their uses, threats, and efforts to conserve and enhance the habitats.

Table 10.1: Summary of Singapore's Coastal and Marine Habitats.

Habitat	Area (km^2)	Status
Mangroves	6.59	Singapore currently has some 35 'true' mangrove plant species, which comprise more than half of the 70 'true' mangrove species found in Asia Mostly occurring along the northern shores and several off-shore islands of Singapore, the remaining forests are estimated to comprise a total area of 6.59km. The largest patches of mangrove are found at Sungei Buloh Wetland Reserve, Pulau Ubin, and Pulau Tekong. While mangrove diversity is high, species are usually represented by small population numbers. About 45 per cent of mangrove species are currently considered endangered or critically endangered. Development pressures, such as damming up of rivers (to form reservoirs) and canalisation of streams or waterways, land reclamation and natural degradation, such as coastal erosion have resulted in the reduction of mangrove forest, which in turn drive out species dependent on mangrove habitats for survival. The threat of rising sea levels may also inundate coastal areas and mangroves.
Coral reefs (sub-tidal)	1.26	Coral reefs consist of fringing and patch types, with live coral cover ranging between 10 to 60 per cent of existing reefs. There are about 250 species of hard coral from 55 genera which accounts for more than 25 per cent of the world's coral species. The reefs support over 120 species of reef fish and undetermined number of gorgonians, nudibranchs and other invertebrates. Synchronised mass spawning of corals has been observed at Singapore reefs (Guest, et al., 2002) indicating that the reefs are healthy and breeding. Threats to coral reefs are coastal development, modifications and climate change. Urban development pressure along Singapore's coast in the past decades has decreased the coral reef cover by about 60 per cent (Chou, 2016; Burke, et al., 2002).

Table 10.1: Summary of Singapore's Coastal and Marine Habitats. (cont.)

Habitat	Area (km^2)	Status
Intertidal (including seagrass, mudflats, reef flats, rocky shores, and sandy beaches)	15.84	Due to Singapore's semi-diurnal tides, the plants and animals in the intertidal areas are exposed to the air twice a day. The communities experience a wide range of stresses associated with tidal range and wave action. Rocky shores used to dominate the southwestern coastline and some southern islands of Singapore, but much of it has been reclaimed. The coastline along the northern shore consists predominantly of sandflats and mudflats. Singapore's seagrass species diversity is relatively high with 12 out of the total 23 Indo-Pacific species. The larger seagrass meadows are currently found at Chek Jawa on Pulau Ubin, Pulau Semakau and Cyrene Reef. Development pressures and coastal modifications continue to be the main threats to Singapore's remaining intertidal habitats. Sedimentation and water clarity issues stemming from coastal works also threaten the marine biodiversity in Singapore's waters.

Source: NParks

10.1 Mangrove Habitats

Mangrove forests are possibly the world's most productive type of wetland both in terms of biodiversity and ecosystem services. The mangrove ecosystem is a source of food and a nursery ground for a number of fish species. Like many parts of Southest Asia, Singapore's once extensive mangrove forests (75 km^2, ca. 200 years ago) have largely disappeared due to the need for development (Corlett, 1992). Mostly occurring along the northern shores and several off-shore islands of Singapore, the remaining forests are estimated to comprise a total area of 6.59 km^2 (Yee, et al., 2010). The largest patch of mangrove in mainland Singapore is found at Sungei Buloh Wetland Reserve (SBWR). Out of 73 true mangrove species worldwide, 22 can be found in Sungei Buloh. There are also large patches on offshore islands in both north and south of Singapore such as Pulau Ubin, Pulau Pawai, Pulau Tekong, and Pulau Semakau. [Refer to **Section 5.2.1** Nature and Parks for more details on the SBWR and Pulau Ubin locations]

10.1.1 Floral Diversity

Of the 70 "true" mangrove species in the world, 35 of them can be found in Singapore, with one species, Brownlowia argentata, considered to be nationally extinct. Many of the common mangrove species can be easily identified in our mangrove forests based on their characteristic root structures, whereas the rarer ones have a more limited distribution and sometimes only found on our offshore islands, such as the Pemphis acidula.

While mangrove diversity is high, species are usually represented by small population numbers. About 45 per cent of mangrove species are currently considered endangered or critically

endangered (**Table 10.2**). Surveys conducted from 2003 to 2007 enabled better assessment of the status of mangrove species in Singapore, including several new finds. Tumu Putih (*Bruguiera sexangula*), previously thought to be locally extinct was rediscovered recently; a small population of several Tumu Putih trees was found on a northern island for the first time in more than 50 years. In addition, two new records, Berus Mata Buaya (*Bruguiera hainesii*) and *Ceriops zippeliana* were also discovered in 2003, increasing the overall number of "true" mangroves found locally.

Table 10.2: List of Conservation Status of the 36 Mangrove Species in Singapore.

Species	Family	Conservation status*
Acanthus ebracteatus	Acanthaceae	Vulnerable
Acanthus ilicifolius	Acanthaceae	Least Concern
Acanthus volubilis	Acanthaceae	Vulnerable
Acrostichum aureum	Pteridaceae	Least Concern
Acrosticum speciosum	Pteridaceae	Least Concern
Aegiceras corniculatum	Myrsinaceae	Endangered
Avicennia alba	Acanthaceae	Least Concern
Avicennia marina	Acanthaceae	Critically Endangered
Avicennia rumphiana	Acanthaceae	Least Concern
Avicennia officinalis	Acanthaceae	Least Concern
Brownlowia argentata	Malvaceae	Nationally Extinct
Brownlowia tersa	Malvaceae	Endangered
Bruguiera cylindrical	Rhizophoraceae	Least Concern
Bruguiera gymnorhiza	Rhizophoraceae	Least Concern
Bruguiera hainesii	Rhizophoraceae	Critically Endangered
Bruguiera parviflora	Rhizophoraceae	Endangered
Bruguiera sexangula	Rhizophoraceae	Critically Endangered
Ceriops tagal	Rhizophoraceae	Vulnerable
Ceriops zippeliana	Rhizophoraceae	Endangered
Dolichandrone spathacea	Bignoniaceae	Critically Endangered
Excoecaria agallocha	Euphorbiaceae	Least Concern
Heritiera littoralis	Malvaceae	Endangered
Kandelia candel	Rhizophoraceae	Critically Endangered
Lumnitzera littorea	Combretaceae	Endangered
Lumnitzera racemose	Combretaceae	Endangered
Nypa fruticans	Arecaceae	Vulnerable
Pemphis acidula	Lythraceae	Critically Endangered
Rhizophora apiculata	Rhizophoraceae	Least Concern
Rhizophora mucronata	Rhizophoraceae	Least Concern
Rhizophora stylosa	Rhizophoraceae	Vulnerable

Table 10.2: List of Conservation Status of the 36 Mangrove Species in Singapore. (cont.)

Species	Family	Conservation status*
Rhizophora stylosa	Rhizophoraceae	Vulnerable
Scyphiphora hydrophyllacea	Rhizophoraceae	Least Concern
Sonneratia alba	Lythraceae	Least Concern
Sonneratia caseolaris	Lythraceae	Critically Endangered
Sonneratia ovata	Lythraceae	Critically Endangered
Xylocarpus granatum	Meliaceae	Least Concern
Xylocarpus moluccensis	Meliaceae	Endangered

* *Conservation status refers to local conservation status extracted from Davison et al. (2008)*
*Note: '**Nationally Extinct**' refers to species which have not been sighted in the wild for the last 30 years.*
*'**Critically Endangered**' refers to species which occur in very low numbers (less than 50)*
*'**Endangered**' refers to species which occur in low numbers (less than 250). This is no evidence of decline or fragmentation*
*'**Vulnerable**' refers to species which occur in one or a few areas (250 to 1000), but their long-term survival is not certain.*
*'**Least Concern**' refers to species that occur in many areas.*

The mangrove floral diversity tends to be richer for our offshore islands, and this is likely due to the restricted access and minimal disturbance, which encourages the mangrove forests to mature and expand. Unfortunately, this is not the case for the mangrove patches on mainland Singapore which continue to face threats from the increasing development and other anthropogenic impacts. The lack of available land for the mangroves to retreat and acclimatise to the rising sea level has also compromised the resilience of several patches of mangroves in Singapore, hence, reducing the mangrove floral diversity.

10.1.2 Faunal Diversity

There is significant faunal biodiversity that can be found in mangroves. The most conspicuous fauna are the well-studied crabs and molluscs. Our mangrove habitats have been found to contain up to 76 species of crabs, including eight rare species (Tan & Ng, 1994). Other invertebrates exist in large numbers, and they include insects and spiders that inhabit the mangroves. In a recent study in 2005, 150 new species of long-legged flies (*Dolichopodidae*) were discovered in Singapore, many of them found within mangroves (Grootaert, 2006).

In addition, reptiles, birds and mammals can also be found in mangroves. Our mangroves have been found to support over 150 species of fish, including 40 species of gobies and five species of mudskippers (Ng & Sivasothi, 1999), and over 227 bird species, which have been recorded since 1988 in SBWR alone (Gan & Li, 2009). A few bird species have adapted specifically to the environmental conditions found in mangroves. They include the Copper-throated Sunbird (*Nectarinia calcostetha*), the Mangrove Pitta (*Pitta megarhyncha*), the Mangrove Blue Flycatcher (*Cyornis rufigastra*) and the Mangrove Whistler (*Pachycephala cinerea*). Other birds, formerly residents of mangrove forests, have been able to adapt and spread into the urban areas. They

include the Sunda Woodpecker (*Picoides moluccensis*), Collared Kingfisher (*Halcyon chloris*) and the Oriental White-Eye Kingfisher (*Zosterops palpebrosa*).

10.1.3 Efforts to Conserve and Enhance Mangrove Habitats

[Refer to **Section 12.1** Ecosystem and Biodiversity Conservation, **Subsection 12.1.1** Mangrove Conservation for full details on conservation efforts]

10.2 Subtidal Habitats

Subtidal habitats comprise three main habitats: soft-bottom benthic, open sea, and coral reefs. The main focus for this section will be on coral reefs, as few studies have been conducted on soft-bottom benthic habitats due to the difficulties of studying the seafloor.

10.2.1 Coral Reef Biodiversity

In Singapore, the coral reefs are located in the southern shores and around the southern islands. Comprising of 250 species of hard corals from over 55 genera with 30 families.[45] Fringing and patch reefs are main forms of corals and grow around both the mainland and more than 40 small offshore islands (See **Figure 10.2**). The fringing reefs present in the offshore islands south of Singapore are generally narrow, with little or no zonation (Chuang, 1977). These habitats occupied an estimated 32 km^2 in 1922, and 39.85 km^2 in 1953. The present reef area (both sub-tidal and inter-tidal reefs) is about 13.25 km^2 , with decreases in intertidal and subtidal coral reef areas by over 61% and 89% respectively since 1953 (Tun, 2012). The remaining reefs are more compact and shallow due to sedimentation and unstable substrate caused by currents (Ng, et al., 2013).

Despite being constantly under stress from various factors, including climate change, Singapore's reefs still support good diversity of about 120 species of reef fish, 120 species of sponges, and undetermined number of gorgonians, nudibranchs and other invertebrates (see **Table 10.3**). So far 111 reef fish species from 30 families have been recorded. The reef in Singapore can be subdivided into three zones: the reef flat, reef crest, and reef slope. Marine life is usually richest on the reef crest with almost every type of coral is presented. The most diverse and abundance fishes on Singapore reefs are the damselfishes (*Pomacentridae*) and wrasses (*Labridae*). Other common fishes are the copperband butterfly fish (*Chelomon rostratus*) and vermiculated angelfish (*Chaetodontoplus mesoleucus*). Some reef fishes are important food fish, such as groupers (*Serranidae*), snappers (*Lutjanidae*), scads and trevallies (*Carangidae*).[46]

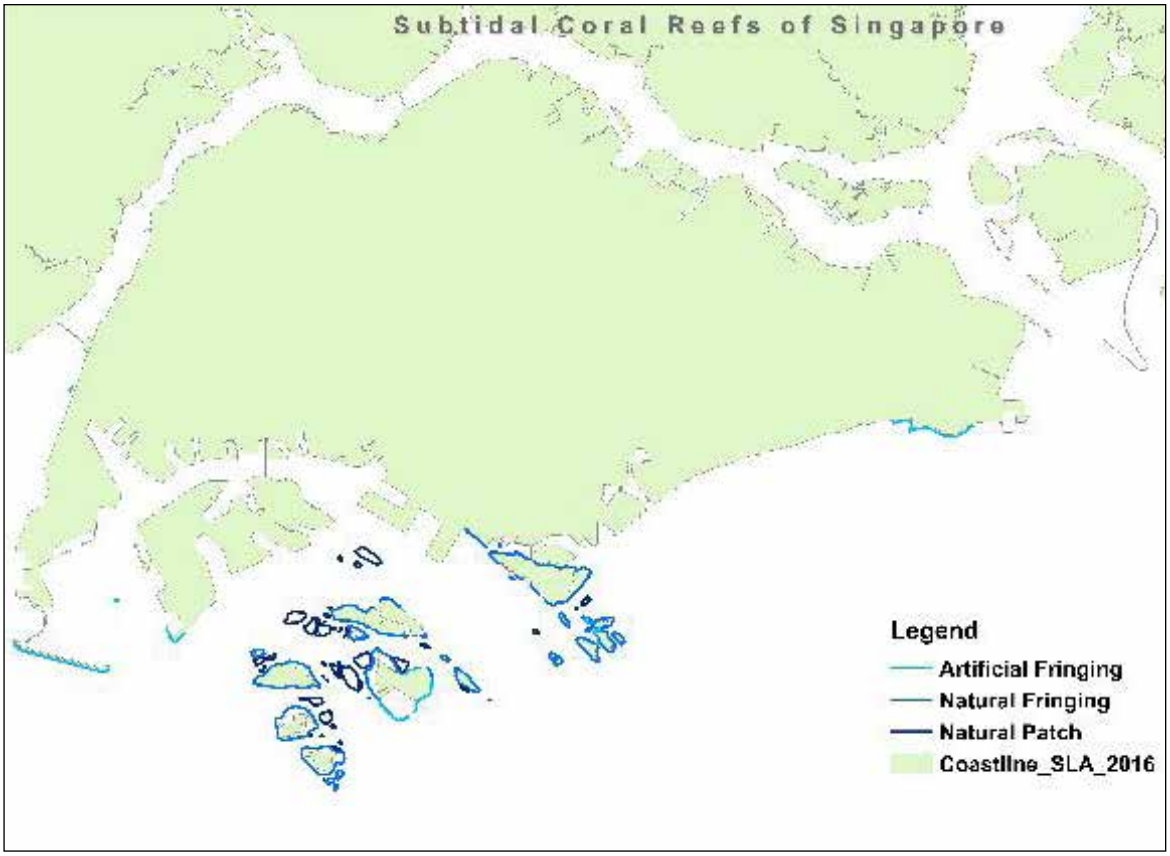
[45] See https://www.nparks.gov.sg/biodiversity/our-ecosystems/coastal-and-marine/coral-reefs
[46] See coralreef.nus.edu.sg/information/islandcover.html

Table 10.3: Number of species for various taxa found in Singapore's waters.

	Taxonomic group	No. of species	Increase in number	New Species	New Records	Rediscoveries	Extinctions
Marine invertebrates	**Crustaceans**	1,000+	8	3	4	1	0
	Molluscs	1,290	5	1	5	0	1
	Soft corals	63	32	2	30	0	0
	Hard corals	255	0	0	0	0	0
	Ascidians	32	14	0	14	0	0
	Sponges	228	3	1	1	1	0
	Echinoderms	120	1	0	1	0	0
	Marine mites	39	0	0	0	0	0

Source: 5th National Report to the CBD.

Figure 10.2: Singapore's Reef (both artificial and natural).



Giant clams are also found in Singapore's reefs. The first giant clam distribution and abundance study in Singapore was conducted in 2003, encompassing 10,000 m^2. 23 individual clams of three species (*T. squamosa, T. crocea*, and *T. maxima*) were found (Guest, et al., 2008). Early research suggests that despite high levels of sedimentation and turbidity, giant clams can survive and grow

well, and that restoring clam populations in Singapore is a feasible option. In 2011, Singapore started a giant clam restocking programme, using existing broodstock and new imported specimens. New clams was bred in early 2012 and being used for restocking (Neo & Todd, 2012).

The Indo-Pacific humpbacked dolphin is frequently seen in our waters. Past records show presence of four dolphin species and one Sirenian species.[47] The dugong is known to be present in the Johor Strait, where they inhabit the seagrass habitats in the rivers of Johor and they may occasionally swim across to Pulau Ubin and Pulau Tekong. Four species of marine turtles, namely the Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*), Green (*Chelonia mydas*), and Leatherback (*Dermochelys coriacea*) have been recorded (Ng, et al., 2011) in our waters. The Hawksbill is more commonly encountered, and there have been incidents of hatchlings found on Singapore's shores, including on the beaches at the recreational beaches at East Coast Park.

Mass synchronised spawning of corals has been observed at Singapore reefs (Guest, et al., 2002). The event takes place once a year, and usually on three or four nights after the full moon in late March or April. During the spawning event, eggs and sperms are released into the water to form free-floating larvae, which floats until they find a suitable home. Over the past decade of surveys, Singapore have recorded an average of 25 to 35 coral species spawning over the spawning period. Good spawning events indicate that the reefs are healthy and breeding.

Ongoing surveys have found numerous species that are recorded in Singapore for the first time, as well as some rediscoveries of species once thought extinct from local habitats. Most notably, researchers have recently rediscovered the Neptune's cup sponge, *Cliona patera*, in local waters (Lim, et al., 2012). Once thought to be globally extinct, this large sponge was first described from Singapore in 1820 (Hardwicke, 1820) (Hardwicke, 1822) (Low, 2012), but their large size made them desirable for collectors and they soon went extinct from local waters by the 1870s when the last two specimens found here were dredged up. There had been no sightings of living individuals of this species since 1908 in Indonesia, but dead specimens washing up on Australian shores in the 1990s gave hints that the species had yet to go extinct (Lim, et al., 2012). In March of 2011, marine biologists were conducting routine surveys when they came across an unusual looking sponge that was later identified as the Neptune's Cup (Tun & Goh, 2011). A second individual was later found just 50m distant from the first, and the two sponges are being closely monitored and their biology studied. Surveys are already turning up new insights into their biology, as their growth is much faster than previously thought (Platt, 2011).

10.2.2 Uses

Coral reefs in Singapore provides nurseries and breeding grounds for reef-associated species. Some reef fishes are important food fish, such as groupers (*Serranidae*), snappers (*Lutjanidae*),

[47] See http://www.tmsi.nus.edu.sg/mmrl/swimms.htm

scads and trevallies (*Carangidae*).[48] Fisheries in Singapore is small scale. [Refer to **Section 4.0** Fisheries and Aquaculture]

Recreational diving and snorkelling are permitted in a few reefs in Singapore's water like Pulau Hantu, Kusu Island, Pulau Jong, Sisters' Islands Marine Park. NParks developed Singapore's first dive trail located at Pulay Subar Laut or the Big Sister's Island. Two dive trails with varying depths have been established to showcase the variety of marine biodiversity and reef features present in Singapore's waters, as well as to deliver messages on conservation and responsible diving.

10.2.3 Threats

Reclamation and dredging activities, if carried out insensitively, could be a major concern for the conservation of existing coral reefs in Singapore as corals are sensitive to environmental changes, such as a high and persistent sediment load (Low & Chou, 1994) (Dikou, 2006). To date, oil spills, ship groundings and other navigation-related impacts on the reefs have been minimal. Other minor impacts to the reefs may also be generated by recreational activities, such as fishing.

Despite threats from development pressure and coastal modification, an encouraging trend has been observed at some reclaimed areas where re-colonisation of marine life occured. An example of this can be found at Changi beach, where seagrasses have re-colonised the new beach after reclamation, and coral reef recruited in the submerged rock bund at Tuas. The area now supports diverse marine life, which indicates that given time, new habitats may form on artificially created structures provided conditions are favourable.

Coral reefs around the world continue to be threatened by various factors, including climate change, and Singapore's reefs are no exception. Recent surveys and coral spawning surveys have shown bleaching sites, and a reduction in scale of mass spawning. To ensure effective conservation of our marine resources, NParks has put in place a series of proactive management measures as part of the Marine Conservation Action Plan. These include long-term and situational monitoring, applied research, technology development and community outreach and education programmes.

10.2.4 Response: Research and Conservation Efforts

Even though corals are easily damaged, they can be resilient and can recover. Efforts have been made to conserve the reefs. Particularly, a few coral nurseries been set up in the waters of Pulau Semakau, Lazarus Island and Kusu Island where small coral fragments are reared to become larger colonies for reef rehabilitation. The fragments were sourced from coral which was in the way of development activities. Recently NParks' *Plant-A-Coral, Seed-A-Reef* programme was launched for

[48] See Reef Ecology Lab http://www.coralreef.nus.edu.sg

organisations and individuals to support the habitat enhancement efforts at the Sisters' Islands Marine Park. Coral nubbins (small coral fragments) will be transplanted from a coral nursery to Reef Enhancement Units (REUs). The *Coral Reef Monitoring Programme* (CRMP) was set up to help monitor the health of the coral reefs in the islands south of Singapore, and document its biodiversity. The reef monitoring project uses internationally recognised methods, such as the line-intercept method and Reef Check to survey the benthos (community of organisms) of the reef, the reef fish community and other mobile invertebrates. The survey will give a clearer indication whether there is a decline or improvement to the state of the reefs.

A *Singapore Wild Marine Mammal Survey* (SWiMMS) programme run by the Tropical Marine Science Institute, National University of Singapore (NUS), was established in 1996 to study the ecology, behaviour, and health of local marine mammals. Distribution information is gathered through sighting programmes, boat surveys, acoustic instruments. The public, including divers, sailing clubs, ferry captains were engaged to provide sighting information.

Recently, agent-based modelling has been used to study coral larvae dispersal patterns and biological connectivity of the reef habitats. The model takes into account various factors to track larvae's behaviours to hydrodynamics, temperature, and air exposure, and predators. The research showed that Singapore's reefs are generally well connected with larvae able to flow freely among them.

[Refer to **Section 12.1.2** on other coral conservation efforts.]

10.3 Intertidal Habitats

Habitats found in the intertidal zone include rocky shores, sandy beaches, mudflats, and seagrass meadows. Due to Singapore's semi-diurnal tides, the plants and animals in the intertidal areas are exposed to the air twice a day. The constant immersion and emersion make the intertidal areas one of the most stressful environments to live in, and each of the habitats are home to fauna that are specially adapted to cope with the changing conditions of each zone.

Rocky shores dominated the southwestern coastline and some southern islands of Singapore, though much of it has been reclaimed. The coastline along the northern shore consists predominantly of sandflats and mudflats. Historically, seagrass meadows lined the sandy southeastern coastline. Many of these original habitats have since given way to extensive coastal modifications on the mainland from the early 1960s to 1980s.

10.3.1 Rocky Shores

Rocky shores are made of solid rocks and boulders, which support a diverse mix of flora and fauna in this complex habitat structure. The only remaining natural rocky shore on mainland Singapore is

found along Labrador Beach. In 2002, the stretch of rocky shore which spans about 300 m was designated as a Nature Reserve. Rocky shore habitats can also be found on some of the offshore islands, such as Sentosa and St. John's Island. Commonly found attached to the rocks are the Pacific turban snail (*Turbo bruneus*). Bristle worms and reef worms can be spotted burrowing in the sand or under rocks.

10.3.2 Sandy Beaches

In the past, continuous sandy shores were found along the southeast coast from Tanjung Rhu to Changi, with smaller areas elsewhere on the mainland and on many of the offshore islands (Corlett, 1991). Even in the 1980s, sandy shores persisted along the eastern coastline and particularly on Pulau Hantu, Pulau Sakijang Bendera and parts of Sentosa (Wee & Corlett, 1986). Due to lower nutrients and the unstable nature of the sandy substrate, this ecosystem usually supports little marine life. However, some beaches in Singapore like the Changi Beach Park hosts vast seagrass meadows. Beaches that are muddier in substrate are richer and more stable in nature and thus host more marine biodiversity, including seaweed and seagrass. Animals found in the sandy beaches are burrowing animals, such as sand bubbler crabs and ghost crabs as well as other wildlife including sea stars, sand dollars and button snails. These crabs sift through the sand and feed on organic particles. Shorebirds that form part of this ecosystem are unique and distinct from those in other areas.

10.3.3 Seagrass Dominant Habitat

Seagrass species diversity is high in Singapore, with 12 out of the 23 Indo-Pacific species found in Singapore waters, along the northern and southern parts of Singapore. These 12 species cover the genera: *Halophila, Enhalus, Thalassia, Syringodium, Halodule* and *Cymodocea*, and have been recorded at 32 sites in Singapore (Yaakub & Lim, 2010). The latest addition to this list, *Halophila decipiens*, was only discovered in Singapore waters in late 2007. Several species of seagrass were thought to have gone extinct when the extensive seagrass meadows on the southeastern shore gave way to reclamation, but populations of these species have since been rediscovered on the offshore islands. There are no recent estimates of the extent of coastline occupied by these angiosperms, but the largest meadows are known to be found on Pulau Semakau (*Enhalus acoroides* and *Syringodium isoetifoliu*m), Tanjung Chek Jawa (*Halophila spinulosa*) and Cyrene Reef (*Enhalus acoroides*, *Cymodocea serrulata*, *Syringodium isoetifolium* and *Thalassia hemprichii*). The total seagrass cover of these three main meadows was estimated to be 31.2 ha (Yaakub, et al., 2013). Smaller areas occur patchily throughout the coastline of Singapore and outlying islands, the most common (but usually never extensive) being *Halophila ovalis*. It is quite likely that there are undocumented seagrass habitats elsewhere off the shoreline.

10.3.4 Mudflats

Mudflats are coastal wetlands formed in sheltered shores where fine sediments can be deposited. Due to the deposition of detritus, the substrate in mudflats is rich in organic contents, but low in oxygen due to the water-logged soil. Mudflats are inundated by the tides twice a day. The exposed flats during low tide is an important feeding ground for many animals, especially for migratory birds. The soft mud also hosts a range of burrowing animals, typically invertebrates, such as worms, crabs, and shrimps.[49] Mudflats are usually found in the northern shores of Singapore due to high sediment load and slow currents of the Johor Strait. Some smaller flats are formed in artificial lagoon after land reclamation. The mudflat in Sungei Buloh Wetland Reserve is recognised as an important stop of the East Asian – Australasian Flyway. Pasir Ris Parks and Chek Jawa also have quite a large area of mudflats.

10.3.5 Intertidal Reef Flats

Reef flats are usually where the reefs meet the shore. At very low tide, some parts of the reef flats are exposed to air and direct sunlight. Organisms found here are usually small colonies of boulder shaped corals (*Dipsastraea*), maze corals (*Platygyra*) and sponges. Pockets of sandy areas maybe surrounded by large brown algae *Sargassum sp*. Besides floral diversity, Singapore's coastal and marine habitats also support rich faunal biodiversity.

The rich community of marine species that can be found in the intertidal areas also include echinoderms. There are four species main groups of echinoderms found in the intertidal habitats, namely sea stars (*Asteroidea*), brittle stars (*Ophiuroidea*), sea urchins (*Echinoidea*), and sea cucumbers (*Holothuroidea*), with the most common widely-occurring being the common sea star (*Archaster typicus*), which occurs in sand flats are found on sandflats or seagrass beds. The largest and most iconic sea star one is the knobbly sea star (*Protoreaster nodosus*), found mainly on Cyrene reef. Sponges are another diverse group of animals. Research undertaken on sponges in the intertidal zone by Lim Swee Cheng, a researcher with the Tropical Marine Science Institute, has identified a total of 102 species of intertidal sponges. It included 40 new records that were found in Singapore, with one species new to science. A total of 317 species of marine algae (seaweed) have has also been recorded in Singapore, of which 35 are new records (Lee, et al., 2009). A wide variety of sea anemones can also be seen on the shores. However, they are poorly studied due to lack of local and regional expertise. A recent survey recorded 16 species of common intertidal and shallow subtidal sea anemones in Singapore, of which 10 are new records for Singapore (Fautin, et al., 2015). *Polychaetes* (generally marine worms) also play a major part in the intertidal ecosystem. A survey by NParks, between 2006 and 2007, found six new records (Family *Neredidae*).

[49] https://lkcnhm.nus.edu.sg/dna/habitats/details/7 (Lkcnhm.nus.edu.sg, n.d.)

10.3.6 Threats

Development pressures and coastal modifications continue to be the main threat to Singapore's remaining intertidal habitats. Sedimentation and water clarity issues stemming from coastal works, if not mitigated, can threaten marine intertidal biodiversity. Intertidal habitats are also very prone to pollution, especially oil spills when they make landing on the shores. Shipping activities with heavy vessel-traffic in our limited sea space is another factor leading to ship groundings, and increasing the risk of collision-related oil spills and chemical spills. There is also the issue of potential Invasive Alien Species that could be brought in to Singapore's coasts from the ballast water of ships that are berthing here, as well as via cargo since a large volume of shipped goods passes through Singapore. Apart from land reclamation, natural degradation processes, such as coastal erosion, have also resulted in the reduction of intertidal habitats.

The occurrences of eutrophication of coastal waters in South East Asia have increased dramatically, with the concurrent rise in loading from domestic and industrial effluents, urban and agricultural run-off and reclamation works. Occurrences of harmful algal blooms (HABs) in Singapore have been reported. [Refer to **Section 11.0** Key Challenges in a Dynamic Environment, **Subsection 11.2.1** Urbanisation, Land for more information on the threats]

10.3.7 Response: Research and Conservation Efforts

Most of the progress being made in documenting the biodiversity here is in collaboration with overseas experts on various taxa. As such, Singapore is still currently conducting a lot of basic research on our biodiversity, hence there have been quite a number of new species discovered, and re-discoveries of species thought to have been lost. One example is the ongoing *Comprehensive Marine Biodiversity Survey* (CMBS) of the mudflats and waters off the coast of Singapore. The CMBS is a five-year national initiative that began in 2010 to take stock of our marine ecosystems, species diversity and distribution of marine life and is organised by NParks in collaboration with taxon experts from tertiary institutions, NGOs and individual enthusiasts. It is estimated that the surveys and expeditions in the Johor Straits and Singapore Strait have discovered more than 50 species that might possibly be new to science, more than 200 new records and about 10 rediscoveries for Singapore since the beginning of the CMBS.

To ensure continuous protection of the intertidal area a group of volunteers known as TeamSeagrass, conducts frequent seagrass monitoring at six different locations – Chek Jawa, Pulau Semakau, Cyrene Reef, Sentosa, Labrador Beach and Tuas. The information collected is shared with *Seagrass-Watch*, an international monitoring programme for seagrasses.

The *Intertidal Watch* is another programme that allows citizens to help. It engages the community, to document and monitor the biodiversity of intertidal habitats in Singapore. The objective is to collect quantitative data over the long term to facilitate science-based decision-making and management of Singapore's coastal areas.

10.4 Rare, Threatened and Endangered Species[50]

10.4.1 Corals, Worms and Molluscs

Recent surveys have raised the total number of known hard coral species to 250, which represents almost a third of all coral species globally. Singapore's marine biodiversity can also be expressed as having more species of corals per hectare of reef than in an equivalent area of the Great Barrier Reef. However, due to the limited availability of Singapore's marine area, absolute numbers of individuals are low.

Surveying the marine environment is inherently more difficult than that of terrestrial habitats and conservation techniques are constantly under development. Please see **Table 10.4** for the list of rare, threatened and endangered corals, worms and molluscs.

Table 10.4: Rare, Threatened, and Endangered Corals, Worms and Molluscs.

Scientific Name	Common Name	National Status	IUCN Status
Seriatopora hystrix Dana	Needle Coral	Critically Endangered (CR)	Least Concern
Stylophora pistillata Esper	Hood Coral	Critically Endangered (CR)	Near Threatened
Mopsella Spongiosa	Sea Fan	Critically Endangered (CR)	Not yet been assessed
Junceella gemmacea	Sea Whip	Endangered (EN)	Not yet been assessed
Meixneria furva	Mangrove flatworm	Data Deficient (DD)	Not yet been assessed
Pantinonemertes sp.	Mangrove Ribbon worm	Endangered (EN)	Not yet been assessed
Chaetopterus Variopedatus	Fairy Tubeworm	Endangered (EN)	Not yet been assessed
Lingula unguis Linnaeus 1758	Lamp Shell	Endangered (EN)	Not yet been assessed
Acanthopleura gemmata	-	Endangered (EN)	Not yet been assessed
Scutus unguis Linnaeus 1758	-	Endangered (EN)	Not yet been assessed
Trochus niloticus Linnaeus 1767	Pyramid Top	Vulnerable (VU)	Not yet been assessed
Turbo petholatus Linnaeus 1758	Tapestry Turban	Endangered (EN)	Not yet been assessed
Haliotis asinine Linnaeus 1758	Rhizophoraceae	Least Concern	
Haliotis clathrata Reeve 1846	Rhizophoraceae	Least Concern	
Haliotis dohrniana Dunker 1863	Rhizophoraceae	Critically Endangered	
Haliotis varia Reeve 1846	Rhizophoraceae	Endangered	
Haliotis ovina Gmelin 1791	Rhizophoraceae	Critically Endangered	
Haliotis planata Sowerby 1882	Abalone	Endangered (EN)	Not yet been assessed
Umbonium vestiarum (Linnaeus 1758)	Common Button Top	Vulnerable (VU)	Not yet been assessed
Nerita planospira Anton 1939	Flat-spired Nerite	Vulnerable (VU)	Not yet been assessed

[50] Information will be based on The Singapore Red Data Book – Threatened Plants and Animals of Singapore (2008) which is currently in the process of being updated.

Table 10.4: Rare, Threatened, and Endangered Corals, Worms and Molluscs. (cont.)

Scientific Name	Common Name	National Status	IUCN Status
Clithon oualaniensis Lesson 1831	Guamanian Nerite	Vulnerable (VU)	Least Concern
Cerithium trailli Sowerby 1835	Traill's cerith	Endangered (EN)	Not yet been assessed
Architectonica perspectiva Linnaeus 1758	Clear Sundial	Endangered (EN)	Not yet been assessed
Lambis lambis Linnaeus 1758	Spider Conch	Vulnerable (VU)	Not yet been assessed
Strombus urceus Linnaeus 1758	Black lipped Conch	Vulnerable (VU)	Not yet been assessed
Strombus atratum Röding 1798	Dark Diana Conch	Critically Endangered (CR)	Not yet been assessed
Turritella terebra Linnaeus 1758	Screw Turritella	Vulnerable (VU)	Not yet been assessed
Trivirostra oryza oryza (Lamarck 1811)	-	Endangered (EN)	Not yet been assessed
Cypraea tigris Linnaeus 1758	Tiger Cowrie	Endangered (EN)	Not yet been assessed
Cypraea arabica Linnaeus 1758	Arabian Cowrie	Vulnerable (VU)	Not yet been assessed
Cypraea annulus Linnaeus 1758	Golden-ringed Cowrie	Endangered (EN)	Not yet been assessed
Phalium glaucum Linnaeus 1758	Grey Bonnet	Endangered (EN)	Not yet been assessed
Murex trapa Röding 1798	Rare-spined Murex	Vulnerable (VU)	Not yet been assessed
Chicoreus ramosus Linnaeus 1758	Ramose Murex	Endangered (EN)	Not yet been assessed
Harpa major Röding 1798	Major Harp	Endangered (EN)	Not yet been assessed
Oliva sericea Röding 1798	Orange-mouth Olive	Vulnerable (VU)	Not yet been assessed
Conus textile Linnaeus 1758	Textile Cone	Vulnerable (VU)	Least Concern
Conus consors Sowerby 1833	Singed Cone	Vulnerable (VU)	Least Concern
Cymbiola nobilis Lightfoot 1786	Noble Volute	Vulnerable (VU)	Not yet been assessed
Amphidromus atricallosus perakensis Fulton1901	Green Tree Snail	Endangered (EN)	Not yet been assessed
Amphidromus inverse Müller 1774	Brown Tree Snail	Critically endangered (CR)	Not yet been assessed
Peronina alta Plate 1893	-	Data Deficient (DD)	Not yet been assessed
Ellobium aurismalchi Linnaeus 1758	Mangrove Land Snail	Critically endangered (CR)	Not yet been assessed
Tridacna squamosa Lamarck 1819	Fluted Giant Clam	Endangered (EN)	Lower Risk/conservation dependent
Atrina vexillum Born 1778	Indo-pacific Fan Shell	Vulnerable (VU)	Not yet been assessed
Pinna bicolor Gmelin 1791	Two-Coloured Fan shell	Vulnerable (VU)	Not yet been assessed
Brechites penis Linnaeus 1758	Waterspout Shell, watering pot shell	Presumed Nationally extinct (NE)	Not yet been assessed

10.4.2 Migratory Birds

Table 10.5 provides a list of rare, threathened and endangered migratory birds. The protection of the feeding and breeding habitats of wild birds is critical to prevent extinction.

Table 10.5: Rare, Threatened, and Endangered Migratory Birds.

Scientific Name	Common Name	National Status	IUCN Status
Oceanodroma monorhis	Swinhoe's Storm Petrel	Globally near-threatened species	Near Threatened
Leptoptilos javanicus	Lesser Adjutant	Critically endangered (CR)	Vulnerable
Egretta eulophotes	Chinese Egret	Critically endangered (CR)	Vulnerable
Fregata andrewsi	Christmas Frigatebird	Critically endangered (CR)	Critically Endangered
Anhinga melanogaster	Oriental Darter	Globally near-threatened species	Near Threatened
Clanga clanga	Greater Spotted Eagle	Critically endangered (CR)	Vulnerable
Limnodromus semipalmatus	Asian Dowitcher	Globally near-threatened species	Near Threatened
Limosa limosa	Black-tailed Godwit	Globally near-threatened species	Near Threatened
Limosa lapponica	Bar-tailed Godwit	Globally near-threatened species	Near Threatened
Numenius arquata	Eurasian Curlew	Globally near-threatened species	Near Threatened
Numenius madagascariensis	Far Eastern Curlew	Critically endangered (CR)	Endangered
Tringa guttifer	Nordmann's Greenshank	Critically endangered (CR)	Endangered
Tringa brevipes	Grey-tailed Tattler	Globally near-threatened species	Near Threatened
Calidris tenuirostris	Great Knot	Critically endangered (CR)	Endangered
Eurynorhynchus pygmeus	Spoon-billed Sandpiper	Critically endangered (CR)	Critically Endangered
Terpsiphone atrocaudata	Japanese Paradise Flycatcher	Globally near-threatened species	Near Threatened
Emberiza aureola	Yellow-breasted Bunting	Critically endangered (CR)	Critically Endangered

10.4.3 Fishes

The local populations of marine and brackish-water fish, unlike their freshwater counterparts, are not geographically restricted to Singapore's coastal waters, and it is difficult to determine their status of abundance. Due to their commercial significance, the fishes are highlighted.

Table 10.6: Rare, Threatened, and Endangered Marine Species.

Scientific Name	Common Name	National Status	IUCN Status
Hippocampus spp.	Seahorses	Vulnerable	Not yet been assessed
Amphiprion clarki	Clownfish/Anemone fishes	Vulnerable	Not yet been assessed
A. Ocellaris	Clownfish/Anemone fishes	Vulnerable	Not yet been assessed
A. Polymnus	Clownfish/Anemone fishes	Vulnerable	Critically Endangered

10.4.4 Echinodermata

The *echinoderm* fauna in Singapore waters is relatively rich, with two main areas in Singapore standing out as being hotspots for Echinoderms (and other organisms). These are the southern islands with their fringing coral reefs and patch reefs, and the other area at the eastern end of Johor straits, in the seabed and the remaining natural intertidal shores of the Changi-Ubin-Tekong area.

Table 10.7: Rare, Threatened, and Endangered *Echinodermata*.

Scientific Name	Common Name	National Status	IUCN Status
Iconaster longimanus	Icon Star	Vulnerable (VU)	Not yet been assessed
Protoreaster nodosus (Linnaeus 1758)	Giant Knobbly Seastar	Endangered (EN)	Not yet been assessed
Anthenea aspera Döderlein 1915	Cake Star	Vulnerable (VU)	Not yet been assessed
Luidia maculate Müller & Troschel 1842	-	Endangered (EN)	Not yet been assessed
Luidia penangensis de Loriol 1876	-	Vulnerable (VU)	Not yet been assessed
Archaster typicus Müller & Troschel 1840	Common sandstar	Vulnerable (VU)	Not yet been assessed
Formia molnilis Perrier 1869	Peppermint Sea Star	Vulnerable (VU)	Not yet been assessed
Cryptasternia sp.	-	Vulnerable (VU)	Not yet been assessed
Euretaster insignis (slanden 1882)	-	Endangered (EN)	Not yet been assessed
Echinaster callosus Marenzeller 1895	-	Endangered (EN)	Not yet been assessed
Prionocidaris baculosa (Lamarck 1816)	-	Vulnerable (VU)	Not yet been assessed
Chaetodiadema granulatum Mortensen 1903	-	Endangered (EN)	Not yet been assessed
Asthenosoma varium Grube 1868	Fire Urchin	Vulnerable (VU)	Not yet been assessed
Echinodiscus truncates Agassiz 1841	Key-hole sand Dollar	Vulnerable (VU)	Not yet been assessed
Laganum depressum Lesson 1841	Sand Dollar	Vulnerable (VU)	Not yet been assessed
Holothuria leucospilota (Brandt 1835)	Black sea cucumber	Vulnerable (VU)	Not yet been assessed
Holothuria scabra Jaeger 1833	Common Sea Cucumber, Sandfish	Vulnerable (VU)	Endangered
Stichopus ocellatus Massin et al. 2002	Ocellated Sea Cucumber	Vulnerable (VU)	Data Deficient
Phyllophorus parvipedes Clark 1914	Tennis-ball Sea Cucumber	Vulnerable (VU)	Not yet been assessed
Stephanometra oxyacantha (Hartlaub 1890)	Feather Star	Vulnerable (VU)	Not yet been assessed
Himerometra robustipinna (carpenter 1881)	Feather Star	Data Deficient (DD)	Not yet been assessed
Euryale aspera Lamarck 1816	Basket Star	Data Deficient (DD)	Not yet been assessed

10.4.5 Reptile

The conservation status of many species cannot be ascertained because of this. Since many species thrive only in pristine habitats, the rapid loss of local rainforest and mangrove will undoubtedly threaten their survival. Due to their secretive habits, the majority of Singapore's 55 extant native snake species are rarely seen, and would thus fall into the endangered category.

Table 10.8: Rare, Threatened, and Endangered Reptiles.

Scientific Name	Common Name	National Status	IUCN Status
Laticauda colubrine (Schneider 1799)	Amphibious Sea Snake, Yellow-lipped Sea Krait	Endangered (EN)	Not yet been assessed
Crocodylus porosus Schneider 1801	Estuarine, Saltwater Crocodile	Critically Endangered (CR)	Lower Risk/least concern
Eretmochelys imbricata (Linnaeus 1766)	Hawksbill Turtle	Critically Endangered (CR)	Critically Endangered
Chelonia mydas (Linnaeus 1758)	Green Turtle	Critically Endangered (CR)	Endangered

10.4.6 Conservation effort

Singapore became a member of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) in November 1986. CITES is an international agreement that ensures that no wildlife will not be threaten with extinction due to trade. The *Endangered Species (Import and Export) Act* gives effect to CITES to manage the import, export, or re-export of endangered species in Singapore. Anyone who imports, exports or re-exports CITES specimens without relevant CITES permits commits an offence under the Act and shall be liable to a fine of up to S$50,000 per scheduled species (not exceeding an aggregate of S$500,000) and/or up to two years' imprisonment.

11 Key Challenges in a Dynamic Environment

11.1 Drivers Towards a More Resilient Singapore

Last year, marked the 30th anniversary of the Singapore River Clean-up and its radical transformation from an open sewer to a thriving recreation spot and clean source of drinking water. Singapore's early days as a young nation saw it grappling with severe environmental issues like air, water, and land pollution.

Whilst the challenges the nation faces today are vastly different from the 1960s, the priority remains the same - catering for economic growth and a good quality of life, maintaining a clean and green environment, whilst optimising our usage of resources. This section discusses the pressures and drivers for change in the context of the myriad of global and local challenges facing Singapore today. For the purposes of this report, they have been broken down between anthropogenic issues, and natural hazards.

In a global context, the most pressing environmental issues would be those of climate change and pollution. However, in local context, the most unyielding challenge faced by a land-scarce Singapore, is that of the proper management in the face of urbanisation.

11.2 Anthropogenic Issues

11.2.1 Urbanisation, Land Reclamation, and Development in Coastal and Marine Areas

Half of the world's population currently live in cities, and this is projected to rise to 68% of the global population by 2050 (UN DESA, 2018). Singapore, as a small island city-state, which lacks a clear rural-urban divide, is no stranger to the challenges that arise from a rapid pace of industrialisation and urbanisation.

In order to cater for its increasing population without compromising on quality of living, Singapore has devoted significant resources to counter its land and resources scarcity. Since the 1960s, Singapore has undertaken land reclamation and coastal development projects to accommodate the population increase and economic activity needed to sustain the country.

11.2.1.1 Habitat Loss and Degradation

Singapore's physical landscape has undergone dramatic transformation since Independence, as the city-state develops to meet the needs of a growing nation. Habitat loss and degradation continue to be threats to biodiversity. [Refer to related **Section 10** Coastal and Marine Habitats] Despite the vast number of species that have been recorded in Singapore, there has been substantial loss of original biodiversity, in both marine and terrestrial ecosystems. For example, of 2,145 native plant species have been recorded for Singapore, 29.8 per cent are thought to have become globally or locally extinct (Kwek, et al., 2009). The predominant cause of these extinctions is most likely rapid and large-scale land use change and resultant habitat destruction; initially through deforestation for agriculture, and later, for urban development (Brook, et al., 2003). Habitat loss, fragmentation and modification cause extinctions by decreasing the availability of breeding and feeding sites, increasing predation, soil erosion and nutrient loss, by limiting dispersal, and by enhancing edge effects.

In the 19th century, much of Singapore's biodiversity was lost due to extensive deforestation to make way for cultivation of economic crops, such as cloves, gambier, nutmeg, rubber and coconuts (Corlett, 1992). Over 1920s to 1990s, there has been a drastic reduction of Singapore's coastal and marine ecosystems, particularly many mangrove forests and coral reefs have disappeared. Estimates of reductions for mangrove forests stand at 7,500 ha (ca 200 years ago to the present area of about 735 ha) (Yang, et al., 2011). Around 60 per cent of total coral reef area – fringing and patch reefs around both the main island and more than 60 offshore islands – has been lost. More recently, a comparison between 1993 and 2011's topographical map showed a decrease in total land area of sand/mudflats and intertidal coral reef flats (Lai, et al., 2015) , largely due to land reclamation.

To conserve and rehabilitate the remaining marine biodiversity, Singapore has adopted a balanced approached to development and conservation, including conservation of coastal and marine habitats. Apart from action plans and strategies (National Biodiversity Strategy and Action Plan, Sustainable Singapore Blueprint, Nature Conservation Masterplan, Marine Conservation Action Plan), an inter-agency committee was formed to carry out surveys, conduct research projects, and build capacity in integrated coastal management. This committee later acts as the coordinating body for IUCM implementation in Singapore. Coastal and marine development projects that might affect biodiversity are also screened through an inter-agency administrative process. In this process, projects identified that may have significant impacts will be required to conduct an impact assessment and incorporate mitigation measures where relevant. [Refer to **Section 13.3.4** Singapore's Nature Conservation Masterplan (NCMP) and National Biodiversity Strategy and Action Plan (NBSAP) for conservation strategy; **Section 13.2.3** for the The Technical Committee on Coastal and Marine Environment (TCCME) for IUCM coordinating body; and **Section 13.2.1** on Environmental Impact Assessment.

11.2.1.2 Sedimentation

For almost three decades, the coral reefs of Singapore have been subjected to high sediment levels. The increased amount of particulates in the water reduces light penetration, having a knock-on effect on productivity of photosynthesising organisms like seagrasses, other aquatic plants, and corals. Since 1980s, most coral reefs have experienced a loss of around 60% in live coral cover (Hilton & Manning, 1995). Recent studies revealed that Scleractinian corals, as well as other reef-related biota, still show good species growth in the upper reef slope zone (Chua & Chou, 1991) (Goh & Chou, 1991). However, the lower reef slopes and reefs flat do not support much coral cover (Chou & Wong, 1984).

To tackle the problem of silty discharge, building contractors are required to implement best practices on Earth Control Measures (ECM) at work sites. They will need to submit an ECM plan, designed and endorsed by a Qualified Erosion Control Professional, to PUB and implement the ECM plan before the start of any construction work. Environmental impact assessment (EIA) and mitigation measures are also required for coastal activities that might potentially result in negative impact, elevated sedimentation or sediment plumes.

11.2.1.3 Increased Likelihood of Flash-flooding – Alterations in Hydrology / Surface Run-off

As a tropical island, Singapore is naturally prone to intense storms. We generally get an annual rainfall of about 2,400mm. The cost of damage during localised flooding is rising despite the fact that Singapore has experienced only four major floods in the last 60 years, and was rated the least vulnerable to climate impact of the 11 major coastal cities in Asia in 2009 Asian Mega-Cities Report.

Stormwater management has become challenging due to upward trends in rainfall intensity and increasing frequencies of heavy rain events, which are compounded by growing urbanisation– hastening surface runoff due to more extensive impervious cover and resulting in an increase in peak surface runoff over shorter periods. [Refer to related **Section 11.3.3** Extreme Weather Events - Flash Flooding]

In the 1960s and 1970s, Singapore experienced widespread flooding during monsoon seasons, especially in Chinatown and Little India areas, which were built on relatively low-lying land. The increase in paved surfaces due to intensification of developments coupled with land that was barely above high tide level led to flooding almost every time heavy rain coincided with high tide. To address this, PUB came up with solutions to provide for better stormwater drainage. [Refer to **Section 12.3.1** for the Flood Control Measures / Drainage Design and Flood Protection Measures and Management.]

11.2.2 Pollution

There are a wide range of pollutants and pollution sources that potentially affect the coastal and marine environment. Studies have shown that some 80 per cent of pollution is derived from land-based sources. Pollution from these land-based sources, if not properly treated, finds its way through drains, rivers and finally to the sea. In order to ensure that the debris does not make its way to the sea, rivers and drains in Singapore are closely monitored and cleared of debris regularly. The pressures affecting Singapore include sewage, industrial effluents, urban/river runoff, nutrients, oil spills, marine litter, polycyclic aromatic hydrocarbons (PAHs), sediments and physical alteration of coastal and marine habitats. The following subsections highlight land-based and ship-source pollution that have the potential to damage the coastal environment.

11.2.2.1 Ship-source Pollution

Singapore is the busiest port in the world in terms of shipping tonnage, with more than 130,000 vessel calls annually. Singapore is also one of the world's top bunkering ports and the world's third-largest petrochemical refiner. At the same time, Singapore is committed to the prevention of pollution from ships, and is party to all six Annexes of the IMO MARPOL convention, the main international convention covering prevention of pollution of the marine environment by ships.

a. Maritime Accidents and Oil Pollution

[Refer to **Section 6.8** Preparedness, Response and Co-operation, **Subsection 6.8.1** Marine Emergency Action Procedure]

b. Wastewater Discharges and Ballast Water Management

Ballast water discharges can have a negative impact on the marine environment as it typically contains a variety of living organisms, which are potentially invasive species that can cause extensive ecological and economic damage to aquatic ecosystems. MPA administers the Prevention of Pollution of the Sea Act (PPSA), with specific regulations addressing Pollution from Ships as well as Ballast Water Management. The IMO MARPOL convention is implemented under the PPSA and its associated regulations, which provides powers to impose fines of up to $20,000 or imprisonment terms of up to two years, or both, (for oil or oily mixtures discharges – fines of up to $1 million or imprisonment terms of up to two years, or both) for non-compliances. [Refer to **Section 6.8** Preparedness, Response and Co-operation, **Subsections 6.8.2** Pollution from ships, and **6.8.3** Ballast water management].

11.2.2.2 Land-based Sources of Pollution

Singapore has seen a significant increase in solid waste output over the years, with the amount of waste sent for disposal rose from 1,260 tonnes per day in 1970 to about 8,440 tonnes per day in 2017. Over and above this, Singapore's limited land availability presents waste disposal challenges that must address any potential deficiencies in collection and treatment facilities for solid waste, toxic industrial wastes and wastewater; which may be potentially detrimental to human health and/or the environment and which require special management, treatment and disposal.

NEA ensures that solid waste is properly collected and treated and that there is no illegal dumping of solid waste and toxic industrial wastes. PUB administers the *Sewerage and Drainage Act* (SDA) and the *Sewerage and Drainage (Trade Effluent) Regulations* that regulate the sewerage system and the treatment and discharge of industrial wastewater into public sewers respectively.

Manufacturing industries, such as oil refining, petrochemicals, biofuels, and shipyards situated along the coast can cause serious pollution if their operations are not properly controlled and managed. Cooling water from power plants and industrial facilities may cause thermal pollution, which can potentially affect corals and other marine life. Industrial effluent may also contain toxins, heavy metals and other pollutants and traces of these may remain even after treatment.

Pollution prevention starts at the planning stage and appropriate zoning of land uses. For example, before EDB brings in new industries, there are close consultations with other ministries to ensure that environmental considerations are incorporated at various stages of land use planning, development control and planning, so as to minimize the impact of pollution on the surrounding land use. Discussions are held with NEA to establish if the pollution that ensues from new industries can be controlled. Only industries that can demonstrate their ability to manage, store and dispose of their toxic wastes effectively are allowed to be established here. [Refer to **Subsection 12.2** Pollution Reduction and Environmental Protection]

11.2.2.3 Marine Litter

Around 60-80% of all marine litter is plastic (Moore, 2008). They can be categorized into mainly two types: 1) End-user products (plastic bottles, bags, packaging etc.); 2) Small resin (Polypropylene and polyethylene) granules or pellets that are used in industries to manufacture plastic products (Azzarello & Vleet, 1987).

Two categories of plastic litter can be classified as either 'Macro' and 'Micro'-plastics, with the duration required for them to completely biodegrade is probably in the hundreds of years (Moore, 2008). Furthermore, the buoyant characteristic, combined with its slow biodegrading nature, leads to tremendous dispersal potential in our oceans.

Marine mammals, turtles, seabirds, and crustaceans are especially vulnerable to plastic marine litter. A total of 267 species of marine organisms worldwide have been known to have been affected by plastic debris, and the number continues to grow as smaller organisms are assessed (Moore, 2008). The amount of plastic found in SE Asian marine litter is comparable to global figures. In the first research of its kind in the region done by Ng and Obbard (2006), Singapore's coastal region has particles of polyethylene, polypropylene, polystyrene, nylon, polyvinyl alcohol and acrylonitrile butadiene styrene, in seawater and sediment particles (Ng & Obbard, 2006). They considered these microplastics to be most likely derived from broken down larger debris, especially the samples from public beaches where end-user plastic litter is common.

Efforts to track the mounting issue of marine trash are garnering traction as surveys are underway with the aim of providing higher resolution data, to uncover the state of microplastic pollution in Singapore waters. The International Coastal Cleanup Singapore in partnership with NParks, is conducting a two-year study involving monthly sampling, to monitor debris and microplastics at nine coastal sites.

To address the issue of marine plastic debris and microplastics, Singapore has in place stringent domestic legislations and regulations on pollution control and waste management. MEWR contributes to the prevention and reduction of marine pollution through (i) management of pollution from land-based sources; and (ii) management of water pollution and quality in inland water bodies and coastal areas. [For information on how NEA combats the issue plastic waste management, please Refer to **Section 12.2.2** and **13.4.2** for examples of Plastic Waste Management Initiatives]

11.2.3 Eutrophication and Harmful Algal Blooms (HABs)

In recent years, Harmful Algal Blooms (HAB) have occurred with greater frequency in Singapore waters. In December 2009, one of the first cases of fish deaths due to algal blooms was reported, affecting 200,000 fish from fish farms in the Johor Strait, off the northern coast of Singapore. While farmed fish were affected, no wild fish were observed to be harmed. Whereas for the two other incidents, that occurred in 2014, both farmed fish and wild fish were affected. Some examples of marine wildlife that were affected were frogfish, horseshoe crabs, and pufferfish that were found washed up on nearby shores (Siau, 2015). HAB is a complex natural phenomenon. The

increasing severity and frequency of HAB events is thus a cause for concern and could construe a potential threat to Singapore's marine biodiversity. Eutrophication events and high levels of sediments in the water, paired with global warming, are some potential causes cited for the increase in frequency of HABs.

11.3 Natural Hazards and Climate Change

Despite Singapore's location in Southeast Asia, fortuitously, it lies outside of the Pacific Rim of Fire and its sheltered position allows the country to be at low risk from being directly impacted by major natural disasters, such as typhoons, volcanic eruptions, and earthquakes. However, the country is more exposed and vulnerable to the effects of climate-related disasters.

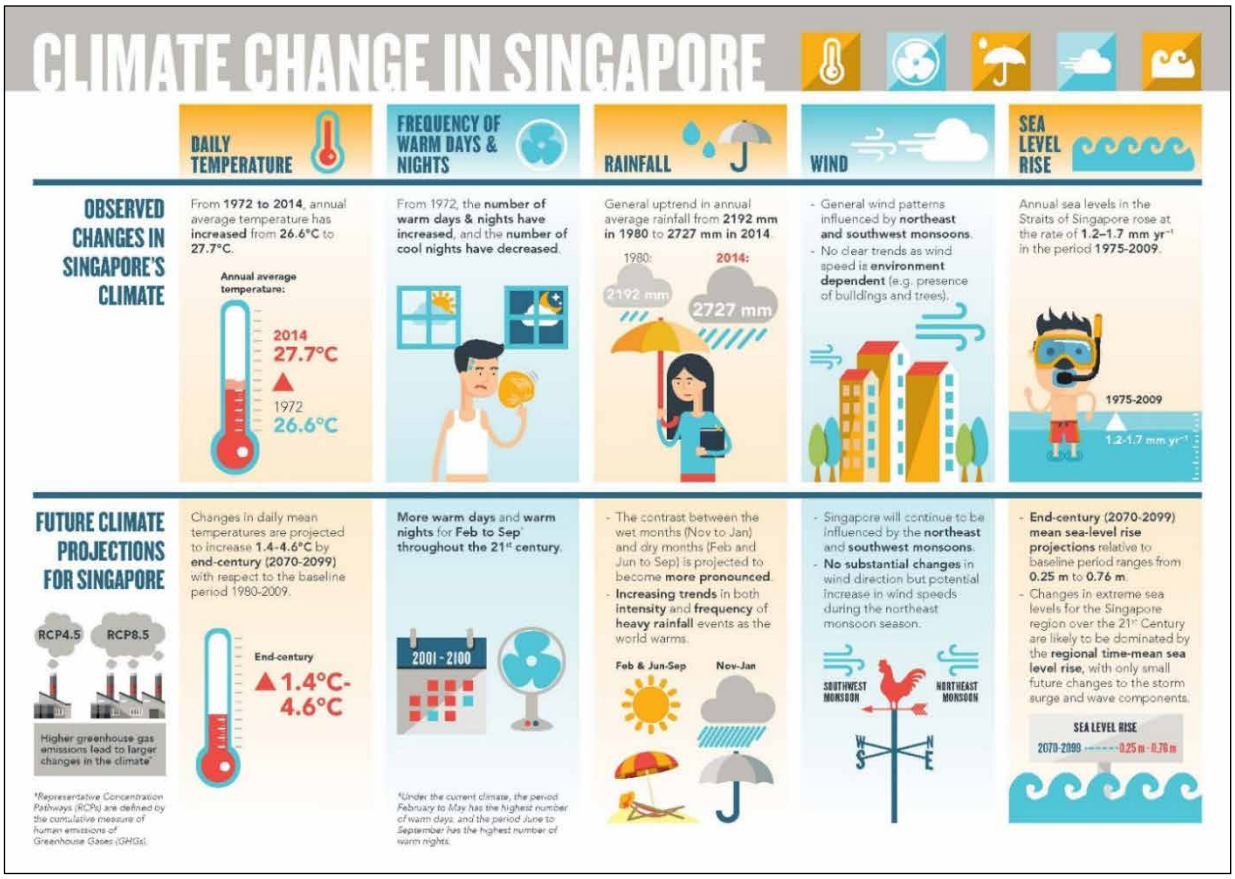
In particular, as a low-lying island state, Singapore is also vulnerable to the impacts of sea-level rise (SLR). Much of Singapore lies within 15m above the mean sea level; and the ground level of about 30% of Singapore is less than 5m above the mean sea level.[51] Changes and variability to our rainfall patterns could also present significant challenges for the management of our water resources and drainage systems. Weather uncertainties, such as dry spells, may affect the reliability of Singapore's water supply, while sudden episodes of intense rainfall could overwhelm our drainage system and lead to flash floods. With climate change, these extreme weather events could increase in both frequency and intensity.

The Centre for Climate Research Singapore (CCRS) published the *2nd National Climate Change Study* in 2015. This was based on high-resolution downscaled projections of global climate models used to inform the Intergovernmental Panel on Climate Change (IPCC) AR5. Singapore is projected to experience higher mean sea levels, higher temperatures, with more extreme weather (intense rainfall or extended dry-spells). **Figure 11.1** summarises these projections.

Singapore's mitigation and adaptation action plans can be found in *Climate Action Plan: Take Action Today, for a Sustainable Future*. The key strategies to reduce carbon emissions include energy efficiency across all sectors, increasing deployment of clean energy, development and deploying low-carbon technologies, and encouraging collective climate action. The adaptation plans cover coastal protection, water resources and drainage, biodiversity and greenery, public health and food security, network infrastructure and building structures and infrastructure.

[51] See https://www.straitstimes.com/singapore/as-sea-levels-rise-singapore-prepares-to-stem-the-tide.

Figure 11.1: Climate Change in Singapore.



11.3.1 Sea-Level Rise and Coastal Erosion

The Intergovernmental Panel on Climate Change (IPCC) projected that by the end of the 21st century, global average sea-level rise (SLR) may reach 0.26 to 0.55 m under the best-case scenario (i.e., greenhouse gas (GHG) emissions are reduced by 70%), or nearly 1 m if GHG emissions continue to increase (Church & Clark, 2013).

For Singapore, the only real option is to protect its shorelines. The Government has been preparing to protect Singapore against the impact of SLR and natural processes like coastal erosion.

To cater for long-term SLR, the minimum land reclamation level for newly reclaimed lands was raised from 3m to 4m above the mean sea level in 2011. To help protect against erosion, about 70 to 80 per cent of Singapore's coastline already have hard walls or stone embankment. The remaining areas retain natural cover, such as beach or mangroves. The Government inspects these structures regularly for their structural integrity and intended functionality. If needed, these structures will be reinforced to protect our coast from erosion. Singapore has ensured that the design of the drainage system caters for impacts of climate change, which includes the widening

and deepening of the drains to cater for the increase in rainfall intensity, and the construction of tidal gates and pumping stations to mitigate the effects of rising sea level. Works have also been carried out to protect our reservoir systems against the rise in sea level due to climate change. These include raising of dikes around the reservoirs and raising the height of the tidal gates. [Refer to **Section 12.3** Climate Change Mitigation and Adaptation]

Climate science is constantly evolving, which means that projections on mean sea-level rise may change. Given this uncertainty, our national framework for coastal protection needs to remain flexible and dynamic to accommodate the latest projections in sea-level rise. BCA is conducting a Coastal Adaptation Study (CAS), which will develop a national framework for Singapore's long-term coastal protection needs. [Refer to **Section 12** Addressing Sustainable Development Aspects (SDS-SEA and SDGs), **Subsections 12.3.1** Climate-resilient infrastructure for more details on actions taken to address the issue of Natural Hazards and Climate Change]

11.3.2 Transboundary Haze Pollution

Transboundary haze pollution remains a problem in the ASEAN region. It is primarily caused by land and forest fires, which arise when open burning is carried out to clear land. It can be made worse by dry seasons, changes in wind direction, and when precipitation is low. Its impact is global, given the vast amount of greenhouse gases released when biomass is burnt. Prevailing winds can sometimes carry the haze to Singapore, particularly during the Southwest monsoon season.

Singapore saw its worst haze episodes in 2013 and 2015, with unhealthy levels of air pollution leading to school closures and air and sea traffic disruptions. The 2015 episode coincided with El Niño, when the weather became dry with reduced rainfall and rising temperatures (Tan, 2018). Transboundary haze pollution affects human health adversely and can also cause significant disruptions to businesses and livelihoods. Singapore continues to adopt a multi-faceted approach via regional cooperation and domestic measures to address this complex problem.

11.3.3 Extreme Weather Events - Flash Flooding

NEA has reported an increase in the number of rain days per annum of 1.5 days per decade, with an increase of average rainfall per month from 96 mm in 1980 to 117 mm in 2012. This increasing rainfall intensity is brought about by changing weather patterns and can exceed the design capacity of the drainage system, resulting in flash flooding. [Refer to **Section 11.2.1.3** Flash-flooding - Alterations in Hydrology / Surface Run-off]

PART 5

GOVERNANCE STRUCTURE AND MECHANISMS SUPPORTING BLUE ECONOMY DEVELOPMENT

12 Addressing Sustainable Development Aspects to Ensure Blue Economy

To show Singapore's commitment to sustainable development, Singapore undertook our first Voluntary National Review at the 2018 High-Level Political Forum on Sustainable Development.

12.1 Ecosystem and Biodiversity Conservation

As party to the CBD, Singapore has an obligation to develop its own set of strategy and action plans to conserve biodiversity. In 2009, Singapore's first *National Biodiversity Strategy and Action Plan* (NBSAP) was developed and launched. Titled "*Conserving Our Biodiversity*", this national document provides a framework to guide biodiversity conservation efforts in Singapore. It aims to promote biodiversity conservation, keeping in mind that as a densely populated country with no hinterland, we have to adopt a pragmatic approach to conservation and develop unique solutions to our challenges. Overall, the NBSAP intends to establish both policy frameworks and specific measures to ensure better planning and co-ordination in the sustainable use, management and conservation of our biodiversity.

The NBSAPs also come under the *Nature Conservation Master Plan* (NCMP), which consolidates, coordinates and further strengthens Singapore's biodiversity conservation efforts [Please refer to **Section 13.3.4** Singapore's Nature Conservation Masterplan (NCMP) and National Biodiversity Strategy and Action Plan (NBSAP) for full description].

The section below highlights a few of the key examples and initiatives that address both SDG 14: Life below Water and SDG 15: Life on Land – on habitat restoration and enhancement efforts, as covered under the first two key thrusts of the NCMP.

12.1.1 Mangrove Conservation

In order to ensure the survival of our mangrove forests, human intervention is often required. While there is legal protection over mangrove forests deemed to be of high biodiversity significance - such as Sungei Buloh Wetland Reserve - there are also many projects and programmes aimed at protecting and conserving Singapore's mangrove habitats.

One such project is the Coastal Protection and Restoration of Mangrove Biodiversity at Pulau Tekong. The innovative approach here involves a combination of hard and soft engineering solutions to arrest the coastal erosion and restore the mangrove areas at the northeastern coastline

of the island. In addition, NParks has been working with different communities such as the non-government organisations, private companies and schools to conserve and enhance Singapore's mangrove biodiversity, as well as to increase public awareness towards the conservation of Singapore's mangroves through the numerous public talks and guided walks. The positive working relationship between NParks and the multiple stakeholders are often crucial in determining the success of their programmes or project. The Pulau Tekong coastal protection project is an epitome of a successful public private partnership which gathered experts from various fields for the different components of the project.

Figure 12.1: Coastal Protection and Restoration of Mangrove Biodiversity at Pulau Tekong.

An example of a ground-up initiative is the Restore Ubin Mangrove (RUM) group, which is supported by the NParks to restore mangrove forests in Pulau Ubin using the Ecological Mangrove Restoration (EMR) method (https://www.nparks.gov.sg/news/2015/6/factsheet-updates-on-the-ubin-project-initiatives-june-2015).

The species recovery programme, which is part of the Nature Conservation Masterplan, will focus on species that are endemic, native or critically endangered, i.e., *Bruguiera hainesii*, and aims to increase the populations of these species and help them survive adverse environmental changes.[52]

[52] NParks, 2015.

Research collaborations with institutions are also regularly carried out to expand the existing knowledge, and allow informed decision-making and better protection over these vulnerable mangrove areas in Singapore. Past research topics include "Mangrove Insects as Indicators of Habitat Quality", "Mangrove Propagule Dispersal in Singapore's Waters and the Broader Thai-Malay Peninsula", "Integrated Risk Assessment of Chemical Contaminants in Mangrove Ecosystems" and "Impacts of Marine Navigation on Mangroves in Coastal Waters of Singapore. Currently, NParks is looking at the development of an island-wide mangrove monitoring programme with a focus on citizen science.

12.1.2 Coral Conservation

Started in April 2005, the CRMP aims to monitor the health of the coral reefs in the islands south of Singapore, and document its biodiversity. Off the islands south of Singapore, particularly the islands of Hantu, Semakau, Jong, Sisters, Kusu and Raffles. Using internationally recognised methods (such as the line-intercept method and Reef Check) to survey the benthos (community of organisms) of the reef, the reef fish community and other mobile invertebrates. Over time, the surveys will give an indication of decline or recovery of the reef. Typically, in Singapore, corals colonies are grown in a nursery and transplanted back onto the degraded reefs. The corals are produced by breaking off small pieces from adult colonies and growing them in nurseries. More recently, scientists have been trying to rear corals from eggs and larvae, although the techniques are still experimental.

Exploration is underway by NParks, on the possibility of using laboratory-reared corals as a way of restoring coral cover on degraded reefs in partnership with Keppel Group, NUS and NEA. Marine biologists from TMSI have been rearing colonies from coral nubins on specifically designed substrates, before transplanting them to coral nurseries. The first coral nursery was launched at a site of Pulau Semakau in July 2007 and was the first concerted effort to enhance existing marine habitats in the hope of maximising the survival of naturally occurring corals. [Refer to **Section 10.2.4** for other research and conservation efforts to protect and monitor coral reefs in Singapore.]

12.1.3 Conservation of Intertidal Habitats

[Refer to **Section 10.3.7** Research and Conservation Efforts for examples of initiatives to protect intertidal ecosystems.]

12.1.4 Establishing "A Marine Park for All"

The Sisters' Islands Marine Park (SIMP) was established in 2015 as Singapore's first marine park. Located to the south of mainland Singapore on Sisters' Islands, the SIMP, which spans 40 ha, and its surrounding areas, contain a wide range of marine habitats, including coral reefs, sandy shores and seagrass areas. The SIMP allows the protection of Singapore's rich marine biodiversity, facilitates cutting-edge research, and provides opportunities to test-bed habitat rehabilitation, restoration and enhancement technologies.

By the end of 2018, SIMP will become home to Singapore's largest artificial reef, which is the result of a joint project launched by Jurong Town Council (JTC) and NParks, in partnership with local marine research and interest group communities. In support of Singapore's Year of Climate Action 2018, the initiative will see an extra 500 m^2 of reef area at SIMP, to supplement the existing habitat enhancement and reef restoration efforts to conserve biodiversity in Singapore's waters. By 2030, the hope is to double the artificial reef areas created at Sisters' Islands to 1000 m^2.

Artificial reef structures that are pre-fabricated off-site, will then be sunk in the waters off Small Sister's Island. Each artificial reef structure is conceptualised to minimise impact to the existing marine environment, utilising materials that promote attachment and growth of corals, and recruitment of fish species. The structures would sit on the seabed without piling or major works that would otherwise disturb the underwater environment. The structures would also occupy the entire water column from sub-surface to the seafloor, hence providing numerous and unique habitat niches for a wide variety of marine life.

The artificial reef project will complement ongoing reef enhancement efforts, and expand the habitat restoration and enhancement programme in both scope and scale. At the same time, the artificial reefs will provide opportunities for various research initiatives to be implemented, and serve as test beds for new technologies to study coral reef resilience. This will contribute to expanding knowledge and understanding of Singapore's marine habitats and the biodiversity they support.

12.1.5 Turtle Hatchery

Singapore's first sea turtle hatchery will be set up at the southern lagoon on Small Sister's Island through a $500,000 donation from HSBC. The Green Turtles and Hawksbill Turtles will be the key species covered under the project.

Turtles visit Singapore's shores throughout the year to lay eggs on the sandy beaches. Since 2012, there have been ten reported sightings of turtles on the shores of East Coast Park and Changi Beach. Members of the public can call the NParks hotline or the Animal Concerns Research and Education Society (ACRES) to report sightings of turtles on Singapore's shores. The organisations follow up on the reported sightings, in consultation with each other to ensure the safety of these turtles. If eggs are found and assessed to be at risk, they will be collected and transferred to the turtle hatchery at the Sisters' Islands Marine Park where they will be monitored and cared for until they hatch and are released into the sea.

The hatchery would also provide research opportunities to study local sea turtle populations. Education and outreach programmes will be developed to create awareness of our local marine biodiversity. These include visits to the turtle hatchery, involvement in egg collection and transfer to the hatchery, and habitat maintenance.

The donation from HSBC will support the building of a facility for receiving rescued eggs and where outreach programmes are conducted on the island, over a period of five years. Educational signs and materials will also be developed for the outreach facility. HSBC staff will be involved in habitat maintenance and possibly collection of eggs when they are found and reported by members of the public.

12.1.6 Enhancing Singapore's Coral Reef Ecosystem in a Green Port

Initiated by Tropical Marine Science Institute (TMSI) in collaboration MPA, the project focused on the development of protocols for both the relocation and restoration of coral reefs. With coral transplantation as the method adopted for the establishment of new reefs, whilst degraded reefs will be rehabilitated. The concepts and principles developed through the programme can be applied to support the sustainable development and management of coastal cities.

This research has four strategic directions:

1. Optimize the methods for establishing coral nurseries and transplantation to augment growth and survival of the coral fragments.
2. Assess the suitability of coral species for rearing in the nurseries and for transplantation.
3. Engage volunteers in the coral rearing and restoration efforts and to examine the efficacy of citizen science in reef restoration.
4. Assess the changes in reef community assemblages following coral transplantation.

Among one of the few in Singapore to include coral nurseries as part of the reef restoration effort, the highlights of the research program include:

1) Optimising methods for coral nursery establishment and coral transplantation in high sediment environment.
   a) Nursery efforts: Identification of three nursery sites; Establishment of coral nurseries and trasplantation: 1251 coral fragments (from 22 coral genera) collected from Sultan Shoal and reared in coral nursery. 92% survived after one year, and have increased in size by up to twice the original diameter (range of 1.05 to 1.91 times).
   b) Different slope orientation of coral nurseries: Fixed horizontal nurseries were more suitable for Singapore's marine environment; Enhances growth and survival of most coral transplant species.
   c) Coral relocation efforts can mitigate the effects of thermal stress events. Demonstrated that coral relocation (by transferring to nurseries or transplantation) can accelerate coral recovery if the relocation site has more favourable conditions (e.g., stronger currents and lower sea surface temperature). This is a potential mitigating approach to reduce stress on corals and lower mortality in times of sea temperature rise.

2) Reef rehabilitation efforts and public outreach
   a) Reef Rehabilitation effort
      (i) Restored a total of 300 m^2 of reefs through the projects (150 m^2 new reefs, 150 m^2 degraded reefs) using 420 nursery-reared corals. Of these, volunteers assisted with the rearing of 216 corals in the nursery in 2014, which were subsequently transplanted to Lazarus in 2015. Total estimated area transplanted restored by volunteers: 80 m^2. Total participants: 52 (25 in 2014, 27 in 2015).
   b) Discovery of uncommon coral species in Sultan Shoal:
      (i) Two colonies of *Echinopora horrida* were found on the Sultan Shoal reef, limited to a relative small area. This species was not recorded in the 2009 coral survey, and museum specimens were last collected in 1980. Tissue has been collected for DNA barcoding.
      (ii) Part of one colony was fragmented, and the fragments are currently reared in the coral nurseries for reintroduction to other reefs to ensure species survival.

12.2 Pollution Reduction and Environmental Protection

The measures and actions discussed below contribute to achieving SDG 14, protection of the marine environment.

12.2.1 Solid Waste Management Measures

Singapore has put in place a solid waste management system to ensure that all waste is collected and treated to safeguard environmental public health standards. The system is based on the principles of providing a cost-effective infrastructure while minimising land-take, and promotion of the 3Rs (reduce, reuse and recycle) to reduce waste and recover resources. While Singapore aims to achieve an overall national recycling rate of 70% by 2030 as part of the *Sustainable Singapore Blueprint 2015* (SSB 2015), the ultimate goal is to work towards becoming a **Zero Waste Nation**.

Only non-incinerable waste that is not recycled is directly landfilled to reduce landfill needs. All incinerable waste that is not recycled is incinerated at waste-to-energy plants to reduce the waste volume by 90%.

Semakau Landfill is Singapore's only landfill. It is an off-shore landfill with a 7-km perimeter bund built to enclose a part of the sea off two islands, Pulau Semakau and Pulau Sakeng, to create a 350-ha landfill. The bund is lined with impermeable membrane to prevent pollution of the sea. The leachate produced is treated at a leachate treatment plant.

To complement ferrous scraps recovered at the WTE plants, Singapore's first metal recovery facility for incineration bottom ash (IBA) began operations in July 2015.

Moving forward, NEA will build the **Integrated Waste Management Facility** (IWMF). The IWMF is an integral part of NEA's long term plan to meet Singapore's solid waste management needs as the amount of waste generated by the country is expected to grow with the increasing population and growing economy. It will adopt an integrated approach to process various waste streams for higher resource and energy recovery while minimising environmental and land use footprint. The IWMF will also be co-located with PUB's **Tuas Water Reclamation Plant** (TWRP) to reap the benefits of various process synergies. The IWMF will be built in two phases and expected to be fully completed by 2027.

a. Waste Minimisation and Recycling

To reduce waste at source, NEA works with industry and non-governmental organisations (NGOs), and jointly initiated the *Singapore Packaging Agreement* (SPA), a voluntary agreement to reduce packaging waste. The SPA provides opportunities for networking and exchange of information on packaging waste reduction best practices through meetings, events and sharing sessions. Since the launch of the Agreement in 2007, the signatories have cumulatively reduced about 46,000 tonnes of packaging waste, with concomitant savings of more than $100 million in the material costs of locally consumed products.

To promote recycling, NEA collaborates with schools to launch the *School Recycling Corner Programme* in 2002. Under the programme, recycling bins and recycling information are provided. Talks are also conducted. All primary and secondary schools, as well as junior colleges, have set up recycling corners in their premises.

A *Preschool 3Rs Awareness Kit*, consisting of a set of pictocards and a teacher's guide, is made available to assist kindergarten teachers in planning activities to kindle pre-schoolers' interest and educate them on both the importance of practicing the 3Rs and what and how to recycle.

NEA also engages industry to promote 3Rs and build up capabilities in 3Rs. For instance, NEA worked with various industry sectors and stakeholders to roll out *3R guidebooks for hotels and shopping malls*, as well as a *3R toolkit for the Meetings, Incentives, Conventions and Exhibitions (MICE) industry*.

b. General Waste Collection

NEA regulates the collection of solid waste via the licensing of general waste collectors (GWC), which primarily serve commercial and industrial premises in Singapore. All industrial and commercial premises are required to engage licensed GWCs to collect their waste for proper disposal at approved disposal facilities.

c. Public Waste Collection

For domestic and trade premises, NEA appoints public waste collectors (PWCs) through open tenders to provide waste and recycling collection services by geographical sectors. As part of the services, every public housing block and every landed house is provided with a co-mingled bin, and paper, plastic, glass and metal recyclables deposited are collected and sent to material recovery facilities for sorting and recycling.

Condominiums and private apartments are required to provide recycling receptacles within their estate grounds.

To further enhance the recycling infrastructure, all new public housing developments launched since 2014 are fitted with recycling chutes, and starting from 1 April 2018, all new non-landed private residential developments taller than four storeys will also be required to install recycling chutes.

12.2.2 Plastic Waste Management

a. "Keep Singapore Clean" Campaign

Singapore has kept the city clean and green over the years through the *Keep Singapore Clean* campaign which started back in 1968. Since then, strict anti-littering laws were enforced through the *Environmental Public Health Act*, and waterways clean-up measures were developed. Singapore also put in place an integrated waste management and collection system to minimise waste at source and ensure proper waste recycling and disposal.

b. Singapore Packaging Agreement

The *Singapore Packaging Agreement* (SPA) is a joint initiative by the government, industry and non-government organisations (NGOs) to reduce packaging waste from consumer products and the supply chain. The SPA provides opportunities for networking and exchange of information on packaging waste reduction best practices through meetings, events and sharing sessions.

c. Reporting System for Management of Packaging Waste

NEA is in the midst of drawing up details for the mandatory reporting requirements for sustainable packaging waste management which will be implemented in 2020. Businesses that place packaging on the consumer market, including plastic packaging, would be required to submit annual reports with information on the types and amounts of packaging they are placing on the market and their packaging waste reduction plans. This aims to bring greater awareness to companies on the potential for waste reduction within their business operations and spur them to take action to reduce the amount of packaging used and packaging waste disposed of.

12.2.3 Wastewater Management Facilities

[Also toward achieving SDG 6 Clean Water and Sanitation - Ensuring access to water and sanitation for all.]

All used water in Singapore is collected and treated at water reclamation plants. PUB operates four water reclamation (i.e., wastewater treatment) plants currently. It also administers the *Sewerage and Drainage Act* and *Drainage (Trade Effluent) Regulations* to regulate the sewerage system and the discharge of industrial wastewater into public sewers, ensuring that all wastewater is collected and treated to regulatory discharge standards using the latest technology.

The year 2008 saw the construction of a 48-km long **Deep Tunnel Sewerage System** (DTSS). This underground wastewater super highway allowed PUB to effectively collect wastewater from almost half of Singapore's land area, and convey it to a centralized wastewater treatment plant for appropriate treatment. PUB is currently enhancing the sewerage network by building the second phase of DTSS. By 2025, Phase 2 of the DTSS will extend the existing system to western Singapore with a 40-km long deep tunnel linked to 60 km of sewers. This will increase the efficiency of Singapore's wastewater treatment processes in the long term.

When fully completed, the entire DTSS Phases 1 and 2 will reduce the land occupied by wastewater infrastructure by 50%. Under the upcoming Tuas Nexus development, a new water reclamation plant at the terminal end of the DTSS Phase 2 for treating used water will be co-located with the IWMF for solid waste incineration. PUB will be able to realise the synergies of the water-waste-energy nexus.

Reducing the country's carbon footprint is done through reducing emissions, reducing energy usage and exploring alternative energy sources. PUB is exploring the use of our raw water reservoirs' vast surface areas for floating solar photovoltaic (PV) systems to supply clean and renewable energy. PUB is also working with industry partners and embark on the transformation into a "SMART" utility by exploiting the IT revolution to better leverage digital technologies for its operations. There are three key focus areas: (i) IoT/sensors, (ii) robotics/automation and (iii) data analytics.

In this regard, various solutions are being studied or piloted. For instance, PUB is developing a **SMART Water Grid**, a network of wireless sensors installed in water supply mains across Singapore, which functions as a real-time platform to monitor water pressure, flow and quality. The system provides decision support tools that helps in network management and allows early detection of anomalous network occurrences, enhancing PUB's operations and the efficiency of water supply to consumers. This helps to minimise the losses of water due to leaks.

In addition, PUB is also testing the use of drones for sewer inspections, robotic "swans" for water quality monitoring of our reservoirs, as well as data analytic software to make sense of the data that is collected by the different sensors deployed for water supply, wastewater collection and drainage.

Collectively, they enable PUB to make better decisions and ensure good water supply 24/7 to the population and businesses.

12.2.4 Management of Sea-based Sources of Pollution

a. MARPOL

Singapore is party to the IMO MARPOL convention, which covers the prevention of pollution of the marine environment by ships. For more information on how Singapore carries out its MARPOL obligations, please refer to "Preparedness, Response and Co-operation" under **Section 6.8**.

b. Ballast Water Management Convention (BWMC)

Singapore is party to the IMO BWMC convention, which is aims to mitigate the problem posed by invasive aquatic species in the ballast water of ships. For more information on how Singapore carries out its BWMC obligations, please refer to "Preparedness, Response and Co-operation" under **Section 6.8**.

c. Oil spills

Singapore is prepared to deal with oil spills efficiently to mitigate the impact of oil spills in the marine environment. For more information on Singapore's oil spill response, please refer to "Preparedness, Response and Co-operation" under **Section 6.8**.

d. Sustainable shipping and green ports

Singapore has in place the MSGI which seeks to promote green ports and green shipping. For more information on Singapore's MSGI, please refer to **Section 8.2.2 and Annex A.3**.

12.3 Climate Change Mitigation and Adaptation

12.3.1 Climate-resilient Infrastructure

a. Wastewater and Drainage Facilities

Singapore has built the Deep Tunnel Sewerage System (DTSS), a 'used water superhighway for the future to meet Singapore's long-term needs for used water collection, treatment, reclamation and disposal. With the completion of Phase 2 of the DTSS, it will convey the island's used water to three centralized water reclamation plants. The treated used water is then further purified into ultra-clean, high-grade reclaimed water called NEWater. [Refer to above, **Section 12.2.2** Wastewater management facilities]

PUB also invests in efforts to enhance flood resilience through requiring the construction of detention tanks or ABC Waters features within developments, improvements to the drainage system, and imposing structural measures such as crest level and minimum platform levels for buildings – taking the "Source-Pathway-Receptor" approach. [Refer to **Section 9.3.3.2** Flood Control Measures / Drainage Design and Flood Protection Measures and Management]

b. Land Reclamation and Future Construction

To help mitigate coastal inundation from sea-level rise, the minimum land reclamation level for newly reclaimed lands in Singapore was raised from 3 m to 4 m above the mean sea level in 2011. This enables our newly formed coastal lands to protect the hinterland. Based on the projected mean sea level rise in the *Fifth Assessment Report* (AR5) by the Inter-Governmental Panel on Climate Change (IPCC), this minimum reclamation level is currently adequate.

Presently, for major redevelopment works on an existing coastal land, the platform levels of the developments could be raised to protect against potential sea-level rise. For example, Changi Airport Terminal 5 will also be built 5.5 m above the mean sea level, and Singapore's new Tuas Terminal will be built with higher operational platform levels to ensure its safe operations. Roads near coastal areas, including a stretch of Changi Coast Road and Nicoll Drive, have also been raised to protect them from rising sea levels.

To minimise coastal erosion and stabilise a section of the beach at East Coast Park, BCA carried out shoreline restoration works using a geo-bag seawall system at a specific stretch near the Road Safety Park in 2010. The geo-bags, which are large sand-filled geotextile bags, are laid several metres into the ground. They help to hold back the park land behind it. The geo-bags have served their functions well, having retained the beach material and maintaining the beach profile effectively.

c. Drainage Design and Flood Protection Measures and Management

Singapore currently has approximately 8,000 km of drains, rivers and canals to collect water and convey to the reservoirs for water supply or discharged to the sea. From 2011 to 2017, the Government has invested S$1.2 billion to upgrade drainage infrastructure and improve flood resilience for Singapore.

An Expert Panel on Drainage Design and Flood Protection Measures was appointed by MEWR on 30 June 2011 to conduct an in-depth review of all flood protection and risk management measures, and assist in formulating long-term implementation plans. In 2011, PUB commenced a systematic review of all flood-prone areas, and have since conducted drainage improvement operations at 338 locations, with a further 74 projects ongoing.

Singapore has marked 2018 as the *Climate Action Year* to focus attention on climate change, and raise the level of national consciousness around the need to take individual and collective action to fight climate change for a sustainable Singapore.

In this regard, PUB has taken a holistic approach to introduce flexibility and adaptability to Singapore's drainage system. Through the "Source-Pathway-Receptor" approach, measures are not only carried out along the "Pathway" (e.g., through widening and deepening of drains and canals), but also implemented at the "Source" where stormwater runoff is generated (e.g., through on-site detention),

and at the "Receptor" where floods may occur (e.g., through platform levels, crest protection and flood barriers). This approach allows stormwater management to be addressed at all parts of the catchment, with building owners and developers playing a role in managing the impact of urban development on flood risks.

Currently, PUB has 210 water-level sensors around Singapore for monitoring of the drainage system, which provide data on water levels in the drains and canals, enhancing the monitoring of real-time site conditions during heavy storms, and response time.

d. Marina Barrage

Designed primarily as a flood alleviation scheme, this tidal-gate system was constructed to mitigate the influence of high tides on the low-lying areas of Singapore (in particular Chinatown and Little India areas) as well as release excess stormwater from the catchment.

12.3.2 Green Buildings

Climate change and global warming pose serious long-term challenges to our vision of a City in a Garden. The rate of increase in surface temperature in Singapore is faster than the global average, because of urban development. One contributor for this is the heat emitted from the buildings. Buildings also contribute roughly a quarter of all carbon emissions in Singapore.

Today, more than one third of the buildings (in terms of gross floor area [GFA]) meet the minimum green building standards. One key measure is the **BCA Green Mark certification system** – introduced in January 2005 - to evaluate new and existing buildings for their impact on the environment and overall performance in areas such as energy efficiency. BCA Green Mark aims to achieve a sustainable built environment by incorporating internationally recognized best practices in environmental design and performance. Examples are: replacing old and energy-intensive equipment (e.g., cooling systems, lighting), making use of available space to harness alternative energy (e.g., installing solar panels on rooftops), designing and building new buildings to use less resources (e.g., water, energy), as well as providing greenery to mitigate Urban Heat Island Effect.

The **3rd Green Building Masterplan** was launched in 2014 to guide Singapore's overall efforts to further building energy efficiency improvement, provide a quality living environment for its people, and become a climate-resilient global city well positioned for green growth. The target is for 80% of the buildings' GFA to be green by 2030. BCA will continue to strengthen its efforts and to push boundaries towards super low-energy buildings with a minimum of 60% energy efficiency improvement over the 2005 building codes. Another focus is to ensure these green buildings perform optimally when in operation. Taking a building's life cycle, this would mean lower operating costs for the building owners, and a healthy environment for people to live, work and play in.

13 Policies, Plans and Supporting Mechanisms

Singapore is a sovereign republic, with a legal system based on the English common law. The Constitution lays down the fundamental principles and basic framework for the three organs of state, namely, the Executive, the Legislative and the Judiciary.

The legislation, or statutory law, of Singapore is made up of Statutes and Subsidiary Legislation. **Statutes or Acts** (numbered as "Chapters") are written laws made by the Singapore Parliament. The most important statute is the Constitution of the Republic of Singapore. All other statutes must be consistent with it. Statutes are published in looseleaf form called "The Statutes of the Republic of Singapore".[53]

Acts of Parliament lay down the law in general. **Subsidiary legislation** (called "Regulations"), or "delegated" or "subordinate" legislation, is written law made by government departments or statutory boards and not directly by Parliament. These are made under the authority of a statute (or "parent Act"). Subsidiary legislation is legislation requiring a high degree of flexibility, as they may be amended frequently from time to time, or may deal with matters which are technical in nature.

This two-tier system of legislation therefore allows Parliament to function more efficiently without being caught up in details found in subsidiary legislation and without the need for Parliament to pass a new Act of Parliament each time subsidiary legislation is amended. The *Parent Act* will usually confer the power to make subsidiary legislation to the administering body of the Act. For example, Section 100 "Powers of Authority to make regulations" of the *Merchant Shipping Act* empowers MPA, with the approval of the Minister, to make regulations. The new subsidiary legislation (SL) is then published in the Gazette.[54]

13.1 Legal Framework for ICM

The coastal zone, comprising the waterfront land, offshore islands and surrounding water, represents a significant component of the physical environment of Singapore. Singapore's limited coastal and marine areas are densely populated and heavily utilised by various industries, including

[53] Singapore Statutes Online, n.d.

[54] New subsidiary legislation published in the Gazette may be freely viewed or downloaded online for five days on the Electronic Gazette website (http://www.egazette.com.sg). The date of entry into force of the subsidiary legislation may be different from the date of the Gazette

shipping, transport, petroleum, petrochemical manufacturing, as well as non-industrial uses such as residential development and recreation. These demands from competing land uses have placed Singapore's coastal and marine environment (CME) under constant pressure and much work has been done to consider at length how Singapore's limited coastal area and resources can be optimised.

There is a strong legal framework in Singapore, with several ICM enabling laws. In hierarchical order, Singapore's legislative system consists of the Constitution of the Republic, followed by the Acts enacted by Parliament, and the subsidiary legislations (such as regulations).

Whilst at the Constitutional level, there is currently no provision for the environment in the legal system. There are 19 Statutory Boards/Divisions from eight Ministries and one Organ of State with specific interests in the CME. Each have their individual policies and strategies with regards to the governance or use of Singapore CME. The general interests and role of key Ministries and Agencies pertinent to Singapore's CME are summarised in **Table 13.1** below.

Table 13.1: Key Government Stakeholders of Singapore's Coastal and Marine Environment.

Ministry	Agency/Division/ Department	Current interests / roles relating to CME
AGC	International Affairs	Provides legal advice on international law, represents the state at various international platforms, translates international obligation into domestic legislation, facilitates policy and legislation relating to international/multilateral obligations
	Legislative Division	Drafts and vets government bills and laws to empower government departments and statutory boards
MEWR	International Relations Division	National Focal point for most environment international agreements and arrangements, represents Singapore at international fora and meetings
	NEA	Environment protection. Key strategies adopted include control of land-based source to prevent pollution to the marine environment, monitoring of the inland and coastal waters to assess the adequacy and effectiveness of the water pollution control programmes
	PUB	Integrated freshwater management. Manages and regulates the freshwater environments and Singapore's water supply
MFA	Directorates	Safeguards the strategic interests of Singapore relating to CME issues. Ratification of multilateral and international conventions relating to the environment. Provides directions with regards to Singapore's strategic positioning in CME affairs
MHA	PCG	Provides and enforces maritime security
	SCDF	Provides humanitarian service and emergency responses in the event of fires and disasters
MINDEF	SAF	Uses and manages the Live Firing Islands, enforcement of maritime security and terrorist deterrent
	RSN	Secures the sovereignty of Singapore's waters. Enforcement of maritime security and security and terrorist deterrent

Table 13.1: Key Government Stakeholders of Singapore's Coastal and Marine Environment. (cont.)

Ministry	Agency/Division/ Department	Current interests / roles relating to CME
MINLAW	SLA	Manages state lands including those of the CME and the foreshore
MND	NParks	Manages natures reserves, including coastal nature reserves, and coastal and marine parks. NParks is also a scientific authority on nature conservation, natural heritage conservation in all ecosystems
	URA	Carries out land use planning, regulates developments, and facilitates and coordinates the EIA process
	BCA (Coastal Protection Department)	Appointed as lead agency to carry out strategic studies in response to Sea-Level Rise
	AVA	Licencing of marine fish farms in designated fish farming sites and regulation of commercial fishing vessels
	HDB	Coastal modification works, coastal restoration and sand dredging
MOT	MPA	Prevention of pollution from ships, oil and chemical spills, response and preparedness
MTI	STB	Tourism appeal and development of Southern Islands. Uses the CME
	JTC	Development of industrial real estate from land reclamation. Uses the CME
	SDC	Tourism appeal of Sentosa, development and management of Southern Islands. Uses / Manages non live-firing southern island Administration of industries with potential and actual impact on CME environment such as oil and gas industries. Uses the CME

There are some 26 Acts and 44 regulations relevant to ICM in existence that cover aspects, such as pollution control and waste management (eight Acts, 30 Regulations); planning and land use management (seven Acts); maritime activity (two Acts and eight Regulations); nature conservation (five Acts and nine Rules and Regulations); fisheries (two Acts, six Rules and Regulations); and coastal industrial real estate (one Act). Most notably, the *Environmental Protection and Management Act* aims to consolidate the laws related to environmental pollution control and to stipulate the protection and management of the environment. A list of ICM-relevant statutes and subsidiary laws is shown in **Table 13.2**.

Table 13.2: ICM Relevant Laws in Singapore.

Laws Relating to:	Acts	Associated Subsidiary Laws	Responsible Agency
Pollution Control and Waste Management	Environmental Protection and Management Act	Environmental Protection and Management (Air Impurities) Regulations	NEA
		Environmental Protection and Management (Trade Effluent) Regulations	
		Environmental Protection and Management (Hazardous Substances) Regulations	
	Environmental Public Health Act	Environmental Public Health (General Waste Collection) Regulations	NEA
		Environmental Public Health (General Waste Disposal Facility) Regulations	
		Environmental Public Health (General Waste Disposal Facility – Exemption) Regulations	
		Environmental Public Health (Toxic Industrial Waste) Regulations	
	Hazardous Waste (Control Of Export, Import And Transit) Act	Hazardous Waste (Control Of Export, Import And Transit) Regulations	
	Prevention of Pollution of the Sea Act	Prevention Of Pollution Of The Sea (Oil) Regulations 2006	MPA
		Prevention Of Pollution Of The Sea (Noxious Liquid Substance In Bulk) Regulations 2006	
		Prevention Of Pollution Of The Sea (Reporting Of Pollution Incidents) Regulations	
		Prevention Of Pollution Of The Sea (Reception Facilities and Garbage Facilities) Regulations	
		Prevention Of Pollution Of The Sea (Sewage) Regulations 2005	
		Prevention Of Pollution Of The Sea (Garbage) Regulations	
		Prevention Of Pollution Of The Sea (Air) Regulations 2005	
		Prevention Of Pollution Of The Sea (Hazardous and Noxious Substances Pollution Preparedness, Response and Co-operation) Regulations 2004	
		Prevention Of Pollution Of The Sea (Oil Pollution Preparedness, Response and Co-operation) Regulations	
		Prevention Of Pollution Of The Sea (Composition Of Offences) Regulations	
		Prevention of Pollution of the Sea (Harmful Anti-Fouling Systems) Regulations 2010	
		Prevention of Pollution of the Sea (Ballast Water Management) Regulations 2017	
	Merchant Shipping (Civil Liability And Compensation for Oil Pollution) Act	Merchant Shipping (Civil Liability and Compensation for Oil Pollution) (Compulsory Insurance) Regulations	

Table 13.2: ICM Relevant Laws in Singapore. (cont.)

Laws Relating to:	Acts	Associated Subsidiary Laws	Responsible Agency
Pollution Control and Waste Management	Merchant Shipping (Civil Liability and Compensation for Bunker Oil Pollution) Act	Merchant Shipping (Civil Liability and Compensation for Bunker Oil Pollution) (Compulsory Insurance) Regulations	MPA
	Public Utilities Act	Public Utilities (Reservoirs, Catchment Areas and Waterway) Regulations	PUB
		Public Utilities (Water Supply) Regulations	
		Public Utilities (Composition Of Offences) Regulations	
		Public Utilities (Central Water Catchment Area And Catchment Area Parks) Regulations	
	Sewerage And Drainage Act	Sewerage and Drainage (Surface Water Drainage) Regulations	
		Sewerage and Drainage (Trade Effluent) Regulations	
		Sewerage and Drainage (Sanitary Works and Sewerage Works) Regulations	
Fisheries	Fisheries Act	Fisheries (Fishing Vessels) Rules	AVA
		Fisheries (Piranha) Rules	
		Fisheries (Fishing Harbour) Rules	
		Fisheries (Fishing Gear) Rules	
		Fisheries (Fish Culture Farms) Rules	
		Fisheries (Composition of Offences) Rules	
	Agri-Food And Veterinary Authority Act	-	
Industrial Real Estate	Jurong Town Corporation Act	-	SDC
Maritime Activity (Ports and Shipping)	Maritime And Port Authority Of Singapore Act	Maritime and Port Authority of Singapore (Port) Regulations	MPA
		Maritime and Port Authority of Singapore (Dangerous Goods, Petroleum and Explosives) Regulations 2005	
		Maritime and Port Authority of Singapore (Pilotage) Regulations	
		Maritime and Port Authority of Singapore (Port Limits) Notification 2010	
		Maritime and Port Authority of Singapore (Pilotage District) Notification 2010	
		Maritime and Port Authority of Singapore (Harbour Craft) Regulations	
		Maritime and Port Authority of Singapore (Pleasure Craft) Regulations	
	Merchant Shipping Act	Merchant Shipping (Safety Convention) Regulations	
Nature Conservation	National Parks Board Act	-	NParks
	Parks and Trees Act	Parks And Trees Regulations	
		Parks And Trees (Composition of Offences) Regulations	

Table 13.2: ICM Relevant Laws in Singapore. (cont.)

Laws Relating to:	Acts	Associated Subsidiary Laws	Responsible Agency
Nature Conservation	Endangered Species (Import and Export) Act 2006	Endangered Species (Import And Export) (Composition of Offences) Rules	AVA
		Endangered Species (Import and Export) (Exemption from Section 4(1)) Order	
		Endangered Species (Import And Export) (Prohibition Of Sale) Notification	
		Endangered Species (Import And Export) (Fees) Rules	
		Endangered Species (Import And Export) (Amendment Of Schedules) Notification	
	Wild Animals and Birds Act	-	
	Sentosa Development Corporation Act	Sentosa Development Corporation Regulations	SDC
Planning and Land Use Management	Singapore Land Authority Act	-	SLA
	State Lands Encroachment Act	-	
	State Lands Act	-	
	Foreshores Act	-	
	Lands Acquisition Act	-	
	Urban Redevelopment Authority Act	-	URA
	Planning Act	-	

13.2 Integrated Urban Coastal Management (IUCM)

In 2009, Singapore adopted and implemented a more specific form of the internationally recognised ICM –developed by PEMSEA - known as IUCM. The legal framework involves various legislation that enable the management and regulation of CME – and forms the backbone of the IUCM efforts. The framework essentially covers biodiversity conservation and the protection of CME, resource management, pollution control and waste management, marine activities, coastal hazards management, recreation and tourism, and heritage conservation.

Whilst there is no overarching legislation for IUCM, it facilitates Singapore's coastal management by enhancing coordination of governmental stakeholders and coherence in governance, policies and processes. It uses governing structures, such as existing administrative processes, a legal framework for coastal management, coordinating mechanisms, and supporting structures to underpin the accomplishment of IUCM's objectives.

13.2.1 Administrative Processes

Utilised in conjunction with existing legislative powers to manage CME. According to their allotted mandates, the relevant government agencies create processes that either complement, or in some instances, replace the use of legislation. Where administrative processes necessitate involvement across multiple agencies, they rely on the pooled technical expertise and resources to address issues holistically. The main processes that relate to CME are as follows:

a. Master Planning Process

The Master Plan is the statutory land use plan that guides development in the medium term over the next 10 to 15 years. It is reviewed every five years and translates the broad, long-term strategies (40 to 50 years) of the Concept Plan into detailed blueprints that guide development in Singapore. The Master Plan shows permissible land use and densities for developments, including coastal land. The master planning process is a collaborative effort between agencies to ensure that plans meet immediate and economic and social needs while maintaining a good quality living environment. The latest version is Master Plan 2014.

URA evaluates and grants planning approval for development projects from the public and private sectors. Through this process, it ensures that developments keep in line with the intention for each parcel of land as planned. For developments proposed in more sensitive places such as coastal and marine sites or nature areas, there is an administrative process in place to assess and manage their environmental impacts.

b. Environmental Impact Assessment

The Government has put in place a process to ensure that development projects are screened for potential environmental impact. Projects that are identified to potentially result in adverse environmental impact are required to carry out environmental studies to assess the impact of the project, and to identify possible mitigating measures. The scope of the assessment might include potential impacts on areas, such as biodiversity, hydrology, water quality, air and noise pollution, vibration, recreation, sediment transport, navigation and transboundary impacts, depending on the project's context. Based on these studies, the Government will weigh the need for the development project against its potential impact and if potential impact can be mitigated by modifying the scale or scope of the development works. Where necessary, agencies will stipulate mitigating measures and Environmental Monitoring and Management Programmes (EMMP) to be put in place to minimise the environmental impact of their development.

c. Committee for Marine Projects (COMET)

All project proposals involving foreshore or marine development must obtain approval from MPA's Committee for Marine Projects (COMET). COMET seeks to ensure that foreshore and marine

development projects do not affect the navigational safety of vessels at the fairways, shipping channels, shipyards, or terminals.

d. Marine Emergency Action Procedure (MEAP)

[Refer to **Section 6.8.1**]

13.2.2 Coordinating Mechanisms

a. Consultative Planning

Singapore has taken a holistic approach to urban planning, beginning with a long-term Concept Plan that is reviewed every 10 years, to a finer resolution of planning in the Master Plan that is reviewed every five years. This allows Singapore to adapt to the changing socioeconomic trends of the population. A key success of the planning framework is the high level of consultation and integration amongst stakeholder agencies in drawing up these plans. Previous plans have also incorporated recommendations from NGOs in the preservation of sensitive habitats with high biodiversity.

b. Coordinated Policy Formation

The Coastal and Marine Environment Policy Committee (CMEPC) is an inter-ministerial committee that was formed in 2007 to provide coordinated, holistic and strategic policy direction for CME-related issues. The CMEPC's main task is to coordinate a balanced approach towards coastal management, focusing on strategic issues, such as development activities, port and shipping activities, navigational freedom, and environmental sustainability. The CMEPC endorses the adoption and implementation of Singapore's IUCM framework. The Committee also seeks to establish local and international networks of experts that can be tapped on to strengthen Singapore's capacity in IUCM.

c. Whole-of-Government (WOG) Approach

Singapore's government agencies adopt a WOG approach to access and synergise diverse knowledge, viewpoints and ideas to enhance policy development. A WOG approach requires agencies to facilitate communication, learning, analysis and decision-making across organisations, and can lead to greater outcomes than the most competent agencies working in silo. A well-known example is the Singapore River Clean-up.

13.2.3 Supporting Structures

Singapore's IUCM is supported by the following key structures, which help in the formulation of effective policies and management solutions. These structures exist in the form of institutional structures, knowledge platforms and data-collection programmes.

a. The Technical Committee on Coastal and Marine Environment (TCCME)

Formed in 2007 with technical experts from various agencies such as NParks, NEA, BCA, MPA, AVA, MEWR, MFA, together with academics and researchers. Co-chaired by NParks and NEA, the Committee supports the CMEPC by providing technical inputs, undertaking studies, and building capacity in CME-related issues. TCCME's role is based on the recognition that sound scientific knowledge and good data are key to ensuring better management of Singapore's coast.

b. The Biodiversity and Environment Database System (BIOME)

An essential component of the IUCM programme, the development of an integrated information system called BIOME began in 2009 with a survey of data availability and projected needs across stakeholders. BIOME serves as a one-stop repository for biodiversity and environment-related data which are contributed by government agencies, educational institutions and NGOs.

Facilities in BIOME include sighting submission, data upload function, search engine, GIS interface for visualisation of CME data and analytical tools. One of its key aims is to facilitate government in current works or operations, and researchers or consultants in their studies on matters relating to biodiversity and environment.

[See also **Section 13.7.3** National Parks Board Initiatives for Raising Public Awareness]

c. Survey and Monitoring Programmes

IUCM is supported by data collected from comprehensive surveys and monitoring programmes. Long-term monitoring of Singapore's seagrass, corals, and mangroves have been established to track biodiversity and gather baseline information for environmental and biodiversity impact assessments.

The Comprehensive Marine Biodiversity Survey, which was initiated in 2010 by NParks in collaboration with a range of stakeholders, lasted five years and data generated was consolidated in BIOME for analysis.

d. Supporting Plans and Strategies

The IUCM framework is supported by many existing plans and strategies for resource management, environmental protection, conservation, and sustainable development. Below are some of the supporting plans and strategies.

- The **Master Plan 2014**, which is the latest statutory land use plan that guides Singapore's land use development in the medium-term.

- The Parks and Waterbodies Plan, which represents existing and proposed green spaces and waterbodies.
- The **National Biodiversity Strategy and Action Plan** (adopted in 2009), develop key strategies for biodiversity conservation in Singapore. This plan serves to fulfil Singapore's commitment to the CBD.
- The **Nature Conservation Master Plan (NCMP)** is a framework that aims to consolidate, coordinate, strengthen and intensify all the current biodiversity conservation efforts over a five-year period from 2015 – 2020. NCMP comprises of four thrusts – physical, programmatic, research and community stewardship
- The **Marine Conservation Action Plan (MCAP)**, which guides our efforts at conserving Singapore's marine habitats and biodiversity. The MCAP include the following key activities: (1) Physical safeguarding; (2) Species Recovery; (3) Habitat Enhancement; and (4) Community Stewardship
- The **National Climate Change Strategy**, which sets out present and future efforts to address Singapore's susceptibility to climate change and contribute to the reduction of greenhouse gas emission. The strategy also layout Singapore's local capacity-building efforts and participation in international climate change discussions.
- The **Climate Action Plan: Take Action Today, for a Sustainable Future**, comprises two documents. 'Take Action Today, for a Carbon-Efficient Singapore" contains information on how Singapore intends to reduce greenhouse gas emissions and increases energy efficiency to meet our 2030 climate pledge. "A Climate-Resilient Singapore, for a Sustainable Future" documents how Singapore may be affected by climate change and our strategy to prepare for them.
- **Clean and Green Singapore**, which is a continuous programme that aims to motivate Singaporeans to care for and protect their living environment by adopting an environmentally-friendly lifestyle.
- The **Singapore Blue Plan 2009**, which is a proposal from NGOs and academics for the integration and balanced conservation and rehabilitation of Singapore's marine heritage.
- The **Sustainable Development Blueprint**, which supersedes the Singapore Green Plan - established in 1992 to tackle environmental issues - and is jointly produced by the people, private and public sectors in Singapore. It contains strategies and initiative for Singapore to achieve both economic growth and maintain a quality living environment over the next two decades.

13.2.4 PEMSEA Regional IUCM Demonstration Site and Learning Centre

Singapore and PEMSEA signed a Memorandum of Understanding (MOU) on 18 November 2013, establishing Singapore as a PEMSEA Regional IUCM Demonstration Site and Learning Centre. The event was attended by representatives from MEWR, MFA, MPA, NEA, NParks. By signing the MOU, Singapore is recognised internationally as a positive example in balancing coastal development, marine environment protection and biodiversity conservation. Experience and best practices in Singapore's IUCM implementation will be showcased and disseminated within the Seas of East Asia region and beyond.

13.3 Key Strategies and Action Plans

Singapore developed its industrial base and achieved high rates of economic growth over a span of four decades. Forward planning policies led to environmental programmes being implemented at a very early stage to promote environmental sustainability.

13.3.1 Environmental Land Use Planning

Agencies aim to avoid environmental problems through proper land use planning and the use of appropriate controls and technologies. They adopt an integrated approach in the planning control of new developments to ensure that environmental considerations and factors are incorporated at the land use planning, development control, building plan and commissioning stages; in order to minimise pollution and mitigate pollution impact on the surrounding developments to achieve a quality environment.

URA, which is the land use planning authority in Singapore, consults the Central Building Plan Department (CBPD) on the environmental requirements related to land use planning. The Jurong Town Corporation (JTC), Housing & Development Board (HDB), EDB and private sector developers also consult CBPD on the allocation of industrial premises and siting for new industrial developments.

CBPD also assesses and evaluates the hazard and pollution impacts of the proposed industries to ensure that they do not pose any health and safety concerns and pollution problems. The proposed industrial plant will only be allowed to be set up if it is sited in an appropriate industrial estate that is compatible with the surrounding land use, and can comply with the chemical safety and pollution control requirements.

13.3.2 Sustainable Singapore Blueprint (SSB)

First released in 2009, SSB sought to outline the national vision and plans for a more liveable and sustainable Singapore by striking a balance between growth and quality living environment for the people of Singapore. The SSB was launched by the Inter-Ministerial Committee on Sustainable Development (IMCSD).

The second blueprint, SSB 2015 was launched at the commencement of a year-long Clean & Green 2015 Campaign in November 2014 and laid out the government's plan to commit S$1.5 billion over the next five years to creating a liveable, vibrant and sustainable city. The SSB 2015 has the following five focus areas:

- An Active and Gracious Community
- Towards a Zero Waste Nation

- "Eco-smart" Endearing Towns
- A Leading Green Economy
- A "Car-Lite" Singapore

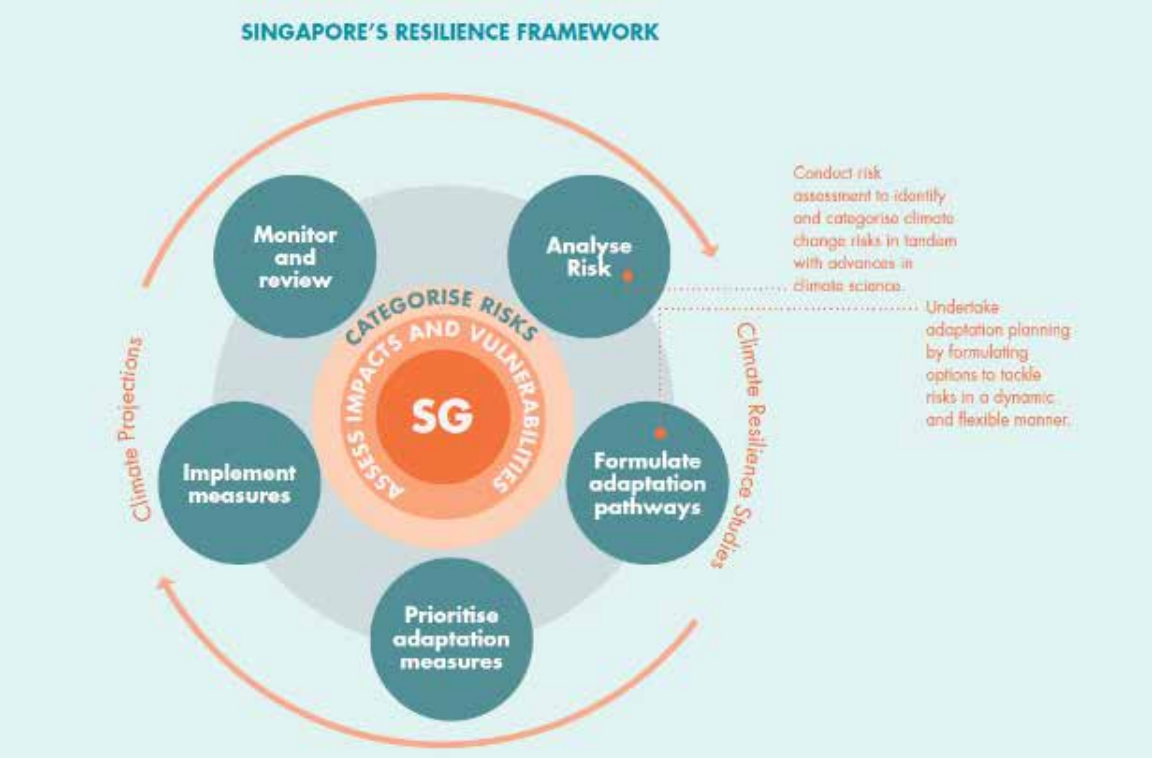
13.3.3 Climate Change Mitigation and Adaptation

a. Singapore's Resilience Framework

Singapore has developed a *Resilience Framework* to guide our plans for climate change adaptation (**Figure 13.2**). The framework helps to identify climate change risks to people and property, and formulate adaptation plans to minimise the adverse effects of climate change.

Some of the adaptation measures will require time to implement, while others may involve the construction of costly infrastructure. The plans must be flexible and dynamic to accommodate future needs and the latest science. It is also important to consider how our measures would affect one another, so that we can implement them in the most efficient and effective manner.

Figure 13.1: Singapore's Resilience Framework.



b. Climate Action Plan

Singapore published its *Climate Action Plan: Take Action Today*, for a Sustainable Future in 2016. This document outlines our mitigation and adaptation plans.

Climate change policies are coordinated by the Inter-Ministerial Committee on Climate Change (IMCCC), which is chaired by Deputy Prime Minister (Teo Chee Hean). The IMCCC is supported by the National Climate Change Secretariat (NCCS), which was established as a dedicated unit in the Prime Minister's Office (PMO) to ensure effective coordination of Singapore's domestic and international policies, plans and actions on climate change. The positioning of NCCS underscores the importance that Singapore places on climate change.

13.3.4 Singapore's Nature Conservation Masterplan (NCMP) and National Biodiversity Strategy and Action Plan (NBSAP)

The challenges to maintain greenery and conserve our remaining natural heritage, are set to increase in the coming years, with projections of denser living and an increased rate of development to match. Added to the mix, the heightened awareness and public feedback on nature and biodiversity, and the need for a master plan to chart the course of biodiversity conservation becomes clear.

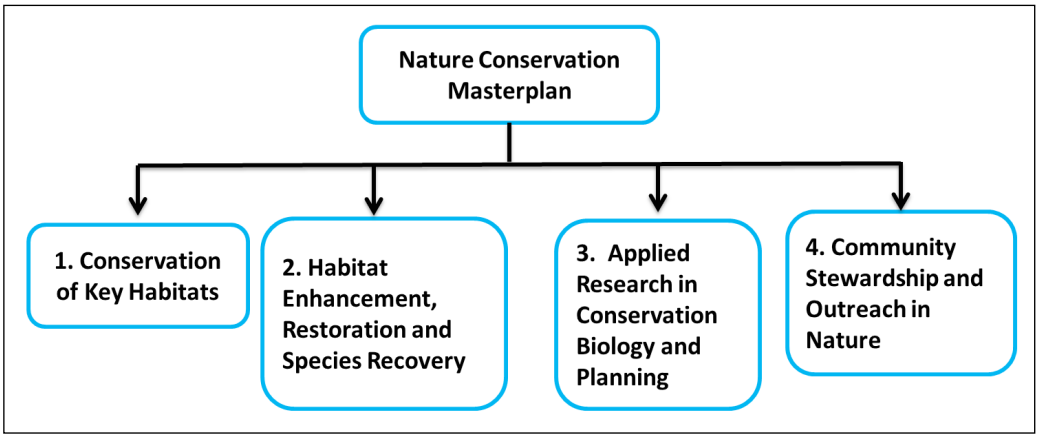
13.3.4.1 Nature Conservation Masterplan (NCMP)

A holistic approach towards biodiversity conservation has been adopted, where the input of various public sector agencies and nature groups have been taken into consideration in the preparation of the master plan - which also fulfils our regional and international commitments, and primarily the CBD.

NParks is currently developing more specific targets based on the CBD Strategic Plan and the Aichi Targets for 2011-2020. This would enable better tracking of Singapore's biodiversity conservation efforts which would also support the achievements of the global targets.

The NCMP is a framework (**Figure 13.1**) that aims to consolidate, coordinate, strengthen and intensify all the current biodiversity conservation efforts over a five-year period from 2015 – 2020.

Figure 13.2: The four key thrusts of the NCMP.



NCMP comprises of four thrusts – physical, programmatic, research and community stewardship (**Figure 13.1**).

1. **Conservation of Key Habitats**
   - *1a Safeguard and Strengthen Core Areas* - four core areas of Singapore have been identified
   - *1b Secure and Enhance Buffer Areas* - Wrapping our Core Areas in a protective blanket
   - *1c Enrich and Manage Additional Nodes of Greenery Throughout the Nation* - We have 350 parks, 3500km of streetscape and many green patches that support nature throughout the city. Plus additional vertical/Skyrise greenery initiatives.
   - *1d Develop Ecological Connections* - Links, in the form of Nature Ways, Park Connector Network, Eco-Link

2. **Habitat Enhancement, Restoration and Species Recovery**
   - Examples: Pulau Tekong Mangrove Project, Bishan-Ang Mo Kio Park
   - *Species Recovery*: Priority on endemic species (e.g. the Singapore Ginger, the Singapore Freshwater Crab), followed by those that are critically endangered and recently rediscovered

3. **Applied Research in Conservation Biology and Planning**
   - Biodiversity surveys: freshwater, vegetation, fauna surveys
   - Comprehensive surveys, long term monitoring, e.g. Bukit Timah and other Nature Reserve Surveys
   - Bird ringing (e.g., Sg Buloh, P. Ubin), Heron Watch
   - Surveys of taxonomic groups, including gingers, climbing plants, corals, sponges and other marine organisms
   - Building our capacity to use up-to-date technology such as GIS, predictive modelling, population viability analysis and DNA
   - BIOME, a biodiversity database

4. **Community Stewardship and Outreach in Nature**
   - Build public interest and involvement in biodiversity conservation
   - Incorporate biodiversity into the school curricula
   - Community in Nature (CIN)
   - Citizen science projects (Bird watch, Butterfly watch)
   - Habitat enhancement (Greening of school for biodiversity, native planting)
   - Nature outreach (Festival of Biodiversity, Nature based activities for youths in NR & NA, CIN Corporations – gardening)
   - SGBioAtlas mobile application
   - Nature Ways, e.g., Tengah, Jurong
   - Community in Bloom

13.3.4.2 National Biodiversity Strategy and Action Plan (NBSAP)

As a party to the CBD, Singapore has an obligation to develop its own set of strategy and action plans to safeguard our biodiversity. NParks developed and launched the *National Biodiversity Strategy and Action Plan* (NBSAP) for Singapore in 2009. Titled "*Conserving Our Biodiversity*", this national document provides a framework to guide biodiversity conservation efforts in Singapore. It aims to promote biodiversity conservation, keeping in mind that as a densely populated country with no hinterland, we have to adopt a pragmatic approach to conservation and develop unique solutions to our challenges. It intends to establish both policy frameworks and specific measures to ensure better planning and co-ordination in the sustainable use, management and conservation of our biodiversity.

The NBSAP is administered by the National Biodiversity Centre (NBC).

The NBSAP outlines five strategies and respective action plans that work towards achieving the CBD objectives.

These five strategies aim to encapsulate the objectives and work of CBD, NParks and other stakeholders:

- **Strategy 1:** Safeguard Our Biodiversity
- **Strategy 2:** Consider Biodiversity Issues in Policy and Decision-making
- **Strategy 3:** Improve Knowledge of Our Biodiversity and the Natural Environment
- **Strategy 4:** Enhance Education and Public Awareness
- **Strategy 5:** Strengthen Partnerships with All Stakeholders and Promote International Collaboration

13.3.4.3 Marine Conservation Action Plan (MCAP)

The MCAP takes reference from the NCMP, and encapsulates NPark's efforts, targeted at conserving Singapore's marine biodiversity. A key focus of the MCAP has been the establishment of Sisters' Islands Marine Park. NParks is undertaking species recovery efforts for the giant clams and Neptune Cup Sponge. Additional efforts to conserve the Green and Hawksbill Turtles will also be established at the Marine Park. To encourage public appreciation of Singapore's diverse marine ecosystem, the Sisters' Islands Marine Park Dive Trail became ready for public access in September 2015. There are also plans for the restoration and enhancement of marine habitats like shallow water reefs and intertidal areas, not only at Sisters' Islands Marine Park, but also Changi Beach Park and Labrador Nature Reserve

Several programmes to increase biodiversity and enhance resilience have been initiated, including the translocation of corals. The diversification and enrichment of hard coral species to within the Sisters' Islands Marine Park has commenced. To maximise the success of coral translocation and optimise the use of natural phenomenon like sea currents for the movement of marine organisms, predictive agent-based is applied.

Other projects on diversifying the surface of hard structures like sea walls, marinas, etc., to emulate natural conditions, and hence, improve built infrastructure for the attachment of marine organisms are being looked into. Enrichment planting has been an on-going activity in several mangrove areas, as well as seagrass enhancement projects involving community participation are underway.

Please see **Annex B**: for the factsheet on initiatives under the MCAP.

13.3.5 Fisheries Act

To provide AVA with the appropriate enforcement powers in line with international developments in fisheries management and trade requirements, a legislative review is currently on-going for Singapore's Fisheries Act and its subsidiary legislations.

13.4 Supporting Initiatives and Financing Mechanisms

13.4.1 Fisheries

All marine food fish farms are licensed by AVA, and farm licensees are required to abide by licensing conditions to maintain the farm and its surroundings. AVA also has a routine surveillance programme in place for local fish farms to ensure that farms are in compliance and their produce are safe for human consumption. The authority also organises farmer workshops to share on good farm management practices and technology developments.

Financially, AVA has committed more than S$23 million to fish farmers to upgrade their farm capabilities and conduct R&D projects. In addition, each farm had been assigned a dedicated account manager to advise them on business development, technology adoption, and financial assistance matters.

Diplomas related to aquaculture are also offered at Republic Polytechnic and Temasek Polytechnic. Facilities, such as the Centre for Aquaculture and Veterinary Science (CAVS) at Temasek Polytechnic, have also been set up to train aspiring aquaculturists.

13.4.2 Plastic Waste Management Initiatives

a. Reduction of plastic bag use

NEA also supports and works with environment groups and retailers to implement ground-up initiatives to reduce the consumption of plastic bags. For example, NEA supported **Zero Waste** and **SG's Bring Your Own (BYO) campaign** in 2017 through the **Call for Ideas Fund**.

b. Research funding

NEA has launched a tender in end of 2017 to establish the commercial and financial viability of proven recycling solutions and technologies in other countries that can be applied in Singapore. Waste streams to be studied include e-waste and plastic waste. Specifically, the study will look into how a synergistic recycling eco-system with increased productivity for recycling processes would potentially improve the economic viability of recycling locally.

NEA is administering the **Closing the Waste Loop (CTWL) research funding initiative** to encourage collaborations with institutes of higher learning, research institutes and private sector partners, to develop technologies and solutions to tackle challenges posed by increasing waste generation, scarcity of resources and land constraints for waste management. The initiative will look at developing solutions towards a plastic resource efficient economy, and to extract value and resources from plastic waste. By keeping them as resources in the economic loop for as long as feasible will help minimise the leakage of plastics and their impacts on the environment.

13.4.3 Singapore Exchange (SGX) New Sustainability Report Rules and Co-funding Initiative

In June 2016, the SGX introduced **mandatory sustainability reporting** on a "comply or explain" basis which requires listed SGX-companies to review their environmental, social and governance issues, and publish annual sustainability reports starting with the financial year ending on or after December 31, 2017.

Sustainability reporting is not a new concept to SGX, previously companies were asked to complete on a voluntary basis since 2011, with approximately 170 firms already having issued reports.

To assist and encourage the maritime sector to embrace this new requirement, MPA launched a **co-funding initiative** to assist SGX-listed maritime companies in Singapore with the production of their Sustainability Report. The companies' initiatives in reducing negative environmental impact, social causes and corporate governance will also be part of the co-funding considerations. Companies who take up this co-funding will have to publish their sustainability report using world standards, such as, but not limited to, *Global Reporting Initiative Guidelines*, before 31

December 2017. This co-funding initiative is part of the new *Green Awareness Programme* under the enhanced *Maritime Singapore Green Initiative*. The Green Awareness Programme's objective is to create greater awareness on possible avenues towards sustainable shipping. [Related to **Section 8.2.2** Sustainable Maritime Transport / Maritime Singapore Green Initiative and **Annex A.3**.]

13.5 Research and Development (R&D)

Many of the challenges confronting our oceans also present opportunities for governments, businesses and communities to offer new solutions, leverage on new and emerging technologies and innovative partnerships. Singapore sees itself as a living lab

13.5.1 Maritime Transport-related R&D

a. MINT Fund

In 2003, MPA established the **Maritime Innovation and Technology (MINT) Fund** with S$100 million to support R&D and test-bedding of maritime technologies by universities, research institutes and companies in Singapore over a period of ten years. It was topped up by another S$100 million and extended to 2021. Since its inception, the fund has supported more than 300 R&D projects in areas including marine environment, alternative energy (e.g. LNG) and navigational safety.

Under the MINT Fund, there is an annual Call for Proposals (CFP) to fund R&D and technology projects that provide, develop and apply innovative and advanced technology solutions for challenges faced by the maritime industry. The MINT Fund will be able to provide up to 50% co-funding for approved maritime R&D and innovation projects developed by local companies in partnership with the maritime industry, institutes of higher learning or research institutes in Singapore. The focus areas in the recent CFP in 2017 are:

- Data analytics and intelligent systems
  - Block chain and digital platforms for maritime services and supply chain
  - Predictive and smart algorithms
  - Machine learning and artificial intelligence for enhanced decision making and image/vision processing
  - Augmented reality/ virtual reality technologies to support operations, maintenance and training
- Safety, security and environment
  - Clean/green energy, such as LNG, electric, fuel-cell
  - Cybersecurity solutions for the maritime industry
  - Wearable and assistive technologies
  - Advanced sensor technologies and smart control systems
  - Advanced communication technologies for ship-ship/ ship-shore communications

- Autonomous systems and robotics
  - Cloud technologies as a shared service infrastructure for robotics
- Smart and innovative infrastructure
  - Innovative design, engineering and manufacturing technologies
  - Modelling and simulation technologies

b. MPA Living Lab

MPA established the MPA Living Lab in 2017, which will provide a technology partnership platform, with sufficient scale and real operating conditions in the Port of Singapore, that technology providers and industry partners can plug into for the co-development and piloting of innovations. The Living Lab will focus on developing capabilities in the following four areas:

- **Data analytics and intelligent systems**: To harness data for smarter decision-making and optimised port operations. For example, a maritime data hub will be set up for industry and technology partners to co-develop innovative applications, such as just-in-time vessel arrivals or predictive analytics to forecast traffic conditions and potential collision for the next-generation vessel traffic management system;
- **Autonomous systems and robotics**: To enhance manpower productivity and safety, MPA will work with industry partners to provide framework conditions for the development and testing of autonomous vessels, drones and other autonomous systems. Sea spaces and regulatory guidelines will be provided for such testing activities;
- **Smart and innovative infrastructure**: To optimise land and sea space by leveraging innovative engineering and technologies. For example, the use of multi-purpose floating platforms for ship mooring and berthing, and timely supply of marine services; and
- **Safety and security**: To enhance port and maritime safety and maritime cyber/physical security and resilience includes technologies such as smart sensors for detection of intrusions and monitoring of maritime incidents.

c. Electrification and Automation of Cargo Handling Systems in Ports

PSA is exploring the electrification of its container handling systems. PSA currently has almost 200 electric quay and yard cranes operating at the Pasir Panjang Terminal. MPA is supporting PSA in the development and deployment of a **fleet of eight hybrid and 22 electric Autonomous Guided Vehicles (AGVs)** for their integration with the automated quay and yard cranes. The test-bedding of the integrated, automated systems of AGV, yard and quay cranes is being carried out in PSA's Living Lab at the Pasir Panjang Terminal. If the trial is successful, PSA will be deploying more than 1000 AGVs at the future Tuas port.

Besides AGVs, PSA is also testing the use of **Unmanned Aerial Vehicles (UAV)** and image processing to detect cracks and corrosion on container handling cranes, and the automation of the coning and deconing operations of containers at the wharf side using robotic arms. PSA is also concurrently developing **driverless truck technologies**. PSA, with the support of the Ministry of Transport (MOT), is working with two automotive companies, Scania and Toyota Tsusho, to design, develop and testbed an **autonomous truck platooning system** for use on Singapore's public roads. Truck platooning involves a human-driven truck leading a convoy of driverless trucks. In the PSA trials, the trucks will transport containers from one terminal to another.

d. Centre of Excellence in Maritime Energy and Sustainable Development (MESD)

The Singapore Maritime Institute and NTU jointly launched a Centre of Excellence in Maritime Energy and Sustainable Development (MESD) on 31 October 2017. The centre will work on joint projects to develop innovations to reduce harmful ship emissions and to help the shipping industry comply with anticipated changes in international regulations in the maritime industry. It will focus on future port and shipping applications in three key areas – energy management, emissions management and sustainable maritime operations.

13.5.2 National Research Foundation (NRF) Specific Research Innovation Enterprise 2020 Plan

Research, innovation and enterprise lie at the foundation of Singapore's national strategy to grow as a knowledge-based innovation-driven economy and society. Public investment in research and innovation has increased over the last 25 years. Under the previous five-year Research, Innovation and Enterprise (RIE) 2015 Plan, the Singapore government dedicated $16 billion over 2011 to 2015 to establish Singapore as a global research and development (R&D) hub. That commitment will be sustained by further injection of $19 billion for the RIE2020 Plan over 2016 to 2020 to research, innovation and enterprise, to take Singapore to the next stage of development.

With continued commitment to research, innovation and enterprise, Singapore seeks to support and translate research, build up the innovation capacity of our companies to drive economic growth, and leverage science and technology to address national challenges.

a. Marine Science R&D Programme

The national *Marine Science Research and Development Programme* (MSRDP) is a national programme by the NRF, hosted at the NUS. It will integrate R&D in tropical marine science and promote active engagement of industry in the drive towards environmental and marine sustainability. The programme was started with S$25 million over a five-year period. There are four main research thrusts under the programme: (1) the study of marine ecosystems and biodiversity; (2) environmental impact and monitoring; (3) coastal ecological engineering; and (4) marine technology and platforms.

b. Campus for Research Excellence and Technological Enterprise (CREATE)

Approved by the Research, Innovation and Enterprise Council in 2006, the Campus for Research Excellence and Technological Enterprise (CREATE) is an international collaboration of top global universities and research institutes in Singapore conceived with the vision of engaging in cutting edge research. Officially opened on 16th November 2012, it is situated in the NUS University Town (U-Town). CREATE established 15 joint research programmes between our local universities and 10 top overseas institutions (including Massachusetts Institute of Technology, Swiss Federal Institute of Technology in Zurich, and Shanghai Jiao Tong University). As of 2015, CREATE laboratories have collectively produced over 2,350 publications in leading academic journals and worked with more than 100 companies. The research outcomes have also led to eight spin-off companies.

c. Corporate Laboratory @ University Scheme

Launched by NRF in March 2013, the scheme encourages public-private R&D partnerships between universities and companies though the establishment of corporate laboratories in local universities. Keppel Corporate Laboratory is one of those labs that tabs on the practical experience of KOMtech as well as faculty, key laboratories and computational facilities of NUS.[Refer to **Section 8.3** Emerging Ocean Industries, **Subsection 8.3.4.1** Deep Sea Mining; **Subsection 8.3.1** Clean Ships Manufacturing for the examples of innovative projects and studies being undertaken by Keppel.]

13.5.3 Research Centres of Excellence

13.5.3.1 Earth Observatory of Singapore (EOS)

The EOS was officially launched in 2009 to conduct research on geohazards in Southeast Asia and around it and ensure a safer and more sustainable societies.

EOS has two purposes:

1. Obtaining scientific knowledge on some of nature's most complex phenomena.
2. Transferring knowledge on to affected populations so they can use it effectively and in a timely fashion.

13.5.3.2 Singapore Centre on Environmental Life Sciences Engineering (SCELSE)

SCELSE is funded by the NRF and hosted by NTU in partnership with NUS. The Centre likes new insights from the life sciences with expertise from the emerging technologies in engineering and natural sciences to understand, harness and control **microbial biofilm** community. Biofilms is at the centre of SCELSE research.

13.5.3.3 The Technology Centre for Offshore and Marine Singapore (TCOMS)

The Agency for Science, Technology and Research (A*Star) and NUS jointly opened the first national research and development centre for the marine and offshore engineering industry. The aim of TCOMS is to explore opportunities for the industry to "undertake higher-value activities" through global partnerships with industry, research institutions and academia. A key feature at the new centre will be a next-generation **Deepwater Ocean Basin** with simulation capability, including smart sensing and data analytics. The EOS was officially government investment of close to S$107 million into infrastructure as part of the development of TCOMS, it is seen as part of a concerted effort by the Government, industry, institutes of higher learning and research institutes to secure a long-term future for the sector through innovation and transformation.

13.5.4 Agency for Science, Technology and Research (A*STAR)

A*STAR is a statutory board under the Ministry of Trade and Industry (MTI). The agency drives research that advances scientific discovery and technological innovation to further economic growth and prove lives. As a Science and Technology Organisation, they bridge the gap between academia and industries in terms of research and development.

13.5.5 Tropical Marine Science Institute (TMSI)

TMSI is a University-level research institute, and reports directly to the NUS Deputy President for Research & Technology. The institute's research mission cuts across marine and fresh water science and engineering research, addressing national strategic agenda pertaining to environment. These cover a range of disciplines including underwater acoustics, environmental science and monitoring, marine and fresh water biodiversity, aquaculture, marine biotechnology, physical oceanography, eco-hydrology, flood, climate and modelling. TMSI's researchers are organised into four clusters: Acoustic Research Laboratory (ARL), Ecological Monitoring, Informatics and Dynamics Lab (EMID), Marine Biology and Ecology Laboratory (MBEL), and Physical Oceanography Research Laboratory (PORL).[55]

a. The **ARL** focuses on underwater communications and networking, bioacoustics, towed line array and autonomous water vehicles. Apart from defence applications, the team has expertise in development of robotic sensors for real-time water management. Recent research products include the "NUSwan" which has been licensed to a commercial partner and the system operationalized by PUB for water quality monitoring. The team has also developed models for shallow water acoustic communication and particle tracking, and involved in technology development for deep ocean surveys.[56]

[55] NUS tmsi,n.d
[56] NUS arl,n.d

b. The **EMID** actively supports various government agencies for environment monitoring and assessment. Key projects included impact assessments for both freshwater (eg. Nee Soon Swamp Forest) and marine (Johor Straits). The team is heavily involved in an initiative towards formation of a national level marine database. The Climate team within EMID has expertise on flood risk modelling, and involved in a number of international projects for food security and climate change management.[57]

c. The **PORL** has expertise in ocean modelling for local and South China Sea. PORL specialises in the numerical modelling of oceans, coastal areas, water quality, oil spills and the atmosphere. Past projects cover environmental impact assessments, coastal engineering, climate change and oil spills.[58]

d. The **MBEL** is a diverse group with researchers involved in both basic and applied research. The biodiversity team coordinated the Comprehensive Marine Biodiversity Survey in 2010, and continues to update marine biodiversity inventories for Singapore. Current projects include deep ocean biodiversity surveys. Research focus areas include study of meiofauna, sponges, mollusks, polychaetes and crinoids. With respect to applications, MBEL researchers are involved in biosecurity (invasive species), marine antifouling technology development, biotechnology, harmful algae/ biotoxin research, ecotoxicology, aquaculture, coral rehabilitation, green engineering, plastic pollution and marine conservation. Most of the researchers from MBEL are based in SJINML.

St John's Island National Marine Lab (SJINML) – TMSI's marine lab was formed in 2001 and in 2016, the facility has been designated as National Research Infrastructure under the NRF. Managed by NUS, the facility is now open to all researchers, local and international.[59]

Projects based in SJINML include the Clarion Clipperton Zone (CCZ) deep ocean survey, marine invasive species research, antifouling technology development, harmful algal bloom toxin studies, and coral culture and seagrass research. SJINML maintains an outreach office that conducts marine science educational training and workshops, as well as student internships.

13.6 Capacity Development, Technology Transfer and Knowledge Management

13.6.1 Maritime Transport-related Capacity Building Programmes and Initiatives

a. Singapore-IMO Third Country Training Programme

As part of our contributions to the IMO, Singapore supports IMO's *Integrated Technical Cooperation Programme* (ITCP) by providing capacity building for other IMO member States under the Singapore-IMO

[57] NUS emid, n.d
[58] NUS porl,n.d
[59] NUS, n.d.

Third Country Training Programme (TCTP). Since the onset of the Singapore-IMO TCTP, Singapore has provided in-kind technical assistance to over 2,000 participants from over 90 countries, from Africa, the Americas, Asia, Caribbean, Eastern Europe, Middle-East and the Pacific Islands. In Singapore, MPA and MFA fund and implement the Singapore-IMO TCTP.

Among the Singapore-IMO TCTP workshops and seminars conducted are those on the implementation of relevant international/IMO instruments for the prevention of pollution from ships. Some recent examples include:

- Workshop on the "Development of maritime energy efficiency and emission strategies and their implementations" (GloMEEP Workshop on Strategy Development and Implementation), 25-27 September 2017, Singapore
- Regional seminar on the Hong Kong Convention (for Safe and Environmentally Sound Recycling of Ships, 2009), 14 to 16 November 2016, Accra, Ghana
- Regional seminar on the International Convention for the Prevention of Pollution from Ships (or MARPOL Convention) and its recent amendments, 29 August - 2 September 2016, Bangkok, Thailand

b. Future Ready Shipping

To date, Singapore and the IMO have co-organised two editions of the *Future-Ready Shipping (FRS) Conference* in 2015 and 2017. Both editions were held in Singapore and gathered various maritime leaders and professionals from developed and developing countries to exchange views and foster a culture of collaboration in energy efficient technologies and technology transfer. The Conference served as a good platform for capacity building, in particular for developing countries and Small Island Developing States (SIDS), to share their experiences and challenges in implementing energy efficient technologies, and to learn more on technology transfers and the latest trends in energy efficient technologies.

13.6.2 Singapore Cooperation Programme (SCP)

MEWR established the SCP in 1992, a long-running initiative to provide training and capacity building courses for partner countries – conducting 300 courses for 7000 officials from developing countries each year. In 2015 they launched the *Sustainable Development Programme* under SCP to support the 2030 Agenda for Sustainable Development, focusing on climate change adaptation strategies and water quality management.

More recently, MEWR also launched a course on *Sustainable Oceans and Marine Resources*. Through the *IMO Singapore Third Country Training Programme*, also supported by the SCP, Singapore has provided capacity building assistance on the implementation of relevant instruments for the prevention of pollution from ships, such as MARPOL Convention.

13.6.3 PUB's Capacity Building Efforts

a. Engaging Communities on the Value of Water (PUB)

One of Singapore's largest transformations was the **cleaning up of the Singapore Rive**r, which was literally an open sewer in the early days. It was an enormous endeavour that required the efforts of various agencies, and saw the relocation of thousands of street hawkers, squatters, and pollutive industries, such as pig farms, and the removal of over 250 tonnes of rubbish that had accumulated in the river and its banks. The clean-up took 10 years, and when it was completed in 1987, the water was finally clean enough for fish and other forms of aquatic life to return. The successful clean-up of the Singapore River set in motion the plan to create a reservoir in the heart of the city. The mouth of the Marina Channel was dammed through the construction of the Marina Barrage in 2008, bringing about the triple benefits of water supply, flood control, and a place for recreation.

Driven by our vision to make Singapore a "City of Gardens and Water", Singapore launched the *Active, Beautiful, Clean Waters (ABC Waters) Programme* in 2006 to transform utilitarian drains into attractive waterways, bring people closer to water, and improve runoff quality using green cleansing features. 36 ABC Waters sites have been completed as of July 2018, and over 100 potential locations have been identified for island-wide implementation in phases by 2030, so that more people can benefit from the ABC Waters Programme.

Individuals and organisations also contribute towards water-related activities under the *Friends of Water Programme*. This initiative recognises the efforts of the community in helping to spread water messages and keeping Singapore's water supply sustainable. PUB also carries out public education targeted at different segments of the community to raise awareness on water conservation. For example, on the education front, PUB works with the Ministry of Education (MOE), to include, among others, water conservation topics in the school syllabus for students. In addition, Singapore brings partners from the 3P sectors (People, Public and Private) to commemorate *Singapore World Water Day* annually through month-long celebrations in March. Events are organised by the community, for the community, to play their part for the water cause.

b. International Cooperation

Singapore has benefitted from technical assistance and cooperation with the World Bank and UN agencies when it was a fledgling nation in the early years of its nationhood. To give back to the international community, the *Singapore Cooperation Programme* (SCP) was started in 1992. More recently, in support of the UN's 2030 Agenda for Sustainable Development, Singapore launched a new *Sustainable Development Programme* under the SCP, as part of the efforts to continue giving back. Under this Programme, Singapore provides technical assistance and capacity building to developing countries in areas, such as developing sustainable water and sanitation solutions.

Singapore also launched the **Singapore Water Academy** in July 2016, which is a practitioner-focused learning institute in urban water management. Established by PUB, the Academy enhances capability development for water professionals both locally and internationally. The Singapore Water Academy partners the Ministry of Foreign Affairs (MFA) to conduct water-related programmes for ASEAN countries and UN agencies, e.g., UNICEF.

Singapore also works closely with the international community in sharing its experience and know-how. PUB engages international organizations that work on water issues, such as UNESCO, the World Water Council, Global Water Partnership and the Asia Pacific Water Forum, and contributes actively to the discourse on sustainable urban water management. Singapore organises the *Singapore International Water Week* (SIWW), a global platform to share and co-create innovative water solutions. SIWW 2016 attracted over 21,000 participants from 125 countries and regions. In addition, the **Lee Kuan Yew Water Prize**, an international water prize, honours outstanding contributions by individuals or organisations towards solving the world's water challenges and the laureates' achievements in sustainable water solutions have made a difference to cities and people around the world.

13.7 Partnership and Participation Mechanisms

13.7.1 MPA Initiatives to Improve Public Awareness

MPA also organises marine environmental outreach programmes to raise awareness on the importance of protecting the marine environment. The outreach targets youths, schools, and members of the public to inspire them to play a part in protecting the marine environment. Some of these outreach programmes include:

- **Marine Environment School Talks** (suitable for participants of all ages): To help youths understand that marine litter is not just detrimental to the marine ecosystem, but to our health as well, and to teach students the ways they can play a part to protect our marine environment.
- **Clean-up on Kayak** (suitable for participants aged 13 and above): To help youths learn more about marine litter and its impacts by engaging them in the collection of litter found in our waters and shores.
- **Underwater Clean-up through Youth Divers** (suitable for participants aged 17 and above): To help youths learn about marine litter and its impacts by engaging young divers in the collection of underwater marine debris and youth-led sharing initiatives.
- **Poster Design Competition 2018** (suitable for participants aged between 7 to 25): A competition to increase public awareness of marine litter and its impacts, and encourage members of the public to contribute in the protection of our marine environment.
- **Underwater Clean-up Exercise Held in Conjunction with World Oceans Day 2018** (suitable for participants aged 17 and above): An event organised to raise awareness on how Singapore can be both a busy port and an environment rich in biodiversity.

13.7.2 3P Sectors (People, Private and Public)

MEWR, together with its two statutory boards, NEA and PUB the national water agency manages Singapore's limited resource and address Singapore's environmental sustainability with the aid of the 3P sectors – private, public and people.

Under the collective commitment by the (3P) sectors, Singapore has gained worldwide recognition. The government's efforts to raise public awareness and promote action are complemented by proactive businesses, organisations and community and youth groups that have similar programmes. The following NCCS programmes illustrate the collective efforts:

a. Education

Inside and outside of the classroom, Students are exposed to environmental education. Climate change is discussed in subjects such as general paper, economics, geography and the sciences. Students also go on excursion to places such as power stations, incineration plants, meteorological stations and green buildings reinforce the significance of climate change and the ways to reduce emissions. NCCS also regularly organises climate change awareness programmes for schools. These includes the annual *National Climate Change Competition*; the biennial *National Climate Change Youth Conference*; *Stop Melting My Home roving drama* and *Race for the Climate!* programme for primary schools. At the science centre an exhibit is setup to explain the causes and impact of climate change. It also inform the students and members of the public how they can play apart to reduce Singapore's carbon footprint.

b. National, Community and Corporate Programmes

The annual *Clean & Green Singapore campaign* encourages Singaporeans to care for and protect the environment by adopting environment-friendly lifestyles. The project created by the central Singapore Community Development Council (CDC) known as *SWITCH (Simple Ways I Take to Change my Habits)* promotes energy conservation, adoption of the 3Rs and greener traveling methods. CDC staff and grassroot organisations also conduct house visits to inform residents the impact of simple lifestyle changes. An example of the climate change initiative led by NGOs is *Earth Hour*, created by World Wide Fund (WWF) which is held annually. The event encourages the community to switch off their lights for an hour. In playing their part, retailers, such as best Denki, provide consumers the monetary saving offered by energy efficient appliances to guide "greener" purchases of appliances.

c. Capacity Building

Leveraging on the NEA's *3P Partnership Fund,* organisations can co-create environmental education and outreach activities on climate change related topics. 3P Partnership Fund is a grant administered by the NEA, created to encourage organisations and companies from the People,

Private and Public (3P) sectors to work together to develop innovative and sustainable environmental initiatives that promote environmental ownership amongst the local community.

Companies can also participate in NEA's Corporate and Schools Partnership Programme (CASP) to groom young student leaders by establishing joint environmental programmes and providing mentors to transfer technical knowledge.

13.7.3 National Parks Board Initiatives for Raising Public Awareness

Public awareness are pre-requisites for action, hence communication on biodiversity issues, are critical in driving public involvement. The objective of making people aware of the coastal ecosystem is to create awareness, develop an interest in the national heritage and instil a sense of national pride. The fourth thrust of the NCMP is: *Community Stewardship and Outreach in Nature*, and is largely implemented through the *Community in Nature (CIN) initiative*.

NParks hopes to increase appreciation, awareness and understanding of Singaporeans for nature through public seminars, road shows and events, promote volunteerism through biodiversity interest groups and incorporate elements of biodiversity conservation into the curricula of all levels of education.

An example is the *Biodiversity Week* for schools. BioBlitz is a form of collaborative wildlife survey to document as many species of flora and fauna as possible, within a set location, over a defined period of time. Upper primary and secondary school students conduct wildlife surveys in their own campus as part of a nation-wide initiative to document urban biodiversity.

a. National Biodiversity Centre (NBC) Biodiversity and Environment Database (BIOME) System

BIOME is a tool created by NParks and serves as a single repository of biodiversity (flora and fauna, plants and animal information of Singapore) and environment-related data, contributed by the government agencies, educational institutions and NGOs.

It is also a platform for outreach, as the public are able to support the initiative and upload the location and sighting directly to the database via a mobile citizen-science based application, SGBioAtlas.

b. NParks Community in Nature (CIN) Initiative

CIN is a national movement, launched in September 2011, to connect and engage different groups in the community to help conserve Singapore's natural heritage. CIN brings together all of NParks' nature-related events, activities and programmes to better reach out to the community to encourage them to bond over and with nature.

As biodiversity conservation involves many stakeholders, the engagement with the community includes: a) educational and research institutions, b) families, c) corporations and companies, d) non-governmental organisations, e) other agencies, and f) passionate individuals. Some of the CIN initiatives include:

1. Greening Schools for Biodiversity
2. Science Communication for CIN Ambassadors
3. Families for Nature
4. Comprehensive Marine Biodiversity Survey
5. Citizen Science Programmes
6. BioBlitz
7. Marine Eco-toxicity Biomonitoring Programme
8. Intertidal Watch
9. Coral Reef Monitoring Programme
10. Horseshoe Crab Project
11. iSeahorse Singapore Project
12. Seagrass Monitoring by TeamSeaGrass

[Refer to related **Section 12.1** Ecosystem and Biodiversity Conservation and specific examples]

c. NParks Friends of the Parks (FotP)

The Friends of the Parks is a ground-led initiative to promote stewardship and responsible use of our Parks. The initiative is modelled after the successful Friends of Ubin Network (FUN) and was conceived during the SGFuture conversations held at the Future of Us Exhibition at the beginning of 2016.

FotP initiative consists of localised communities representing active stakeholders and volunteers in our parks. Likewise, Friends of the Marine Park is a community comprising boaters, divers, scientists, fishermen and more, who will work on projects to conserve the island. The community will see dive professionals helping to maintain the dive trails at the SIMP and developing guidelines for kayakers entering the marine park.

13.7.4 PUB Singapore's National Water Agency

PUB works with the various stakeholders to ensure water sustainability. The community are encouraged to participate in PUB-led programmes and events.

The World Water Day, a day designated by the United Nations to celebrate the importance of water sustainability, is a nationwide event held annually. In Singapore, the theme for 2018 has been localised and named "Make Every Drop Count" to reflect the importance of water conservation

in the equation of water supply and demand management. *Singapore World Water Day* (SWWD) is a platform used to celebrate and encourage the community to conserve, value and enjoy water.

PUB also works closely with schools and the MOE to inculcate in students, the important value of conserving and enjoying our water resources. School Programmes includes

1. The NEWater Scientist Programme
2. Rain Garden Workshop
3. Geographical Investigation Field Studies
4. Water Ambassador Programme

On a constituency level, PUB works at the grassroots level to encourage residents to take ownership of their water resources. PUB also highlights to residents the importance of keeping drains and waterways clean. PUB also works alongside NGOs and public/private sectors to instill the appreciation for the environment and resources. These are NGOs that are passionate and committed to conserving Singapore's resources.

[Refer to related **Section 8.1.1** Background to Singapore's Sustainable Water Story, **Subsection 8.1.1.4** Public Awareness and Changing Consumption Growth and Patterns]

13.7.5 Other Outreach Initiatives

Waterways Watch Society (WWS) is a special volunteer group that aims to monitor, restore and protect the aesthetics of Singapore's waterways. WWS aspires to bring the community together to love the waters and to inspire stewardship for our environment.

The Nature Society (Singapore) (NSS) is a non-profit organisation dedicated to the appreciation, conservation, study and enjoyment of the natural heritage in Singapore, Malaysia and the region. Run by volunteers, NSS works closely with PUB to conduct the following programmes:

1. Quarterly bird watching walks for the community at Kranji Marshlands and Lorong Halus Wetland
2. Biodiversity surveys to improve bird habitats at Kranji Marshlands

13.8 Meeting International Commitments

Singapore contributes to global efforts in charting a sustainable development pathway for the world. This year, Singapore will undertake its *first Voluntary Review* of the UN Sustainable Development Goals under the 2030 Agenda for Sustainable Development to reflect Singapore's strong commitment towards implementing the SDGs. Singapore will also continue to do its part to fulfil commitments made under the UNFCCC Paris Agreement on climate change. Singapore has designated *2018 as the Year of Climate Action* to rally ground efforts to take climate action.

13.8.1 Multilateral Agreements and International Conventions

To date, Singapore has acceded to or ratified 25 multilateral agreements relating to the environment and sustainable development as listed in **Table 13.3**.

Table 13.3: Multilateral Environmental Agreements and International Conventions Acceded to or Ratified by Singapore.*

Date of ratification	Convention	Status	Focal Agency
POLLUTION			
1989	Vienna Convention for the Protection of the Ozone Layer	Acceded to/ratified	MEWR, NEA
1989	Montreal Protocol on Substances that Deplete the Ozone Layer	Acceded to/ratified	MEWR, NEA
1993	London Amendment to Montreal Protocol	Acceded to/ratified	MEWR, NEA
2000	Copenhagen Amendment to Montreal Protocol	Acceded to/ratified	MEWR, NEA
2000	Montreal Amendment to Montreal Protocol	Acceded to/ratified	MEWR, NEA
2007	Beijing Amendment to Montreal Protocol	Acceded to/ratified	MEWR, NEA
1996	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Acceded to/ratified	MEWR, NEA
2005	Stockholm Convention on Persistent Organic Pollutants	Acceded to/ratified	MEWR, NEA
2005	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Acceded to/ratified	MEWR, NEA
2017	Minamata Convention on Mercury	Acceded to/ratified	MEWR, NEA
BIODIVERSITY CONSERVATION			
1986	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	Acceded to/ratified	AVA
1995	Convention on Biological Diversity (CBD)	Acceded to/ratified	NParks
CLIMATE CHANGE			
1997	UN Framework Convention on Climate Change (UNFCCC)	Acceded to/ratified	NCCS
2006	Kyoto Protocol to United Nations Framework Convention on Climate Change	Acceded to/ratified	NCCS
2014	Doha Amendment to Kyoto Protocol to United Nations Framework Convention on Climate Change	Acceded to/ratified	NCCS
2016	Paris Agreement on Climate Change**	Acceded to/ratified	NCCS

Table 13.3: Multilateral Environmental Agreements and International Conventions Acceded to or Ratified by Singapore.* (cont.)

Date of ratification	Convention	Status	Focal Agency
SHIPPING/MARITIME			
1994	United Nations Convention on the Law of the Sea (UNCLOS)	Acceded to/ratified	MFA/AGC/MOT***
1990-2005	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) and Annexes I to VI	Acceded to/ratified	MPA
1999	International Convention On Oil Pollution, Preparedness, Response & Cooperation 1990 (OPRC)	Acceded to/ratified	MPA
2003	Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances 2000 (OPRC-HNS Protocol)	Acceded to/ratified	MPA
2010	International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001 (AFS)	Acceded to/ratified	MPA
1997	International Convention on Civil Liability for Oil Pollution Damage, 1992 (CLC 92)	Acceded to/ratified	MPA
1997	Protocol of 1992 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 (Fund 92)	Acceded to/ratified	MPA
2006	International Convention on Civil Liability for Bunker Oil Pollution Damage 2001 (bunker Convention)	Acceded to/ratified	MPA
2017	International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (Ballast Water Management Convention)	Acceded to/ratified	MPA

Note:
* The table of multilateral agreements is non-exhaustive
** Singapore has ratified the Paris Agreement, and intends to reduce its Emissions Intensity by 36% from 2005 levels by 2030, and stabilise its emissions with the aim of peaking around 2030. Singapore is also on track to meeting our earlier 2020 pledge of a Business-As-Usual (BAU) minus 16% emissions target. Information on our progress towards meeting this target can be found in Singapore's 2nd Biennial Update Report.
*** UNCLOS falls under the purview of AGC/MFA/MOT. MFA acts as the focal point.

13.8.2. Regional Mechanisms

Singapore is also a member of several regional mechanisms and works closely with other regional organisations in the areas of sustainable development and the environment, with MEWR or its subsidiary agencies being the national focal point for many of the regional partnerships (**Table 13.4**). Singapore works with the ASEAN for the protection of the environment, and biodiversity conservation.

Table 13.4: Regional Mechanisms.*

Signed in	Regional mechanism	Focal Agency
2003	PEMSEA Putrajaya Declaration on the Sustainable Development Strategy for the Seas of East Asia.	MEWR
2006	PEMSEA Haikou Partnership Agreement for the Implementation of the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA)	MEWR
2009	PEMSEA Manila Declaration on Strengthening on the Implementation of the Sustainable Development and Climatic Change Adaptation of the East Asian Seas	MEWR
2012	PEMSEA Changwon Declaration Toward an Ocean-based Blue Economy: Moving Ahead with the Sustainable Development Strategy for the Seas of East Asia	MEWR
2015	PEMSEA Da Nang Compact on The Sustainable Development Strategy for the Seas of East Asia 2015	MEWR

Note: * The table of regional mechanisms is non-exhaustive.

13.8.2 International Commitments in Biodiversity Conservation

Biodiversity conservation requires concerted efforts across multiple levels – national, regional and international. Singapore fosters strategic partnerships with regional and international organisations and facilitates collaboration on the conservation of biodiversity across national boundaries by sharing our experience and expertise on conservation in an urban context via our participation in key biodiversity-related regional and international fora.

On the international front, Singapore entered into the CBD, which is an international agreement for the conservation of biodiversity, the sustainable use of its components and the fair and equitable sharing of benefit from the use of generic resources. The CBD entered into force in 1993 and Singapore subsequently became a Party to in 1995, for which NParks is the national focal point. As a party to the CBD, Singapore has an obligation to develop its own set of strategy and action plans to conserve biodiversity. [Refer to **Section 13.3.4** Singapore's Nature Conservation Masterplan (NCMP) and National Biodiversity Strategy and Action Plan (NBSAP)]

At the regional level, under the framework of *ASEAN Cooperation on Environment*, NParks is the national focal point for the ASEAN Working Group on Nature Conservation and Biodiversity, and is a governing board member of the ASEAN Centre for Biodiversity. It is also co-focal point with NEA for the ASEAN Working Group on Marine and Coastal Environment (AWGCME).

PART 6

CONCLUSION AND RECOMMENDATIONS

14 Summary and Conclusion

14.1. Overall Assessment of the State of Ocean Economy and Ocean Health

Singapore is a highly urbanised island city-state with no hinterland. The sea is at the doorstep of our city – our coastline is inextricable from our urban surroundings. Within this context, Singapore's coastal and marine activities, including biodiversity conservation, take place within a limited sea space.

14.1.1 State of Our Ocean Economy

In the last 50 years since its independence, Singapore's coastal and marine areas have become heavily utilised by various industries, particularly port operations, ship building and petrochemical industries, as well as non-industrial uses like residential development and recreation. At any time, over 1,000 vessels may be plying Singapore's waters. The coastal waters are also home to the country's only offshore landfill and several marine aquaculture farms. In fact, nearly all coastal or marine areas in Singapore are no more than half a kilometre from any human-related activity.

Singapore's maritime industry is a key pillar of Singapore's economy. Made up of shipping, port, maritime services and offshore & marine engineering sectors, Singapore's maritime industry contributes 7% of Singapore's Gross Domestic Product (GDP) and employs over 170,000 people. Singapore is committed to developing a maritime transport industry that is not only competitive and efficient, but also responsible and sustainable.

Other industries, such as fisheries and aquaculture, marine and coastal tourism, oil refinery, and oil and gas (O&G) equipment and services, also contribute to Singapore's ocean economy. There is a need to further develop the ocean accounts of Singapore, including ecosystem service valuation, to be able to assess the contribution of the oceans to Singapore's economy, social development and well-being, innovative transformations, and resiliency.

Singapore industrialised through an import-substitution strategy to reduce its reliance on entrepôt trade. The country also established various economic agencies to spearhead different aspects of its economic development, such as the EDB in 1961 and the STB in 1964. From 1960 to 1964, Singapore's gross domestic product (GDP) growth averaged 5.2% per annum (p.a.), while the manufacturing sector's share of GDP grew from 11% to 13%. This later increased

significantly between 1965 to 1978, when Singapore's GDP growth averaged 10% p.a., with the manufacturing sector's share of GDP growing rapidly from 14% to 24% – largely due to the adoption of an export-oriented strategy by attracting foreign investors to Singapore to develop the manufacturing and financial sectors.

14.1.2 State of Our Seas and Coastal and Marine Ecosystems

Despite growing urbanisation, Singapore's coastal and marine environment continues to support a diverse range of habitats and biodiversity. Although the country's intertidal and sub-tidal reef areas are just over 12 km^2 in size, they are home to over 250 hard coral species, 12 seagrass species, 100 marine fish species, and countless others. We consider this biodiversity as part of our natural heritage that we strive to conserve and protect.

The country's fragile marine environment needs to be carefully managed and preserved in a holistic and integrated manner for the benefit of future generations. This is why the government ensured that the marine and coastal environment is not compromised by urban development, and that the marine environment conservation strategies are in-line with broader sustainable development efforts. As such, Singapore approaches marine biodiversity conservation through its unique *Integrated Urban Coastal Management* (IUCM) approach.

Singapore's marine conservation and management strategies are captured under the *Marine Conservation Action Plan* (MCAP), which guides efforts at conserving Singapore's marine habitats and biodiversity. The MCAP is an evolving plan, grounded in science to meet the current and future conservation needs of Singapore's coastal and marine environment. The MCAP include the following key activities: (1) Physical safeguarding; (2) Species Recovery; (3) Habitat Enhancement; and (4) Community Stewardship.

14.2 Sustainable Development is a Journey

Sustainable development has underpinned Singapore's policymaking since its independence. As a small island city-state, Singapore had relied on maritime trade as an entrepôt port. Upon independence on 9 August 1965, Singapore essentially lost its hinterland. Singaproe was almost entirely dependent on external sources for basic needs like food, energy, and water. The future was uncertain. Many were sceptical that Singapore could survive on its own, let alone prosper.

Under these dour circumstances, Singapore's pioneer team of leaders set out to transform Singapore into a viable nation-state. Faced with limited land and resources, its pioneer leaders had to quickly address pressing concerns while adopting a long-term perspective in policymaking. They concentrated efforts in developing education, security, infrastructure, healthcare, and housing, while bearing in mind the need to be prudent and strategic so as to maximise resources. To sustain its growth and keep up with the times, successive generations of leaders made a conscious effort

to continually re-invest the resources that its economy has generated into the development of human capital, research & development, and the identification of new areas of growth. They searched for ways to create and add value, and focused on ensuring that the Singaporean people were well-equipped with the knowledge and skills to take on the jobs of the day.

In pursuing economic development, Singapore has been careful not to disrupt its natural environment. A Garden City abundant with lush greenery and clean surroundings was created to make life more pleasant for people to live, work, and play in. We chose clean energy solutions. Today, Singapore is widely-recognised as a City in a Garden, with nearly 50% green cover and 72 ha of rooftop gardens and green walls. Singapore is among the 20 most carbon-efficient countries, and natural gas generates 95% of its electricity. For Singapore's leaders, it was no mean feat to maintain this delicate balance between economic, social, and environmental priorities to achieve long-term, sustainable development.

To effectively develop and implement integrated and sustainable policies, Singapore adopts a *Whole-of-Government* (WOG) approach. The WOG approach entails the sharing of information among public agencies, thus, widening agencies' worldviews, and emergent challenges and opportunities are uncovered early. Agencies assess problems from multiple perspectives, and better consider the spill-over effects of policy actions and implications on each other's plans. As challenges become increasingly complex and cross-cutting, the WOG approach has grown in importance and serves as the national planning framework.

Singapore also adopted a *Whole-of-Nation*, bottom-up approach to develop creative, sustainable solutions. We support and collaborate with multiple stakeholders, to realise desired and holistic outcomes. For example, as Singapore works towards building a smart city, we have adopted a people-centric approach and consult extensively with the private sector and civil society, who supply the know-how, and citizens, who provide feedback for continuous improvement. This approach also secures greater buy-in and commitment to action by all segments of society.

Sustainable development is a journey. Maintaining the momentum on this journey requires constant commitment and attention to the landscape of opportunities and challenges ahead, even as we celebrate our progress.

14.3 Challenges and Opportunities

Looking ahead, we anticipate many challenges to Singapore's continual growth and development. We must be resilient and innovative to overcome these challenges. **Table 14.1** summarises challenges and opportunities for Singapore.

Table 14.1: Challenges and Opportunities for Blue Economy.

Challenges	Opportunities
Limited Land As Singapore's population and economy grow, we will need to continually optimise the use of our limited land, whether through redevelopment, planning, or building underground in order to keep up with demand.	**New Growth Districts** One of our strategies to optimise space is by rejuvenating our spaces. This includes redeveloping our *Greater Southern Waterfront* region after the relocation of existing city terminals to Tuas, and the redevelopment of the Paya Lebar Air Base, after its relocation to Changi. **Spatial Strategies** Strategies to encourage sustainable development include setting up economic centres outside the traditional central business district, such as Changi Business Park in the East and One-North in the West. In tandem, we are planning for more housing in central Singapore to enable more people to work nearer their homes. **Underground Infrastructure** We are exploring options to shift more of our transport and utilities infrastructure and storage facilities underground. Some examples under study include an *underground goods mover system* to reduce freight transport on roads, underground electrical substations and rock caverns for stormwater drainage and storage to increase our water resilience.
Habitat Fragmentation Although Singapore continues to support habitats around our main coastline and within our offshore islands, habitats are fragmented and occur in isolated patches.	**Maintaining Ecological Stepping Stones** Unlike fragmented terrestrial habitats that can become ecologically isolated, fragmented but hydro-dynamically connected coastal and marine areas can generally maintain ecological connectivity through a network of "stepping stones" – smaller habitat patches or fragments that facilitate movement of populations between larger ones. A study of the ecological connectivity of Singapore's mangrove, intertidal and sub-tidal habitats indicated that despite the spatial fragmentation, ecological connectivity continues to be maintained across all habitats due to the continued presence of these "stepping stones". Thus, a key strategy in Singapore's coastal and marine conservation efforts is to **map out these "stepping stones"** to ensure they are adequately maintained for continued ecological connectivity.

Table 14.1: Challenges and Opportunities for Blue Economy. (cont.)

Challenges	Opportunities
Habitat and Biodiversity Loss Given the rapid pace of Singapore's growth and limited land, shallow coastal and marine areas can be lost with urbanisation.	**Habitat Enhancement, Restoration and Species Recovery** To ensure the long term sustainability of Singapore's coastal and marine habitats, concerted efforts are required to restore and enhance lost or degraded areas. In many circumstances, habitat enhancement, restoration and creation offer opportunities for species recovery initiatives for endemic, critically endangered, rare and re-discovered species. An important element of the MCAP are the coastal and marine habitat enhancement and restoration efforts, which have been carried out since 2008. For instance, an innovative coastal protection and restoration of mangrove biodiversity project was implemented along a severely degraded mangrove area which incorporated both hard and soft engineering solutions to arrest coastal erosion and restore the mangroves. More recently, purpose-built and nature inspired intertidal units were fabricated and installed along one of Singapore's armoured coastal revetment to increase surface complexity and provide micro-niches to enhance intertidal biodiversity. Separately, a habitat enhancement and restoration framework was developed for the SIMP, with the implementation of reef enhancement units to enhance degraded reef areas coupled with a donor-supported *Plant-a-Coral, Seed-a-Reef* species recovery programme to propagate and out-plant locally rare coral species. A giant clam propagation and reintroduction programme was also initiated to reintroduce the locally extinct *Tridacna gigas* species and increase the numbers of two other locally rare *T. squamosa* and *T. maxima species*.
Water Security and Weather Resilience Conventional water sources– local catchments and imported water – face several threats, including weather uncertainties and pollution.	**Cutting-Edge Technology** We have invested in other water supply sources in the form of *NEWater* and desalination. We are progressively building up these sources ahead of demand to ensure the resilience of Singapore's water system in the long term. During dry months, a small amount of NEWater can be injected into local reservoirs to maintain healthy stock levels. The water from the reservoirs is treated for potable use at the water treatment plants. This ensures that adequate drinking water can be provided for all. By 2020, Singapore will have two additional desalination plants. To bring down the cost and energy used for desalination, and ensure its long-term viability, we are exploring other forms of technology to extract freshwater from seawater. This involves plans to scale up the demonstration of *electrodeionisation* (EDI) technology, which uses an electric field to extract dissolved salts from water. Our target is to halve desalination's energy usage. These challenges also present us with the opportunity to expand our water industry. Water was identified as a strategic growth sector in Singapore in 2006 with technology development as a key driver. A total of S$670 million in funding was set aside to promote R&D and grow the industry.

Table 14.1: Challenges and Opportunities for Blue Economy. (cont.)

Challenges	Opportunities
Increased Water Demand As the proportion of non-domestic water use is expected to increase from 55% of water demand today, to 70% by 2060, we have to better manage our water system to ensure the sustainability of our water supply without compromising economic growth.	**Infrastructure Planning & Innovation** Singapore's approach is to plan for our water infrastructure ahead of demand. We have also worked with industry partners to develop a *Smart Water Grid*, a network of wireless sensors installed in potable water supply mains across Singapore, which functions as a real-time platform to monitor water pressure, flow and quality. The system provides decision support tools for network management and allows early detection of anomalous network occurrences, enhancing the efficiency of water supply to consumers. This helps minimise losses of water due to leaks and ensures a reliable water supply.
Energy Security and Diversification of Energy Sources In Singapore, we have limited renewable energy options, with most of our electricity generated using natural gas. Singapore does not have hydro resources, our wind speeds and mean tidal range are low, and geothermal energy is not economically viable.	**LNG and Solar** LNG enhances our energy security as it allows us to source for natural gas globally. To meet Singapore's gas demand, we launched a two-stage Request for Proposal (RFP) in June 2014 to appoint up to two new LNG importers to supply Singapore's next tranche of LNG. The appointment of two new LNG importers and the flexibility for any gas user to source LNG from the spot market contribute to the development of more competitive and dynamic gas and electricity markets in Singapore. As of end-2017, solar PV deployment in Singapore has risen to around 143 Mega Watt peak (MWp). In order to ensure that our national grid can support the greater deployment of solar energy, we are investing in system-level solutions such as solar forecasting and energy storage technologies to manage intermittency. For example, in October 2017, two consortiums were appointed to implement Singapore's first utility-scale *Energy Storage System* (ESS). A total of 4.4 megawatt hour of grid-storage solutions will be deployed in two substation locations. This project aims to evaluate the performance of different ESS technologies under Singapore's hot, humid and highly urbanised operating environment. Insights gained from the test-bed would help establish clear technical guidelines for ESS deployment (e.g., grid connection and safety requirements for installation) to catalyse the use of ESS in Singapore. The Energy Market Authority (EMA) had also launched a consultation paper to seek industry feedback on the policy framework for energy storage systems.
Reducing Singapore's Emission Intensity Under the Paris Agreement, Singapore has pledged to reduce our emissions intensity by 36% from 2005 levels by 2030, and to stabilise our emissions with the aim of peaking around the same time.	**Deploying Mitigation Measures** Our suite of mitigation measures is aimed at improving energy efficiency, increasing the deployment of renewable energy, and fostering technology and innovation. Promoting more efficient use of energy is a key part of our mitigation strategy. We have adopted a mix of regulations, incentives, and capability building measures to encourage energy efficiency improvements in the industrial, buildings, transport, and household sectors. For example, we have recently enhanced the *Energy Conservation Act* to strengthen energy efficiency practices among companies, and there are plans to implement *Minimum Energy Performance Standards* (MEPS) for common industrial equipment. The Government also provides grants and support to help companies perform energy audits, enhance energy efficiency and reduce emissions.

Table 14.1: Challenges and Opportunities for Blue Economy. (cont.)

Challenges	Opportunities
	Singapore will implement a **carbon tax** across all sectors without exemption from 2019. This will send a transparent, fair and consistent price signal across the economy to incentivise emission reduction in the most economically efficient way.
Impact of global shifts on Singapore's small and open economy Structural shifts in external environment and demographic trends.	**Leverage opportunities to innovate, deepen capabilities, remain connected and stay relevant** In the future economy, the workforce in Singapore should have in-depth skills and be motivated towards life-long learning, businesses should be innovative and nimble, our city connected and vibrant, continually renewing itself, and the Government coordinated, inclusive, and responsive. To this end, the CFE has identified seven mutually reinforcing strategies: • Deepen and diversify our international connections • Acquire and utilise deep skills • Strengthen enterprise capabilities to innovate and scale up • Build strong digital capabilities • Develop a vibrant and connected city of opportunity • Develop and implement Industry Transformation Maps • Partner each other to enable innovation and growth
Changing Demographics Our population is expected to age rapidly, with the number of Singaporeans over 65 years of age and above doubling to 900,000 by 2030. The dependency ratio is also expected to decrease, with only two working adults supporting each elderly person by 2030.	**An Enabling City** Singapore aims to capitalise onthe changing demographics by transforming the country into an enabling place for seniors to live independently and comfortably while remaining integrated in the community. For example, we have introduced barrier-free accessibility, more seating and community spaces in housing estates, and a programme to equip flats with senior-friendly fittings such as grab bars and slip-resistant floor tiles. To better engage our seniors, there are integrated spaces with senior facilities, such as day care, and health and community programmes in our estates. We are enhancing our parks with senior-friendly amenities. We will be piloting a network of ten therapeutic pocket gardens based on horticulture therapy to support seniors with dementia and post-stroke patients through the provision of contemplative spaces and activity zones.
Future Waste Management In 2017, Singapore generated about 7.7 million tonnes of waste. The amount of waste generated is expected to increase in tandem with population and economic growth. The household recycling rate was 21% in 2017. At the same time, our manpower constraints limit the resource available for our waste management industry.	**Finding Innovative Solutions** Apart from continual public education on waste minimisation and recycling, there is a need for innovative solutions to make recycling convenient for households. Singapore is also studying the benefits of *smart waste collection systems* to optimise waste collection operations, manpower and resources. This includes leveraging technologies, such as bin fill sensors, a smart card access system for waste disposal chutes, and the use of side-loader bins that require only one operator to carry out recyclables collection. In addition, Singapore will be reaping synergies from the water-energy-waste nexus at our upcoming signature *Integrated Waste Management Facility* (IWMF), which will be integrated with the *Tuas Water Reclamation Plant* (TWRP). This will allow for synergies, such as effluent water from wastewater treatment being used for cooling waste incineration equipment; while food waste can be co-digested with used water sludge to enhance biogas production to increase the overall plant thermal efficiency. Integrating the facilities will also reduce carbon emissions by more than 200,000 tonnes annually.

Table 14.1: Challenges and Opportunities for Blue Economy. (cont.)

Challenges	Opportunities
Limited Scope for Deploying Renewable Energy With limited land and geography, available resources, technology options, and other domestic considerations, we are faced with constraints on our ability to deploy alternative energy. Singapore's small size and high urban density limits the extent to which large amounts of alternative energy can be commercially deployed. While solar energy is the most promising renewable energy option, competing land uses and high cloud cover mean that we are not able to generate sufficient baseload electricity from solar based on current technologies.	**Develop Options to Further Deploy Renewable Energy** To increase solar photovoltaic (PV) deployment in Singapore to 350 MWp by 2020, and to 1GWp beyond 2020, we are investing in R&D as well as test-bedding to improve the performance of solar PV systems and develop innovative ways of integrating solar and other alternative energy systems into our urban environment. Some of our projects include: • Housing and Development Board (HDB) has launched an initiative to install solar panels on rooftops of high-rise public housing developments. • The EDB's and PUB's *floating photovoltaic (PV) project* currently pilots ten systems of 1MWp total floating solar panel installations on water surfaces at Tengeh Reservoir. • As part of the *Renewable Energy Integration Demonstrator*, Singapore's first long-span wind turbine was installed at an offshore landfill in October 2017. It is sensitive enough to generate power with wind speeds as low as 3m per second. We hope to develop "*hybrid micro-grids*" in the next few years. • To support the solar ecosystem in Singapore, the *SolarNova programme* led by EDB and HDB aggregates solar demand across government agencies. This move is crucial to building up local expertise in solar manufacturing, project development, system integration, financing, and to encourage greater adoption of solar energy.
Climate Science Expertise We will undertake efforts to enhance our climate science capability and better understand the diverse impacts of climate change on Singapore and the wider region.	**Further Enhance Resilience** As the country enhances its understanding on climate science and the climate change impacts on Singapore, the adaptation plans are flexible enough to accommodate future adaptation needs and the latest science. Singapore will continue to collaborate and share information on climate science and challenges arising from climate change impacts with international partners through various channels, including the WMO Regional Office for Asia and the South-West Pacific located in Singapore. We are also exploring opportunities with the WMO Regional Office to enhance cooperation among the national meteorological and hydrological services in the 58 states and territories under its charge, and with the wider scientific community. For instance, the *Southeastern Asia-Oceania Flash Flood Guidance* (SAOFFG) aims to provide real-time information on small-scale flash floods to disaster management agencies in Brunei Darussalam, Indonesia, Malaysia, Papua New Guinea, the Philippines, Singapore and Timor-Leste.

14.4 Examples of Initiatives for Blue Economy

14.4.1 Coastal and Marine Habitat and Biodiversity Conservation

14.4.1.1 Marine Conservation Programmes

The Sisters' Islands Marine Park (SIMP) was established in 2015 as Singapore's first marine park. Located to the south of mainland Singapore on Sisters' Islands, the SIMP spans 40 hectares, and its surrounding areas and houses a wide range of marine habitats, including coral reefs, sandy shores and seagrass areas. The SIMP showcases Singapore's sub-tidal coral reef and shallow sea-

floor areas, in addition to the unique biodiversity within the inter-tidal areas and coastal forests. The SIMP provides Singaporeans and visitors with a unique recreational experience while educating them about our marine natural heritage. At the same time, the SIMP allows us to protect and safeguard our rich marine biodiversity, facilitates cutting-edge research, and provides opportunities to test-bed habitat rehabilitation, restoration and enhancement technologies.

14.4.1.2 Marine Conservation Programmes

Singapore's marine conservation and management strategies are captured under the Marine Conservation Action Plan (MCAP), which guides our efforts at conserving Singapore's marine habitats and biodiversity. The MCAP is an evolving plan grounded in science to meet the current and future conservation needs of Singapore's coastal and marine environment.

Species recovery is important to safeguard the survival and sustainability of species native to or of particular significance to Singapore. It is a key activity under the MCAP. Working with key research partners, we have initiated the following marine species recovery programmes:

- Marine turtles (*Eretmochelys imbricata* and *Chelonia mydas*);
- Giant clams (*Tridacna squamosa*, *T. maxima* and *T. gigas*);
- Neptune's Cup Sponge (*Cliona patera*); and
- Several locally rare hard and soft coral species.

The SIMP is the focal point for the species recovery programme, where strategies and methods are tested and monitored before applying them to other coastal and marine areas in Singapore. We also have plans to induct more species into the programme.

We have also installed biodiversity enhancement units around Singapore to help existing biodiversity within Singapore's coastal and marine habitats flourish. These include the creation of inter-tidal pools and surface complexity enhancements along coastal seawalls, and the use of enhanced floating structures that increase visibility and bring marine biodiversity closer to the people.

14.4.1.3 Involving the Community as Stakeholders

Successful nature conservation initiatives are intrinsically linked to cultivating mind-sets and behaviours that value nature appreciation. Thus, community outreach and stewardship programmes are vital in encouraging nature conservation efforts with members of the public and other stakeholders. Building on the pool of volunteers nurtured through

community engagement projects like the Comprehensive Marine Biodiversity Survey, the MCAP keeps these volunteers engaged in nature appreciation and conservation through talks and workshops, SCUBA diving, citizen science activities and nature ambassador opportunities.

The SIMP and other initiatives like the Ubin Living Lab are focal points for complementary community stewardship programmes under the MCAP. Activities, such as guided intertidal walks, have begun at the SIMP, as well as other outreach activities and events organised in conjunction with a number of NGO stakeholders, such as the Marine Conservation Group of the Nature Society of Singapore, Our Singapore Reefs, Hantu Bloggers, and other various academic partners.

MPA also organises outreach programmes to raise awareness and inspire youths, schools, and members of the public to play a part in protecting the marine environment.

14.4.1.4 Research and Test-Bedding of New Technologies

Science-based decision-making ensures successful and sustainable implementation of nature conservation initiatives. Singapore has invested in key areas of applied research that will help fill knowledge gaps in the development and implementation of nature conservation policies. At the same time, the scope and scale of research have expanded to include developing new tools and techniques to better understand and manage the coastal and marine environment.

Research at the SIMP addresses marine genetic connectivity, climate change and its impacts on marine biodiversity, and the application of clean and renewable sources of energy. In addition, MPA and the NUS's Centre for International Law (CIL) established the CIL-MPA Oceans Governance Research Programme in April 2016 to contribute to the greater understanding of maritime law and ocean governance. The Programme has generated research publications and presentations at academic journals and international platforms, as well as convened conferences and roundtable workshops to share and discuss research findings with experts from governments, intergovernmental organisations, industry and academia.

14.4.2 Sustainable Maritime Transport

Singapore is committed to developing a maritime transport industry that is not only competitive and efficient, but also responsible and sustainable.

As part of the efforts to promote clean and green shipping in Singapore, the Maritime Singapore Green Initiative (MSGI) was launched in 2011 to reduce the environmental impact of shipping and

shipping-related activities on the coastal and marine environment. The MPA pledged to invest up to S$100 million over five years under the MSGI's three programmes: The *Green Ship Programme*; *Green Port Programme*; and *Green Technology Programme*. In July 2016, the MSGI was extended to 31 December 2019 and further enhanced. Two new programmes were introduced: The *Green Awareness Programme*, and the *Green Energy Programme*. Among the various initiatives, ship owners are encouraged to adopt environmentally-friendly practices and reduce the environmental impact of their operations through voluntary programmes. The MSGI also supports local maritime technology companies in developing and deploying green technologies through co-funding grants of up to 50% of the qualifying costs.

Singapore has also put in place strategies to address oil and chemical spills and other maritime incidents in the marine environment, such as the *Marine Emergency Action Procedure*. Regular emergency exercises are conducted to ensure operational readiness in responding to such incidents. For example, the multi-agency *ChemSpill exercise* simulates a chemical spill, and tests agencies' capabilities and co-operation to combat chemical pollution. The exercise is conducted every alternate year in conjunction with the biennial International Chemical and Oil Pollution Conference and Exhibition (ICOPCE).

Singapore also actively supports international cooperation efforts on sustainable maritime transport. In 2015 and 2017, the country worked with the IMO to co-organise two editions of the Future-Ready Shipping (FRS) Conference in Singapore. The FRS Conference gathered maritime leaders and professionals worldwide to exchange views and foster collaboration on energy-efficient maritime transport technologies. It also served as a platform for capacity building for developing countries and Small Island Developing States (SIDS).

MPA also works with the IMO to provide capacity-building courses for countries under the MPA-IMO Third Country Training Programme (TCTP). The MPA-IMO TCTP offers courses on the implementation of relevant IMO instruments, including those that protect the marine environment through the prevention of pollution from ships.

ANNEXES

Annex A: Summary Tables

Annex A.1. Status of Singapore's Coastal and Marine Habitats.

Habitat	Area (km^2)	Status
Mangroves	6.59	Singapore currently has some 35 'true' mangrove plant species, which comprise more than half of the 70 'true' mangrove species found in Asia Mostly occurring along the northern shores and several off-shore islands of Singapore, the remaining forests are estimated to comprise a total area of 6.59km. The largest patches of mangrove are found at Sungei Buloh Wetland Reserve, Pulau Ubin, and Pulau Tekong. While mangrove diversity is high, species are usually represented by small population numbers. About 45 per cent of mangrove species are currently considered endangered or critically endangered. **Pressures and threats**. Development pressures, such as damming up of rivers (to form reservoirs) and canalisation of streams or waterways, land reclamation and natural degradation such as coastal erosion have resulted in the reduction of mangrove forest, which in turn drive out species dependent on mangrove habitats for survival. The threat of rising sea levels may also inundate coastal areas and mangroves.
Coral reefs (sub-tidal)	1.26	Coral reefs consist of fringing and patch types, with live coral cover ranging between 10 to 60 per cent of existing reefs. There are about 250 species of hard coral from 55 genera which accounts for more than 25 per cent of the world's coral species. The reefs support over 120 species of reef fish and undetermined number of gorgonians, nudibranchs and other invertebrates. Synchronised mass spawning of corals has been observed at Singapore reefs (Guest, et al., 2002) indicating that the reefs are healthy and breeding. **Pressures and threats**. Threats to coral reefs are coastal development, modifications and climate change. Urban development pressure along Singapore's coast in the past decades has decreased the coral reef cover by about 60 per cent (Chou, 2016; Burke, et al., 2002).
Intertidal (including seagrass, mudflats, reef flats, rocky shores, and sandy beaches)	15.84	Due to Singapore's semi-diurnal tides, the plants and animals in the intertidal areas are exposed to the air twice a day. The communities experience a wide range of stresses associated with tidal range and wave action. Rocky shores used to dominate the southwestern coastline and some southern islands of Singapore, but much of it has been reclaimed. The coastline along the northern shore consists predominantly of sandflats and mudflats. Singapore's seagrass species diversity is relatively high with 12 out of the total 23 Indo-Pacific species. The larger seagrass meadows are currently found at Chek Jawa on Pulau Ubin, Pulau Semakau and Cyrene Reef. **Pressures and threats**. Development pressures and coastal modifications continue to be the main threats to Singapore's remaining intertidal habitats. Sedimentation and water clarity issues stemming from coastal works also threaten the marine biodiversity in Singapore's waters.

Value of ecosystem services (US$, in millions)	N.A
Marine protected areas (% of territorial waters)*	1.5%
ICM (% of coastline)	100%

* *World Bank, 2017. The Green Little Data Book 2017.*

Annex A.2. Marine Water Quality.

Parameters Monitored		Water Catchment Streams (% of time)	Non-water catchment rivers/ streams (% of time)
Dissolved Oxygen (>2mg/L)	2016	99%	95%
	2017	97%	100%
Biochemical Oxygen Demand (<10mg/L)	2016	97%	92%
	2017	98%	95%
Total Suspended Solids (<200mg/L)	2016	100%	95%
	2017	100%	98%

Monitoring Results of Coastal Waters.

Parameters Monitored		Straits of Johor East (% of time)	Straits of Johor West (% of time)	Straits of Singapore (% of time)
Enterococcus Count (<200 per 100 ml)	2016	98%	97%	98%
	2017	97%	94%	100%

Source: NEA

Annex A.3. Examples of Blue Economy Inititative.

Blue economy initiative	Maritime Singapore Green Initiative (MSGI)
Background	In 2011, to reduce the environmental impact of the maritime transport sector, the MPA pledged up to $100 million over 5 years to the MSGI. The MSGI essentially provides grants to maritime transport operators that work to reduce negative environmental impacts. The voluntary programmes were designed to recognise and incentivise maritime companies to adopt clean and green shipping practices and go beyond the International Maritime Organization (IMO) mandated requirements when it comes to sustainability. In 2016, following industry's support, enhancements were made to the Initiative and new programmes were added. The Initiative was also extended to 30 December 2019. With effect from 1 July 2016, the MSGI comprises the following five programmes: • Green Ship Programme • Green Port Programme • Green Technology Programme • Green Awareness Programme • Green Energy Programme
Innovations and best practices	A description of the five programmes under the MSGI is as follows: • The **Green Ship Programme** provides incentives to Singapore-flagged ships for the reduction of carbon emissions through better energy efficiency design that is beyond what the IMO mandates. The same incentive is also extended to Singapore-flagged ships that install scrubbers or use of LNG to reduce the emission of pollutants. • The **Green Port Programme** aims to encourage ocean-going ships calling at the Port of Singapore to reduce the emission of pollutants like sulphur oxides and nitrogen oxides. MPA will reduce port dues by 25% for ocean-going vessels that burn clean fuels, LNG or use approved measures to control emissions for their entire port stay. • The **Green Technology Programme** encourages local maritime companies to develop and adopt eco-friendly technologies that reduce the emission of pollutants. It offers a grant that covers up to half of the total qualifying cost to develop and adopt the green technologies. • The **Green Awareness Programme** promotes environmental awareness as well as recognition of maritime companies at the forefront of sustainability efforts. This is done through seminars and workshops, and co-funding incentives to promote early sustainability reporting ahead of requirements of the Singapore Exchange (SGX). • The **Green Energy Programme** promotes the adoption of cleaner and greener marine fuels and one focus area is the adoption of LNG fuel.
Benefits and outcomes	The MSGI underscores Singapore's commitment as a responsible flag and port State to clean and green shipping. The programmes under the MSGI were jointly developed from engagements with industry partners and customers to promote and ensure environmentally friendly shipping and port activities. As of December 2017, some 436 Singapore-flagged ships qualified for the Green Ship Programme. Meanwhile, in 2016, the Green Port Programme saw more than 4,100 vessel calls switching to marine fuel with sulphur content not exceeding 1%. As of 2016, 108 companies have voluntarily signed the Green Pledge to demonstrate their commitment in promoting clean and sustainable shipping in Singapore.
Supporting policies and institutional arrangements	Both financial and non-financial resources are employed towards the MSGI. Financial resources include the sum of SGD100 million. Non-financial resources are needed to undertake consultation with Industry partners and stakeholders as well as administer the MSGI.
SDGs being achieved	The MSGI addresses Sustainable Development Goal Target 14.1, as it falls under the management of ship-based pollution and/or port waste management

Source: MPA

Annex A.4. Policies and Governance.

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
International agreements adopted	• SDGs (SDG 14); • UN Convention on the Law of the Seas (UNCLOS)	• ASEAN Regional Plan of Action for the Management of Fishing Capacity (RPOA-Capacity) • Signatory to the Regional Plan of Action to Promote Responsible Fishing Practices including Combating IUU Fishing in the Southeast Asia Region (RPOA-IUU).	• ASEAN Declaration on Cruise Tourism	• MARPOL • SOLAS • COLREGS • BWMC • Ballast Water Management Convention		• CBD and Aichi biodiversity targets • CITES	• Stockholm Convention on Persistent Organic Pollutants • Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade • Minimata Convention on Mercury • Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal • Montreal Protocol on Substances that Deplete the Ozone Layer • Vienna Convention for the Protection of the Ozone Layer	• SDGs		• MARPOL • Ballast Water Management Convention • International Convention on the Control of Harmful Anti-fouling Systems on Ships	• UNFCCC; • Paris Climate Agreement • Kyoto Protocol

Annex A.4. Policies and Governance. (cont.)

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
National policies and laws	• Ocean Policy	• Fisheries Act and its subsidiary legislation		• Prevention Of Pollution of the Sea Act • Merchant shipping Act		• Parks and Trees Act • National Parks Board Act • Endangered Species (Import and Export) Act 2006 • Wild Animal and Bird Act	• Environmental Protection and Management Act • Environmental Protection and Management (Hazardous Substances) Regulation • Environmental Protection and Management (Ozone Depleting Substances) Regulations • Environmental Public Health Act • Environmental Public Health (Toxic Industrial Waste) Regulations • Hazardous Waste (Control of Export, Import and Transit) Act • Hazardous Waste (Control of Export, Import and Transit) Regulations	• Environmental Public Health Act (EPHA) • Environmental Public Health (General Waste Collection) Regulations • Environmental Public Health (General Waste Disposal Facility) Regulations • Environmental Public Health (General Waste Disposal Facility – Exemption) Regulations • Environmental Public Health (Public Cleansing) Regulations • Code of Practice on Environmental Health (COPEH)		• Prevention Of Pollution of the Sea Act	
Strategic Action plans		• Develop sustainable aquaculture inputs and production systems	• National Tourism Plan	• Plan to be LNG bunker ready in line with IMO's global sulphur limit of 0.5% for marine fuels • Maritime Singapore Green Initiative	• Develop sustainable aquaculture inputs and production systems (EDB) • Urban Solutions and Sustainability Domain under RIE2020	• Nature Conservation Masterplan • Marine Conservation Action Plan		• Singapore Sustainable Blueprint 2015 (Moving towards a Zero Waste Nation) • Solid Waste Management Plan	• Keep Singapore Clean and Anti-Littering	• Plan to be LNG bunker ready in line with IMO's global sulphur limit of 0.5% for marine fuels • Maritime Singapore Green Initiative	• National Climate Change Strategy (2012) • Climate Action Plan (2016)

Annex A.4. Policies and Governance. (cont.)

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
Mandated gov't agencies		• Agri-Food & Veterinary Authority (AVA)	• Singapore Tourism Board (STB)	• Maritime and Port Authority of Singapore (MPA)	• PUB, EDB, SPRING, IE Singapore for the water industry	• NParks, AVA	• NEA, PUB	• NEA	• NEA	• MPA	
Gov't budget allocation (Yes/None; Increasing/ Decreasing/ Remain the same)		• Yes; remain the same	• Yes;	• LNG - S$18 Million to co-fund the building of nine LNG-fuelled harbour craft, S$6 Million to co-fund the building of two LNG bunker vessels, S$2 Million to co-fund the building of an LNG truck loading facility. • Maritime Singapore Green Initiative - Financial resources include the sum of S$100 million.	• Yes; remain the same (EDB) • Yes (NRF Funding to grow the water industry)	• Yes, remain the same	• Yes	• Yes	• Yes	• Yes	• LNG - S$18 Million to co-fund the building of nine LNG-fuelled harbour craft, S$6 Million to co-fund the building of two LNG bunker vessels, S$2 Million to co-fund the building of an LNG truck loading facility. • MSGI - Financial resources include the sum of S$100 million.	• Yes

Annex A.4. Policies and Governance. (cont.)

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
Other funding sources						• Garden City Fund Donors					
Staff allocation and capacity dev't **(Yes/None; Adequate training and support for capacity development; Increasing/ Decreasing/ Remain the same)**		• Yes; remain the same	• Yes; increasing		• Yes, remain the same	• Yes, remain the same	• Yes, there are key officers in PCD overseeing the different areas on the management of chemicals and toxic industrial waste as well as keeping tabs on the development of the international agreements which Singapore is a party to and where PCD is the competent authority. • NEA ensures that there are sufficient trained personnel to oversee solid waste management in Singapore and also to carry out enforcement works.	• NEA regulates the general waste collection industry and licensed waste collectors are required to have trained and certified workforce to provide efficient waste collection services. All general waste collected are disposed of at disposal facilities authorised by NEA. The disposal facilities are managed and operated by NEA and its PPP service providers.			• Yes; Adequate training and support for capacity development

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
Targeted research and development		• Identify new and suitable species for local aquaculture sites. • Mitigation of environmental impacts such as HABs • Animal health / nutrition research • Aquaculture farming systems		• Animal health / nutrition research • Aquaculture farming systems innovation • Yes (PUB)	• Species recovery • Habitat enhancement • Community stewardship programme			• Development of Integrated Waste Management Facility (IWMF) to meet Singapore's long term waste disposal needs. The IWMF will optimise resource recovery from waste and recyclables collected under the National Recycling Programme. • Mechanical biological treatment plant to process household waste and recover various recyclables including plastics • Waste-to-Energy Competitive Research Programme that supports high-impact Waste-to-Energy (WtE) and Waste-to-Resource (WtR) research	• Study to establish the commercial and financial viability of proven recycling solutions and technologies that can be applied in Singapore for waste steams including plastic waste • Closing the Waste Loop Research and Development (R&D) initiative to fund research in developing solutions towards a plastic resource efficient economy, and to extract value and resources from plastic waste • Upcoming initiative to implement mandatory reporting requirements for sustainable packaging waste management	• Centre of Excellence in Maritime Energy and Sustainability Development (MESD)	• Urban Solutions & Sustainability under the Research, Innovation, and Enterprise 2020 programme

Annex A.4. Policies and Governance. (cont.)

	Ocean and coastal management	Fisheries	Marine tourism	Ports and shipping	Emerging blue economy industries	Coastal and marine ecosystems and biodiversity conservation	Pollution reduction				Climate Change
							Hazardous waste	Solid waste, Sanitation, Wastewater & nutrients	Plastic waste	Ship-based pollution	Adaptation and Mitigation
Public awareness; Stakeholder participation		• Collaboration with polytechnics and universities • Promotion of local produce through public campaigns • Workshops and dialogue sessions with industry stakeholders			• Collaboration with polytechnics and universities (EDB)	• Marine Environment School Talks • Clean-up on Kayak • Underwater clean-up through youth divers • Poster design competition 2018 • Underwater Clean-up exercise held in conjunction with World Oceans Day 2018 • Friends of the Marine Park • Plant-A-Coral, Seed-A-Reef • Inter-tidal watch • Seagrass watch • Coastal clean-up	• PCD consults stakeholders such as industry and public on the proposed implementation of new control measures for chemical and toxic industrial waste management.	• Collaboration with schools to promote 3Rs		• Maritime Singapore Green Pledge • Marine Environment School Talks • Clean-up on Kayak • Underwater clean-up through youth divers • Poster design competition 2018 • Underwater Clean-up exercise held in conjunction with World Oceans Day 2018	• Yes
Inter-agency coordination mechanism		• Interagency working groups			• Working groups	• Inter-agency committees (TCCME and CMEPC) • Inter-agency working groups	• NEA adopts a Whole-of-Government (WOG) approach towards waste management e.g. with Urban Redevelopment Authority (URA) for district pneumatic waste conveyance system (DPWCS).				• Inter-ministerial Committee on Climate Change
Partnerships (with donors, int'l financial institutions, NGOs, etc.)					• Yes (PUB)	• NParks works with research institutions under multiple Research Collaboration Agreements (RCAs) • Marine stakeholders are engaged through Friends of the Marine Park initiative		• Yes, NEA works with various NGOs e.g. Zero Waste SG, Singapore Environment Council (SEC), as well as industry associations e.g. Waste Management and Recycling Association of Singapore (WMRAS) on 3R initiatives.		• Singapore-IMO Third Country Training Programme	• C40

Annex A.5. Summary: State of Ocean Economy and Ocean Health.

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	**Top 3 issues**	**(a) key policies/ laws; (b) national action plan**	**Best practice or blue economy initiative**
State of ocean economy				
Ocean economy • GVA; contribution to GDP	To be based of DOS data			
Fisheries and aquaculture • Output; GVA	↑ Slightly increasing	• Environmental externalities such as pollution and HAB events. • Competition from other countries, lowering profits for farmers • Combatting IUU fishing and preventing the entry of IUU fish into the supply chain.	• Fisheries Act and Subsidary legislation • Funding to encourage the uptake of technologies and enhance the capability and capacity of industry players	• Adoption of technologies such as the closed containment aquaculture systems • Good aquaculture practices for fish farming
Tourism • No. of tourists • GVA	↑			
Ports and shipping • Passenger volume • Cargo and container throughput volume • GVA	↑ Increasing • Cargo and container throughput in 2017 has increased since 2016. (See Section 6.2.4: Port Performance Indicators). MPA does not report data on passenger volume or GVA.		• Prevention Of Pollution of the Sea Act • The Maritime Singapore Green Initiative – comprising the Green Ship Programme, Green Port Programme, Green Technology Programme Green Awareness Programme and Green Energy Programme - provides incentives to companies that adopt clean and green shipping practices over and above the minimum required by IMO.	• The Maritime Singapore Green Pledge, part of the Green Awareness Programme, is signed by organisations that have expressed a commitment to environmentally-friendly shipping. It has garnered more than 100 signatures.

Annex A.5. Summary: State of Ocean Economy and Ocean Health. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Ship building and marine offshore engineering **2016 Output: S$13.1bn; GVA: S$3.8bn**	↓ While output and value added may begin to stabilize in 2018, a firmer recovery is not expected until 2019 and beyond.	• Uncertain oil prices	• Enhance productivity • Encourage innovation & R&D • Align jobs and skills of workers	Capture near term growth opportunities in the Liquefied Natural Gas (LNG) market and renewables.
Employment in ocean economy	Based off MOM + CPFB information			
Mainstreaming of valuation of ecosystem services; natural capital accounting	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021	N.A – Natural Capital Project data in 2021
State of ocean health				
Fish stocks	N.A	N.A	N.A	N.A
Catch per unit effort	N.A	N.A	N.A	N.A
Mangroves - area; cover - condition	↑ Slightly increased recently in coverage. Condition varies in different mangrove patches	• Coastal development • Coastal erosion • Sea-level rise	• Nature Conservation Masterplan • Marine Conservation Action Plan	• Pulau Telong Mangrove Restoration • Mangrove salvation and propagation programme
Coral reefs - area; cover - condition	↑ Slightly increased recently Slightly increased recently in species due to new discovery Condition varies in different reefs	• Land reclamation • Sedimentation • Climate change	• Nature Conservation Masterplan • Marine Conservation Action Plan	• NParks' Plant-A-Coral, Seed-A-Reef programme • Coral Reef Monitoring Programme • Reef Enhancement Units • Coral nursery
Intertidal habitats - area; cover - condition	↓ Slightly decreased in coverage Condition varies in different areas Increase in species counts due to recent discovery	• Land reclamation • Coastal pollution including oil spills and chemical spills • Coastal erosion	• Nature Conservation Masterplan • Marine Conservation Action Plan	• Marine Ecotoxicology Biomonitoring • Habitat enhancement on artificial shores
Prevention of extinction of known threatened species	There have been records of new discovery and rediscovery	• Habitat loss • Lack of historical records	• Nature Conservation Masterplan • Marine Conservation Action Plan • WABA	• Red Data Book Update • Comprehensive Marine Biodiversity Survey • DNA technology • Species recovery programme

Annex A.5. Summary: State of Ocean Economy and Ocean Health. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Marine water quality **- DO** **- N** **- P** **- TSS, TDS** **- Heavy metals** **- POPs, PTS** **- microplastics** **etc.**	N.A -Baseline data being collated	N.A	Environmental Protection and Management Act; Environmental Public Heath Act; Public Utilities Act; Sewerage and Drainage Act; Water Quality Guidelines 2008	Sewerage system - Wastewater treatment and reuse - Real-time continuous water quality monitoring system for coastal waters
Marine protected areas (% of territorial waters)	N.A	N.A	Marine Conservation Action Plan; National Biodiversity Strategy and Action Plan; Nature Conservation Masterplan	Sisters Islands Marine Park
Pressures and threats				
Population growth in the coastal areas				
IUU fishing	No change	• Limited legislative powers pending review of Fisheries Act • Limited manpower • Capacity development	Fisheries Act	Review of current legislation to enhance powers to combat IUU fishing
Habitat conversion and destruction; reclamation	↑	• Limited land and sea space • Growing population • Climate Change	Strategic long term land use planning	Whole-of-Government approach to land use planning Habitat enhancement and Building with Nature
Coastal erosion and sedimentation	N.A.	The effects and impact of coastal erosion are dependent on the local site conditions and these vary from location to location. Hence, coastal protection and shoreline restoration work had to be site-specific rather than a "one size fits all" strategy.	BCA's Coastal Adaptation Study (CAS), which is still ongoing, will develop a national framework to safeguard Singapore's long-term coastal protection needs.	To help mitigate beach erosion at the East Coast Park, novel coastal protection measures were implemented at selected sections of the beach as a pilot project. Based on our monitoring of these sections annually, the measures are effective, and can be considered at other locations where feasible.
Wastewater (untreated) discharge	N.A	N.A	N.A	N.A

Annex A.5. Summary: State of Ocean Economy and Ocean Health. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Solid waste generation and dumping	In 2017, 7.70 million tonnes of solid waste was generated, a decrease of 110,000 tonnes from 7.81 million tonnes in 2016.		• NEA actively promotes the 3Rs (reduce, reuse and recycle) to reduce waste and recover resource. • Our solid waste management system ensures that all waste is collected for proper disposal/ recycling and do not end up in water courses leading to the seas and oceans.	
Plastic waste generation	The amount of plastic waste generated decreased slightly from 822,200 tonnes in 2016 to 815,200 tonnes in 2017.		• Working with industry and non-governmental organisations (NGOs) to reduce packaging waste through Singapore Packaging Agreement • Supporting and working with environment groups and retailers to implement ground-up initiatives to reduce the consumption of plastic bags and disposables • Study to establish the commercial and financial viability of proven recycling solutions and technologies that can be applied in Singapore for waste steams including plastic waste • Closing the Waste Loop (CTWL) R&D Initiative to develop technologies and solutions to tackle increasing waste generation, scarcity of resources and land constraints for waste management • Upcoming initiative to implement mandatory reporting requirements for sustainable packaging waste management	
Oil spills	N.A	N.A	• Prevention of Pollution of the Sea Act	• Marine Emergency Action Procedure
Greenhouse gas emissions	↑	Singapore is alternative energy disadvantaged, and is a highly urbanized, densely populated city-state, which makes deploying large-scale renewable energy difficult.	Key policies include the Energy Conservation Act which targets large energy users, introduction of a carbon tax from 2019, etc. Singapore's Climate Action Plan was published in 2016.	Singapore has switched away from fuel oil to natural gas, the cleanest fossil fuel, for electricity generation; the proportion of Singapore's electricity generated by natural gas has risen to about 95% in 2016
Population with access to sanitation and wastewater management systems	N.A	N.A	N.A	N.A

Annex A.5. Summary: State of Ocean Economy and Ocean Health. (cont.)

Indicator	Status / Trend	Major Issues and Challenges	Response	
	INCREASING (↑) / DECREASING (↓) / NO CHANGE (–)	Top 3 issues	(a) key policies/ laws; (b) national action plan	Best practice or blue economy initiative
Population covered by solid waste management services	N.A	N.A	N.A	N.A
Tourist establishments with habitat, solid waste and wastewater management	N.A	N.A	N.A	N.A
Ports and ships with environmental management systems	As of December 2017, some 436 Singapore-flagged ships qualified for the Green Ship Programme under the MSGI, up from 37 ships in 2012			Maritime Singapore Green Initiative
Waste management in offshore oil and gas	N.A	N.A	N.A	N.A
Sea level rise	↑	Climate science is constantly evolving, which means that projections for rises in mean sea level may change. Hence, our national framework for coastal protection need to remain flexible and adaptive.	BCA's Coastal Adaptation Study (CAS), which is still ongoing, will develop a national framework for Singapore's long-term coastal protection needs.	From 2011, we have required all new reclaimed land to be at least 4m above the mean sea level, up from 3m previously.
Coral bleaching	Varied depending on the year. Post-bleaching recovery appeared to be rapid	• Climate change and variability in weather patterns • Coastal activities	• Nature Conservation Masterplan • Marine Conservation Action Plan	Coral bleaching monitoring is conducted following NOAA's advisory for the region and Sea Surface Temperature data
Storms, typhoons, heavy rains, storm surge, flooding	↑	Increasing rainfall intensity - the annual maximum rainfall intensity in an hour has increased from 80 millimetres in 1980 to 107 millimetres in 2012	PUB seeks to capture, convey and discharge excess rainwater through its "Source-Pathway-Receptor" approach. By building detention tanks, widening drains, and raising ground levels across Singapore, PUB helps to mitigate flood risk in Singapore.	From 2011 to 2017, the Government has invested S$1.2 billion to upgrade drainage infrastructure, and these measures have been effective in relieving Singapore of widespread and prolonged floods.

Annex B: Supplementary Information

Annex B.1. Individual OHI Goal Score Evaluation Comparison for Singapore 2012 - 2017.

Parameters Monitored	2012	2013	2014	2015	2016	2017
Index	58.56	59.34	59.81	60.31	58.95	58.95
Food provision	7.25	6.68	7.81	7.37	7.70	7.17
Fisheries (subgoal)	14.96	15.13	15.44	16.17	16.51	17.17
Mariculture (subgoal)	1.71	1.86	2.31	2.87	3.33	3.44
Artisanal opportunities	100.00	100.00	100.00	100.00	100.00	100.00
Natural products	0.93	0.57	1.75	4.93	4.55	4.57
Carbon storage	82.90	82.93	82.90	82.94	83.02	83.01
Coastal protection	82.06	82.18	82.09	82.17	82.34	82.27
Tourism and recreation	51.53	58.55	62.60	64.84	51.89	51.83
Livelihoods and economies	95.28	96.36	96.36	96.36	96.36	96.36
Livelihoods	90.57	92.71	92.71	92.71	92.71	92.71
Economies	100.00	100.00	100.00	100.00	100.00	100.00
Sense of place	35.52	35.65	35.72	35.77	35.88	36.04
Iconic species (subgoal)	70.26	70.51	70.66	70.75	70.98	71.29
Lasting special places (subgoal)	0.79	0.79	0.79	0.79	0.79	0.79
Clean water	50.29	49.22	48.64	48.80	47.88	47.91
Biodiversity	79.83	81.26	80.24	79.96	79/91	80.35
Habitat (subgoal)	81.03	83.91	81.79	81.24	81.06	81.84
Species condition (subgoal)	78.62	78.61	78.69	78.69	78.75	78.87

In 2017, the overall Ocean Health Index (OHI) score of Singapore is 59, compared to the overall global score of 70. The country ranks #183 among 221 countries and exclusive economic zones (EEZs).

[1] The Ocean Health Index (OHI) establishes reference points for achieving widely accepted socio-ecological goals and scores for 220 countries and territories, Antarctica and 15 High Seas regions on how successfully they are achieved. Evaluated globally and by country, these goals represent the wide range of benefits that a healthy ocean can provide; each country's overall score is the average of its respective goal scores. A goal is given a score of 100 if its maximum sustainable benefits are gained in ways that do not compromise the ocean's ability to deliver those benefits in the future. Lower scores indicate that more benefits could be gained or that current methods are harming the delivery of future benefits.

Annex B.2. Factsheet on Marine Conservation Action Plan (MCAP) Initiatives.

The following are some of the programmes and initiatives that NParks has under the MCAP.

Programmatic Plans

A) Species Recovery

I. Reintroduction of the Giant Clam (*Tridacna gigas*)

The largest species of bivalve mollusc in the world, these Giant Clams can grow up to 1.2m in size. This species is no longer found in local waters. However, there is historical evidence that Tridacna gigas used to grow in our waters, as realised by the archaeological discovery of the shells in various places in Singapore.

NParks is currently working with Dr Neo Mei Lin from the Tropical Marine Science Institute (TMSI) to reintroduce these iconic marine animals back into our local waters. Currently, six individuals have been successfully relocated from the TMSI aquarium to a natural reef area at Small Sister's Island where they are being closely monitored.

The Giant Clam specimens were first transferred from the tanks in TMSI to buckets and transported by boat to Small Sister's Island. During the boat trip, the Giant Clams were continually flushed with fresh seawater to ensure that they were kept moist at all times. The specimens were then transferred onto baskets and lowered into the water using a lift bag. Finally, researchers transferred them to a suitable site with a low amount of silt so the clams can be placed stably. Introduction of these clams to other reefs will be carried out if the reefs are assessed to be suitable for their growth.

II. Neptune's Cup Sponge (*Cliona patera*)

The Neptune's Cup Sponge is one of the larger known sponges. It is so-named due to its wineglass shape and can grow up to a metre in height and diameter. The specimen that was first used to describe this species was collected in Singapore waters in 1820. It was thought be extinct since early 1900s until it was rediscovered in Singapore in 2011. Singapore is currently the only country that has a known location with a living specimen of the Neptune's Cup Sponge.

The Neptune's Cup sponge has been successfully transplanted to the Marine Park in early 2015. Over the next few months, NParks will be working with Mr Lim Swee Cheng (TMSI) to experiment with a new propagation technique for the sponge. If propagation of this sponge is successful, NParks will work towards slowly increasing the population of the Neptune's Cup Sponge in our local waters.

III. Coral Gene Bank and Nurseries

A coral nursery will be set up at Sisters' Islands to collect all 255 species of corals found in Singapore waters. The nursery plays an important role in the conservation of corals, especially in view of rising sea temperatures. Corals undergo bleaching when the temperature of the waters gets too high. This means that they lose a major source of food and are more susceptible to disease. With the creation of a coral nursery, rarer corals that are threatened with coral bleaching can be moved to a controlled environment which would help to ensure their survival.

IV. Turtle Hatchery and Outreach Facility

A turtle hatchery - Singapore's pioneer sea turtle conservation project will be set up at Sisters' Islands Marine Park. Sponsored by HSBC, the Green Turtles and Hawksbill Turtles will be the key species covered under the project.

The hatchery will provide a safe refuge for rescued and collected turtle eggs, giving them a chance to hatch safely. This is important as only a few from each clutch of 100+ to 200 eggs make it to adulthood. The hatchery would also provide research opportunities to study local sea turtle populations.

Feasibility studies are currently underway to assess the conditions of the shore on Small Sister's Island for the creation of a nursery.

Education and outreach programmes will also be put in place to create awareness of our local marine biodiversity. These include visits to the turtle hatchery, involvement in egg collection and transfer to the hatchery and habitat maintenance.

The $500,000 sponsorship from HSBC will support the building of a facility for overnight visits during hatching periods and for outreach programmes that are conducted on the island, over a period of five years. Educational signs and materials will also be developed for the outreach facility. HSBC staff will be involved in habitat maintenance and possibly collection of eggs when they are found and reported by members of the public.

B) Habitat Enhancement

A biodiversity enhancement unit is any designed structure that enriches and enhances existing biodiversity in the marine habitats. Through the installation of such units, NParks also hopes to increase visibility and accessibility of marine biodiversity to the general public. Enhancement units can be as simple as a structure that provides surfaces that are suitable for marine organisms to settle and grow on. Some examples of biodiversity enhancement units are listed in the following table.

Biodiversity Enhancement Unit	Details
Tidal Pool Units	Made of concrete suitable for the marine environment, these units retain seawater at low tide. This creates a habitat similar to natural rock pools, providing an additional hiding place for marine organisms. To design the units, researchers first had to study the natural rock pool habitats for features that made them suitable habitats for marine organisms. These include the presence of crevices, grooves and pits found in the rocks. The features were inputted into a software programme (CASU) which then created a design that would most closely mimic a natural habitat. Multiple designs can be created based on the different features inputted into the software.
Fish Aggregating Devices	A fish aggregating device is any structure that is used to attract and aggregate fish. Fish aggregating devices can be floating or fixed, depending on the environmental conditions and their purpose. They are widely used as a tool to aid small-scale fisheries to target and catch fish species that otherwise would be difficult. They can also be used to effectively restore and enhance fish biodiversity in target conservation areas.
BioBoss Tiles	BioBoss tiles are concrete structures (200x200x32mm) that were also created using the software CASU. These tiles are incorporated into the seawalls, providing microhabitats for marine organisms, and hence increasing biodiversity on these coastal defences. These tiles were designed in a collaborative project between NParks and NUS.
Floating Pontoon	A floating pontoon that serves as a biodiversity enhancement unit is similar to the usual floating pontoons one sees at Marinas but with modifications to encourage biodiversity. NParks is working with consultants to design these pontoons to maximise biodiversity enhancement potential.

I. Changi Beach Park

Tidal pool units will be placed on a portion of the seawall at Changi Beach Park, Car Park 5 (CBP CP5) and will be ready by the end of the year. A total of 15 tidal pool units, with three different designs, will be installed at the area.

II. Sisters' Islands Marine Park

BioBoss tiles will be placed along the smooth surfaces of the existing rock bunds to attract different marine organisms. Apart from this, other enhancement measures such as floating pontoon, tidal pools and fish aggregating devices will also be installed around Sisters' Islands.

C) Community Stewardship Plans

Sisters' Islands Marine Park Dive Trail

A new pilot dive trails has been developed off Sisters' Islands. Trial dives have been conducted over the past few months to assess the suitability of the routes as well as to test out the user friendliness of the underwater signs. These dive trails vary in level of difficulty and cater to divers of different levels.

The diorama that has been set up at Festival of Biodiversity 2015 offer a glimpse of what the dive trails will feature.

Dive trails will be ready for public access by end September 2015.

Annex B.3. UN Sustainable Development Goals.

Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

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