The future of fisheries in the East and South China Seas
## CONTENTS

Authors & Acknowledgements ................................................................. 1
Executive Summary ............................................................................... 2
Glossary ............................................................................................... 4

1 Introduction .................................................................................. 5
1.1 The OceansAsia Project ............................................................... 5
1.2 Report Objectives and Prior Work ........................................... 5
1.3 Asia’s Large Marine Ecosystems ................................................. 6
1.4 Hong Kong’s Seafood Imports .................................................... 9

2 Key Concerns ............................................................................. 10
2.1 Governance ............................................................................... 10
2.2 Overexploitation of Fisheries ................................................... 11
2.3 Fishing Industry Subsidies ......................................................... 12
2.4 EEZ Boundaries ........................................................................ 12
2.5 Environmental Degradation and Climate Change ...................... 12
2.6 Illegal, Unreported, and Unregulated (IUU) fishing .................... 12
2.7 Feed-Grade Fishing .................................................................. 14

3 Impacts of Overfishing & Climate Change by 2100 ...................... 16
3.1 Methodology ............................................................................ 16
3.2 Changes in Biomass ................................................................... 17
3.3 Changes in Catch & Revenue .................................................... 20
3.4 Ecosystem-level Summary .......................................................... 22

4 The Perils of Feed-grade Fisheries ............................................... 24
4.1 The Rise of Feed-Grade Fishing in Asia ................................... 24
4.2 Impacts of the Rapidly Growing FGF Industry ....................... 26
4.3 Scenario Modelling of Potential Futures ................................. 26

5 Recommendations ..................................................................... 28
5.1 Initiate Regional Dialogues ....................................................... 28
5.2 Address Feed-Grade Fishing Practices .................................... 28
5.3 Integrate Climate Change and Fisheries Management Policies .... 29

6 Conclusion .................................................................................. 30

References and End Notes .................................................................. 31
Authors & Acknowledgements

We would like to thank RS Group and the Estée Lauder Companies Charitable Foundation for supporting this research through their funding. We would also like to acknowledge Dr. Virginie Tassin Campanella for her work and insights on ocean governance. This report is part of the ongoing OceansAsia project, which was commissioned by ADM Capital Foundation in 2014. It follows the 2015 report Boom or Bust: The Future of Fish in the South China Sea.

Authors:
U. Rashid Sumaila
William W.L. Cheung
Louise S.L. Teh
Ashley H. Y. Bang
Tim Cashion
Zeyu Zeng
Juan Jose Alava
Sophie le Clue
Yvonne Sadovy de Mitcheson

Affiliations:

Suggested citation:
The East and South China Seas (ECS and SCS) play a valuable ecological and economic role in Asia, providing food security and livelihoods to millions of people. Catches from these fisheries hold a value of USD 7.4 billion per annum in the ECS and USD 15.4 billion in the SCS as of 2018. At the same time, these ecosystems have faced decades of damage from overfishing, climate change, marine plastic pollution, and other stressors. In order to restore and effectively manage these marine ecosystems for the benefit of both present and future generations, urgent policy action is required at the regional level from fisheries stakeholders and governing bodies.

A continuation and expansion of the previous report *Boom or Bust: the future of fish in the South China Sea*, this report provides the scientific basis needed to support ongoing actions and inform new policies. In addition to taking stock of the current state of ECS and SCS ecosystems, our research identifies key threats. These include the emergent regional phenomenon of feed-grade fishing and its use in aquaculture. The potential fate of these valuable marine resources is then explored under various climate change and fisheries management scenarios. By using sophisticated ecological modelling techniques, the application of climate change and fisheries management scenarios in the models provides crucial scientific evidence outlining the impacts of human activity on the ECS and SCS marine resources.

Our analysis reveals the most and least viable routes towards achieving sustainable marine ecosystems across the ECS and SCS. We have focused on the ten most highly consumed species groups on the Hong Kong seafood market given the city’s regionally significant consumption and import of seafood. In both ecosystems, many of these key species, such as croakers and groupers, are under serious threat from overexploitation and will be reduced to population sizes of only a fraction of what they were just a few decades ago. This is especially true under a severe climate change scenario, where fish biomass is expected to fall by up to 15 times in the SCS and 1.4 times in the ECS from present day to 2100.

In the most extreme scenario modelled, a 50% increase in fishing effort combined with severe climate change could result in an annual loss of USD 11.4 billion in fisheries revenues, or 6.4 million tonnes of fish biomass, in the SCS ecosystem by 2100. Under the best-case scenarios for both climate change and fishing management (i.e. a low emission scenario with 50% decrease in fishing effort), the SCS is still projected to lose USD 6.5 billion, or 1.5 million tonnes in biomass across the ten species groups per year. This highlights the critically overexploited state of the SCS fisheries, made worse by warming sea temperatures that trigger the northward migration of species away from traditional fishing grounds.

The future of the ECS is not as dire as that of the SCS; when fishing effort is decreased by 50%, the ECS exhibits potential to surpass present-day fish and invertebrate biomass by the year 2100. However, this is accompanied by a major change in the types of species being caught, with many of today’s commonly consumed fish species becoming short in supply as climate change and human activity alter the habitats of these species.
The SCS serves as a cautionary tale for the ECS. If fishing effort is left unchecked to pursue short-term economic gains (i.e., the USD 890 million gain projected under the higher fishing effort scenario), the ECS may eventually cross a tipping point and follow the trajectory of the SCS — one where overexploitation leads to irreparable economic and biological losses. Simultaneously, the rapid growth in aquaculture and the resulting need for fish-based feed has fuelled the unsustainable catch of juvenile fish from wild populations. In a practice known as feed-grade fishing (FGF), fish and invertebrates are indiscriminately caught in large quantities to produce feed for aquaculture and livestock, depleting fish populations at accelerated rates. Driving these issues are broader, interacting factors such as inefficient governance, stressors from climate change, and socio-economic development trajectories.

Based on data from five Chinese provinces, we ran further scenario modelling to explore the dangers of FGF practices. Results showed that the continued proliferation of feed-grade fisheries for aquaculture will result in revenues that are at least ten times lower than if only mature fish were caught and sold for direct human consumption. Additionally, the removal of juveniles from wild populations through FGF practices will cause further declines in total biomass. Given the risk that fish-fed aquaculture poses to ECS and SCS fish stocks, aquaculture industries must urgently consider shifting to alternative protein and feed sources in order to reduce pressures on marine resources.

There are large benefits associated with the reduction in both fishing effort and greenhouse gas emissions, in relation to both the ECS and SCS, which will allow for the full or partial recovery of fish biomass levels and fisheries revenues. An optimal approach is for ECS and SCS nations to collaborate on regional levels to form multilateral fisheries management agreements. The major concerns affecting the two large marine ecosystems can only be effectively addressed from a regional level, in contrast to the current fragmented approach of ECS and SCS governance.

With a strong commitment to regional fisheries management and climate change mitigation, the ocean’s fisheries resources can continue to support the region’s human, social, and economic well-being for generations to come. To preserve the ecological and economic longevity of Asia’s most valuable fishing grounds, it is crucial that action is taken on the following three main themes: initiating regional dialogues, addressing feed-grade fishing practices, and integrating climate change and fisheries management policies. Without action, there will likely be devastating social, economic, and ecological consequences for Asia’s marine ecosystems and the billions of people who depend on it.
### GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aquaculture:</strong></td>
<td>The farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. There are two main types of aquaculture: marine (mariculture) and freshwater.¹</td>
</tr>
<tr>
<td><strong>Fish catch:</strong></td>
<td>Catches of fishery products, such as fish, molluscs, crustaceans, and others. Also referred to as simply ‘catch’, it is expressed in live product weight (tonnes).</td>
</tr>
<tr>
<td><strong>Fish landings:</strong></td>
<td>The catches of marine fish arriving at the port, often expressed as a weight of the live products.</td>
</tr>
<tr>
<td><strong>Fish stock:</strong></td>
<td>The living resources in a population from which catches are taken in a fishery.²</td>
</tr>
<tr>
<td><strong>Fishery:</strong></td>
<td>All fishing activities on a given marine or aquatic resource. The fishery may be commercial, subsistence, or recreational in nature.³</td>
</tr>
<tr>
<td><strong>Fishery management:</strong></td>
<td>The integrated process of planning, analysis, and decision-making surrounding the allocation of resources and enforcement of regulations within a fishery. Management is carried out by a specific authority that aims to ensure the continued productivity of the living resources.⁴</td>
</tr>
<tr>
<td><strong>Feed-grade fish:</strong></td>
<td>Non-target fish and invertebrates that traditionally hold low value and are instead used to produce fish-based feed, fish meal/oil, etc. Also known as ‘trash fish’.</td>
</tr>
<tr>
<td><strong>Fishing effort:</strong></td>
<td>Cumulative power of the engines of the vessels in all fishing fleets operating in a Large Marine Ecosystem, adjusted for the likely number of fishing days of each fleet segment.⁵</td>
</tr>
<tr>
<td><strong>Fishing subsidy:</strong></td>
<td>Any direct or indirect financial transfer from public entities to the private fishing sector, which enables the fishery to make more profit than it would otherwise.</td>
</tr>
<tr>
<td><strong>Functional group:</strong></td>
<td>A set of species that share similar characteristics or have similar effects on major ecosystem processes.</td>
</tr>
<tr>
<td><strong>Invertebrates:</strong></td>
<td>A broad classification of organisms without spinal columns (backbones). In marine ecosystems, these include commercially valuable species groups such as crustaceans (e.g., lobsters, crabs, shrimps), molluscs (e.g., mussels, clams, scallops), and cephalopods (e.g., octopus and squid).</td>
</tr>
<tr>
<td><strong>Illegal, unreported, and unregulated (IUU) fishing:</strong></td>
<td>Illegal fishing refers to fishing activities that breach local, regional, or international laws applied to fisheries. Unreported fishing refers to fishing activities that are not reported or misreported to relevant authorities for fisheries management. Unregulated fishing occurs for fish stocks where there is no applicable conservation or management measure, or without licensing that is mandated under regional or international jurisdiction laws.⁶</td>
</tr>
<tr>
<td><strong>Large Marine Ecosystems (LME):</strong></td>
<td>Large, ecologically distinct regions of the world’s oceans that are 200,000 km² or greater in size and characterised by distinct bathymetry, hydrography, productivity, and trophically dependent populations.⁷</td>
</tr>
<tr>
<td><strong>Mariculture:</strong></td>
<td>Type of aquaculture carried out for marine species; the farming and husbandry of marine plants and animals in marine environments.⁸</td>
</tr>
<tr>
<td><strong>Maximum Sustainable Yield (MSY):</strong></td>
<td>The highest theoretical amount of catch that can be continuously taken from a stock under existing environmental conditions without affecting the reproductive process of the population.⁹</td>
</tr>
<tr>
<td><strong>Overfishing:</strong></td>
<td>The unsustainable depletion of fish stocks by fishing at a rate at which the species cannot replenish.</td>
</tr>
<tr>
<td><strong>Regional fisheries management organisations (RFMOs):</strong></td>
<td>International organisations that regulate regional fishing activities in the high seas. While some have a purely advisory role, most have management powers to set catch and fishing effort limits, technical measures, and control obligations.¹⁰</td>
</tr>
<tr>
<td><strong>Small-scale fisheries:</strong></td>
<td>Traditional fisheries involving households as opposed to commercial companies, typically target fish from various shallow coastal ecosystems, including coral reefs, mangroves, and seagrass beds. Common gears used in small-scale fisheries include hook and line, gillnet, fish corral, traps, spear, long line, bag nets, troll line, and cast net, among others.¹¹</td>
</tr>
<tr>
<td><strong>Target fish:</strong></td>
<td>Species that are the primary or intended catch of a particular fishery.</td>
</tr>
<tr>
<td><strong>Trash fish:</strong></td>
<td>See ‘feed-grade fish’.</td>
</tr>
</tbody>
</table>
1. The OceansAsia Project

Asia’s marine waters are divided into 13 Large Marine Ecosystems (LMEs), which generate over 50% of the global annual fish catch. The Asian continent is home to 60% of the world’s population and employs 85% of the world’s fishers and aquaculture workers.

Given the overwhelming importance of Asia’s fisheries globally, the sustainability of the world’s oceans as a whole is influenced by the health of Asia’s LMEs. The deterioration of Asia’s LMEs inevitably places increasing burdens on LMEs elsewhere in efforts to support a growing global demand for fish.

The East and South China Sea (ECS and SCS) LMEs in particular, contain globally significant biodiversity and habitats. These two ecosystems border some of the world’s most populous countries, including China, South Korea, Japan, Thailand, Indonesia, and Vietnam. For generations, ECS and SCS fisheries have played a central socioeconomic and cultural role in the region and continue to be an important anchor of food and employment security.

However, both ecosystems have experienced decades of declines in fish and invertebrate populations. Among the myriad of global, regional and local-scale effects of human development and environmental degradation, the sustainability of ECS and SCS fisheries is threatened by ineffective management and governance. The future of both ECS and SCS fisheries faces additional uncertainty due to the acceleration of climate change, which has already triggered shifts in the distributions of economically-important marine species. Previous modelling of the SCS has shown that all of its fish and invertebrate species are predicted to experience population declines ranging from 9-59% by 2045.

Despite numerous bilateral and regional agreements, the lack of cooperative multilateral governance in the region is a barrier to sustainably manage the commercially important fisheries stocks of the ECS and SCS. Many of these stocks are migratory, moving between or among the exclusive economic zones of the surrounding countries. If the ECS and SCS are to continue supporting a significant portion of the world’s human population with its fisheries, there is an urgent need for nations to collaboratively improve their marine resource management strategies.

There is a severe paucity of ecosystem-level research on the value and volumes of ECS and SCS fisheries, making it difficult to develop regional management policies. While the fisheries of several countries in Asia are individually documented to various degrees, there lacks a holistic and standardized assessment of the status and relative socioeconomic importance of fisheries throughout the region, let alone the fate of these fisheries in the face of current and future stressors.

The OceansAsia Project aims to fill this knowledge gap by providing research to:

a) understand the state of Asia’s LMEs;

b) identify the challenges of preserving biodiversity in a commercially-significant ecosystem; and

c) outline relevant solutions to facilitate the long-term sustainability of marine ecosystems for present and future generations alike.

1.2. Report objectives and prior work

In our study, we evaluate the state of ECS and SCS fisheries and model the effects of various fisheries management scenarios in Asia: a ‘business as usual’ (BAU) case and three other scenarios that reflect positive or negative developments to fisheries management efforts. The marine functional groups modelled are
species that are popular in Asian markets and specifically in Hong Kong – a disproportionately large consumer and importer of seafood.

This report highlights the importance of regional fisheries management efforts as well as the critical implications of climate change. Here, we hope to focus the attention of stakeholders, including the public, fishing industry, businesses, and government, and provide a scientific foundation to support policy reform.

Prior Work
The research also aims to provide science-based evidence to support a call for action to rebuild and protect the marine resources of Asia’s LMEs, furthermore dispelling the widely held misconception that aquaculture is ‘the solution’ to overfishing in the region.

In doing so, the report synthesises the findings of the following work, which should be referred to for details:
1) Status, Trends, and the Future of Fisheries in the East and South China Seas (Institute for the Oceans and Fisheries, University of British Columbia, Canada)16
2) History, profiles, and implications of feed fish and fishmeal supply from domestic trawlers in the East and South China Seas (Swire Institute of Marine Science, University of Hong Kong, Hong Kong)17

The current study is a continuation and expansion of our previous research, presented in the report: Boom or Bust: the future of fish in the South China Sea.18 There, the SCS was modelled over a 30-year period whereby projections of future changes in fish stocks were derived for three major habitats:

1.3. Asia’s large marine ecosystems
Asia’s thirteen large marine ecosystems (LMES) span a total of 15.7 million km², ranging from tropical waters of the Indonesian Sea to the West Bering Sea that borders the Arctic Circle (Figure 1). Combined, these LMEs generate more than 50% of the world’s marine fish catch. The South China Sea (SCS) and East China Sea (ECS) contributed 12% and 6% of global fish catches respectively in 2016, making them the two most important fishing grounds in the West Pacific.20
The East and South China Seas are bordered by 14 fishing nations which are home to over 2.2 billion people (Figure 2). These nations engage heavily in the seafood and fishing industry, with total annual values of fish imports and exports in the magnitude of tens of billions of US dollars – 56 billion for the SCS and 40 billion for the ECS. Though the ECS is significantly smaller than the SCS, its catch is more valuable per unit weight. Around 5 million people in the ECS and SCS countries are engaged in fishing, the majority of whom are engaged in small-scale fishers. Key facts for both the SCS and ECS are provided in Table 1.

Globally, marine ecosystems are increasingly threatened by overfishing, pollution, global warming, ocean acidification, deoxygenation, and other stressors. These ecosystems are also being degraded by the direct impacts of human development, such as coastal land reclamation, that will only intensify as Asia’s economies continue to grow.

Despite East and South China Sea countries being amongst the most developed and rapidly industrializing countries in Asia, the majority of their fisheries are in small-scale, coastal communities. The continual decline of the countries’ small-scale fishery resources will have detrimental impacts on the subsistence fishing communities that are already burdened by pressures from wealth inequality.
East China Sea

The East China Sea is bordered by mainland China, South Korea, Japan, and Taiwan. Since the mid-1990s, total fisheries catch from the ECS has been approximately 6 million tonnes per year, equating to a value of over USD 7.4 billion in 2018. These fisheries provide employment for an estimated 1.4 million predominantly small-scale fishers. Over the last two decades, mainland China has been the largest fishing economy within the ECS, accounting for 71% of total fish catches on average. This contrasts with Japan, Korea, and Taiwan, which account for 14%, 9%, and 3% of catches, respectively.

South China Sea

The SCS supports a population of fishers almost twice that of the ECS at about 2.7 million, the majority of whom are engaged in small-scale fisheries. It supports the economies of twelve fishing entities: mainland China, Macao, Hong Kong, Taiwan, Thailand, Vietnam, Cambodia, the Philippines, Malaysia, Brunei, Singapore, and Indonesia.

In total, the SCS fisheries economy employs around 3.7 million people, but this is likely an underestimate due to the existence of extensive illegal, unregulated, and unreported (IUU) fishing. Since the 2000s, the SCS LME has contributed 11-17 million tonnes in reported annual fisheries catch, equating to a value of USD 12-22 billion. Previous studies have indicated that the SCS is severely overfished, which has resulted in biodiversity and habitat losses that threaten the sustainability of both the ecosystems and economies that rely on them.
### Table 1: Indicators of Productivity, Trade and Management Performance for the ECS and SCS

<table>
<thead>
<tr>
<th>BORDERING COUNTRIES/TERRITORIES (no.)</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE (km²)</td>
<td>3,400,000</td>
<td>744,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRODUCTIVITY</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch (million tonnes)*</td>
<td>10.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Landed value (billion USD)*</td>
<td>15.4</td>
<td>7.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRADE</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual exports, 2014 (billion USD)</td>
<td>39</td>
<td>17</td>
</tr>
<tr>
<td>Annual imports, 2014 (billion USD)</td>
<td>18</td>
<td>22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FISHING CAPACITY</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of vessels, 2014 (thousands)</td>
<td>1,770</td>
<td>183</td>
</tr>
<tr>
<td>No. of fishers, 2014 (millions)</td>
<td>2.7</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MANAGEMENT PERFORMANCE</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak year for catch</td>
<td>2014</td>
<td>2014</td>
</tr>
<tr>
<td>Catch in peak year (million tonnes)</td>
<td>11.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Catch per unit effort decline in past few decades</td>
<td>3-4 times</td>
<td>~ 3 times+</td>
</tr>
<tr>
<td>Subsidy intensity**</td>
<td>0.22</td>
<td>0.31</td>
</tr>
<tr>
<td>Unreported portion of total catch</td>
<td>0.50</td>
<td>0.12</td>
</tr>
</tbody>
</table>

* Quantity (weight/value) of fish caught in the South China Sea and East China in 2018. Value is provided in Real 2010 USD. Source: Sea Around Us.

** Subsidy intensity is defined as the total subsidy divided by the total catch value. The ECS value is derived from the Chinese portion of the ECS only.

### 1.4 Hong Kong’s seafood imports

Less than 5% of Hong Kong’s land area is suitable for agriculture and much of its marine waters are overexploited. As a result, the city imports 95% of its seafood. In 2015, Hong Kong imported USD 3.5 billion of seafood, a threefold growth since 2001. Hong Kong’s large seafood industry draws heavily from the fisheries of neighbouring East and South China Sea nations. Over three-quarters of Hong Kong’s imports of marine fish, by value, are sourced from mainland China, with a further 20% supplied by Malaysia, Thailand, the Philippines, and Japan.

Imports of crustaceans such as lobsters, shrimps, prawns and crabs were USD 211 million in 2015, sourced mainly from mainland China, Thailand, Vietnam, Malaysia, and Japan. Hong Kong is thus particularly vulnerable to the impacts of climate change and overfishing in the ECS and SCS that may affect the future supply and prices of commercially-available seafood.
Key concerns over the state of the ECS and the SCS marine ecosystems include illegal, unreported, and unregulated fishing, overfishing, coastal pollution and habitat loss. Driving these issues are broader interacting factors such as inefficient or ineffective governance, capacity-enhancing fishing subsidies, climate change, and socio-economic development trajectories.

2.1 Governance

Globally, fishing activities typically are regulated and monitored by international accords, agreements, and, if any, multinational bodies known as a Regional Fisheries Management Organisations (RFMO). There are no RFMOs that are dedicated to governing the SCS or ECS despite their importance to the global fishing industry. The lack of a cohesive governance system with respect to both of these LMEs has greatly impacted the protection, preservation, and sustainable use of fisheries.

There have been some cooperative commitments to the sustainable use and management of fisheries under various global and regional agreements. Globally, this includes the United National Convention on the Law of the Sea (UNCLOS, signed 1982) and the Convention on Biological Diversity (CBD, signed 1993). The CBD is a multilateral treaty focused on global biodiversity conservation and the sustainable use of resources, while the UNCLOS regulates all marine and maritime human activities in oceans and seas. Other agreements include the 1995 UN Fish Stocks Agreement, the 1995 UN Food and Agricultural Organisation (FAO) Code of Conduct for Responsible Fisheries, and the 1993 FAO Compliance Agreement.

Regionally, and more recently, the Association of Southeast Asian Nations (ASEAN) issued a number of policy measures to assist and guide member countries in conducting policy and legal reforms for fishery management and monitoring. Various fishery commitments have also been made via the Asia-Pacific Fishery Commission (APFIC) and the Asia-Pacific Economic Cooperation (APEC). However, the monitoring and implementation of these policies still remains a large challenge across nations in the region. Though China’s Belt & Road Initiative, as of a review conducted in 2018, no agreements had been signed to adopt marine protection or preservation policies.

There is some degree of cooperative fisheries management in the northern ECS, but this has only taken shape through bilateral agreements (e.g., mainland China–Japan, mainland China–Korea, and Korea–Japan). However, there is no multilateral agreement that spans the ECS as a whole. This continues to be an issue when ECS countries illegally fish within the EEZs of neighbouring countries, causing diplomatic disputes, as is the case in the SCS as well.

The SCS is also lacking a region-wide multilateral fisheries agreement, with many countries instead favouring bilateral agreements with other ASEAN countries.

Multilateral agreements are cited to be more difficult to negotiate than bilateral agreements. However, they are far more effective in providing a unified, legal basis for sustainable fisheries management and economic collaboration in areas within and beyond national jurisdictions. Indeed, many of the commercially valuable species are migratory and therefore require regional cooperation to collectively manage these stocks within the EEZs and in the high seas. As a result, the lack of multilateral fisheries agreement across the ECS and SCS regions continues to be a barrier to monitoring and managing fish stocks.
While governments have legislation in place to manage their national fisheries resources, this is not enough to address the challenges of this region, particularly with regards to the management of migratory species within and beyond national jurisdictions. Crucially, fisheries management policies within ECS and SCS countries have not effectively addressed overcapacity or sought to restore fisheries or marine ecosystems. A further issue is the paucity of species-level catch data and stock assessments, which prevents the formation of management plans with clear objectives. In the few cases where stock assessments have historically been conducted, data show rapid declines in fish stocks.

### 2.2 Overexploitation of fisheries

Fisheries in the ECS and SCS are generally considered to be overexploited (Box 1). This is reflected in ongoing declines in catch quantity and in the sizes taken of both fish and invertebrate species. It is also accompanied by changes in catch species composition, relative abundance, and marine food web structures, as increasing fishing pressure removes more and more top predators from the ecosystem.

Of the 3.2 million fishing vessels operating in marine waters worldwide, over half operate in the SCS and ECS. Yet, these ecosystems supply only 18% of the world’s total catch, indicating a large excess in fishing vessels deployed in this region. The over-allocation of fishing vessels has contributed to years of overexploitation and depletion of fish stocks. Catch levels in SCS and ECS both reached their peak in 2014, subsequently dropping to levels resembling those from the 1990s.

Data obtained from the European Union’s comprehensive evaluation of the world’s 66 LMEs show that the ECS and SCS are classified as the highest risk category. This assessment took into account five key components: productivity, fish & fisheries, pollution & ecosystem health, socioeconomics, and governance. The ECS ranks second highest amongst the world’s LMEs for shipping pressure (an indicator derived from commercial shipping activity), while the SCS also ranks in the upper 25%. As a direct source of pollution and a source of disturbance to marine ecosystems, the commercial shipping industry is a large contributor to the degradation of the region’s fisheries.

#### BOX 1 Cases of overexploitation in commercially important species

<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large Yellow Croaker</strong></td>
<td>This species is one of the four fish species traditionally targeted by mainland China in the ECS. It was once among the top three commercial marine fisheries of mainland China, but was severely depleted by the 1980s after three decades of heavy exploitation. Despite subsequent management efforts, including hatchery-production and restocking programmes, wild stocks of large yellow croaker in the ECS have not recovered to previous levels.</td>
</tr>
<tr>
<td><strong>Largehead Hairtail</strong></td>
<td>After experiencing severe overfishing in the Chinese ECS and SCS throughout the 1990s, hairtail stocks declined further despite a variety of fisheries regulations, e.g., seasonal fishing moratoriums, spawning ground closures, and minimum mesh sizes.</td>
</tr>
<tr>
<td><strong>Filefish</strong></td>
<td>In the Korean ECS, catches of this species declined rapidly in the 1990s, largely thought to be driven by climate change impacts on marine conditions. Similarly, the green filefish is one of five commercially important species that were fished to regional extinction during this time.</td>
</tr>
<tr>
<td><strong>Chub Mackerel</strong></td>
<td>In the ECS, chub mackerel stock size has decreased continuously since the 1970s, highlighting the overexploitation of fish populations and lack of effective management efforts in national and regional management. Various stock assessments have determined that this species is fully exploited, with an immediate need to reduce fishing effort and protect juveniles.</td>
</tr>
<tr>
<td><strong>Japanese Scad</strong></td>
<td>Throughout the SCS, Japanese scad stocks have declined since the 1980s. Though measures have been taken to recover the stock, the species is still classified as over-exploited.</td>
</tr>
</tbody>
</table>
2.3 Fishing industry subsidies

Despite the ongoing overexploitation of ECS and SCS fisheries, governments continue to encourage and enable continued growth in fishing effort by subsidising the fishing industry’s fuel, boats, gear, etc.59 This occurs against the FAO guidelines and recommendations to reduce fishing effort, hindering efforts to sustainably manage fisheries.60

For instance, the Chinese government provided RMB 38.13 billion (~USD 6.0 billion) in subsidies to mainland Chinese fisheries companies between 2011 and 2013, contributing to the continued pressure on fish stocks.61 The fisheries industries in Japan, Korea, and Taiwan are no exception; all receive fuel subsidies from their respective governing bodies.62 In the SCS, the Philippines, Indonesia, Vietnam, and Thailand ranked 3rd, 4th, 5th, and 8th respectively in the top ten largest subsidy-providing developing nations fisheries in the world.63 There is a clear and urgent need to eliminate harmful fisheries subsidies in the ECS and SCS, as is the case elsewhere in the world. Negotiations are ongoing at the World Trade Organisation to prohibit subsidies that threaten the sustainability of fisheries.

2.4 EEZ boundaries

Since multiple economies in the region have a stake in the same fish stocks, one of the largest barriers to effective fisheries management is the overlapping geopolitical boundaries in ECS and SCS waters. This was exacerbated after member states began instituting 200 nautical mile Exclusive Economic Zones (EEZs) in response to the United Nations Convention on the Law of the Sea (UNCLOS) in 1982. These are areas within which signatory nations have sole rights to both the use and responsible management of its marine resources.64 The inevitable migration of commercially valuable fish species across EEZ boundaries often gives rise to tension over the designated rights to these resources.65

2.5 Environmental degradation and climate change

The deteriorating state of ECS and SCS coastal and ocean environments exacerbates stress on the region’s fisheries. Anthropogenic activities and population growth in densely populated areas have resulted in pollutant levels that threaten the health and well-being of human populations and marine ecosystems alike.66 Environmental conditions such as eutrophication and hypoxia, which are exacerbated by human activity, also inhibit fisheries management measures and degrade the habitability of coastal ecosystems.70

Further, the effects of climate change, such as rising sea surface temperatures and ocean acidification, are projected to negatively affect marine species and ecosystem resilience, further stressing marine resources.71 already, the ECS has experienced a rate of warming that is ten times higher than the global rate.72 The SCS is warming at a slightly slower rate, but even minor increases in sea temperatures are significant given that much of the SCS is warm and tropical.

As ocean temperatures warm beyond the tolerable thermal limits of many marine organisms, they will face higher levels of mortality, changes to reproductive rates, and seek refuge in higher, cooler latitudes. This shift in species distribution could result in the regional disappearance of species that have traditionally been mainstays of commercial markets and seafood supply for decades.73

The absorption of rising atmospheric carbon dioxide by the ocean has also led to an increasingly acidic marine environment, a phenomenon known as ocean acidification. For many invertebrates that have calcium carbonate shells and exteriors, such as shrimps, crabs, and shellfish, acidified water conditions can degrade the quality of their exoskeletons and pose threats to survival.74

2.6 Illegal, unreported, and unregulated (IUU) fishing

An important regional focus for ECS and SCS governance lies in the fight against IUU fishing. This effort has been driven in large part through pressure from external trade actors such as the European Union rather than from regional stakeholders. Unreported fishing refers to catch from fishing sectors that are generally not recorded or documented fully in national statistics, such as small-scale subsistence and artisanal fisheries, recreational fisheries, and particularly discarded bycatch or catch used as fish feed (feed-grade feed). Illegal and unregulated fishing involves the use of illegal gear (e.g., poison, explosive, electric gear, etc.), catches made that are prohibited by regulations, including the take of undersized fish (which include juveniles), fishing over-quota, fishing in closed areas, or fishing without licenses, etc.
The issue of IUU fishing is rampant throughout Asia’s marine ecosystems. Asia was estimated to have lost between USD 3.9 billion and 7.6 billion in annual revenue between 2005 and 2014, which is redirected from the legitimate marine fish market by illicit and illegal trade. The proportion of unreported to reported catches is up to 50% in the SCS and 12% in the ECS. The Western Central Pacific and Northwest Pacific, which house the SCS and ECS respectively, have the highest percentage of IUU fishing as a proportion of catch after West Africa.

The Western Central Pacific region is estimated to have the highest annual loss in gross revenue (up to USD 4.5 billion), negative economic impacts from unreported catch (up to USD 10 billion), and annual loss of incomes (up to USD 2.4 billion) as a result of illegal marine resource trade. Despite the participation of ECS and SCS nations in international commitments to combat IUU through monitoring and reporting, these practices remain a large challenge throughout the region. Additionally, not all coastal states of the SCS and ECS have ratified the 2009 FAO Agreement on Port States Measures.

### Key Concerns

The Western Central Pacific region is estimated to have the highest annual loss in gross revenue (up to USD 4.5 billion), negative economic impacts from unreported catch (up to USD 10 billion), and annual loss of incomes (up to USD 2.4 billion) as a result of illegal marine resource trade. Despite the participation of ECS and SCS nations in international commitments to combat IUU through monitoring and reporting, these practices remain a large challenge throughout the region. Additionally, not all coastal states of the SCS and ECS have ratified the 2009 FAO Agreement on Port States Measures.

### Illegal, Unreported, and Unregulated (IUU) Fishing

#### Illegal Fishing
- No authorisation to fish
- Contravention of national laws or international obligations

#### Unreported Fishing
- Fishing activities unreported or misreported
- Reporting contravenes international, RFMO or national laws and regulations

#### Unregulated Fishing
- Fishing vessels without nationality
- Fishing in areas or for fish stocks where there are no regulating conservation or management measures

### Global IUU Fishing

- 11-26 million tonnes per year
- US$ 10-23 billion per year

Source: ASEAN Post, 2020
2.7 Feed-grade fishing

The decline in high-value fish species and growing demand for fish-based feed for the livestock farming and aquaculture industries have resulted in a shift in the fishing industry. Some fishing sectors have altered their focus from taking a relatively small number of marketable-sized fish to catching and sometimes targeting large quantities of feed-grade fish (FGF).

These non-target fish are caught in large volumes by non-selective gear types, particularly bottom trawlers. Because these fish were historically discarded due to their low value, they are known as ‘trash fish’ (Box 2, 3). Today, these formerly non-target species, which include a range of fish and invertebrates, have become profitable due to the high demand for fish-based feed for livestock and aquaculture feed. As a result, massive amounts of miscellaneous fish and invertebrates, irrespective of species, size or life history stage, are being targeted for use as organic feed matter.

Due to the commercial importance of ‘trash fish’, we suggest the elimination of this misleading term and hereon refer to these fish as ‘feed-grade fish’.

**BOX 2 The trash fish paradox**

The term ‘trash fish’ reflects the fact that these fish originally had no economic value, but this has changed as they have increasingly found value as feed in the aquaculture sector.

‘Trash fish’ are, contrary to their name, crucial components of marine ecosystems. They include the juveniles of commercially important species or the prey that supports these species as well as other key species that support marine food webs. The overexploitation of so-called ‘trash fish’ thus contributes greatly to the ongoing degradation of fisheries.

Over the last six decades, 27% of global marine fisheries landings, by weight, were used for non-human consumption, largely for as livestock and aquaculture feed. This practice has become a mainstay in the broader East Asia region – especially in mainland China, which now accounts for ~62% of global aquaculture production.

Studies of FGF practices in the SCS revealed that a large proportion of captured fish were in their juvenile stage of development, including species of commercial importance such as groupers and snappers. The catches also include a wide diversity of small juvenile and invertebrate species.

The constant removal of juveniles significantly undermines the reproductive capacity of their stocks and jeopardizes their long-term sustainability, while the loss of large volumes of smaller species undermines food supplies for species in the ecosystem. The juveniles that are harvested by feed-grade fishers often belong to species that, if left in the wild to grow bigger, are otherwise directly sold for human consumption with much higher value. In some cases, FGF fisheries harvest the juveniles that have been released from restocking programmes aimed to restore fish populations.

The implications of FGF practices are further explored in Chapter 4.
KEY CONCERNS

Eventually, the depletion of various Hong Kong fisheries by trawlers was so severe that the city banned trawling in 2012, also citing concerns on the habitat destruction inflicted by bottom trawling. This ban shifted the Hong Kong seafood market to an even higher reliance on imports from the SCS and ECS.

The increasing demand for FGF has also led to the use of smaller and smaller mesh sizes in trawlers, allowing more juveniles and small, ecologically important fish to be caught. In countries such as mainland China and Vietnam, mesh sizes are often smaller than the legal minimums, which are poorly enforced and regulated.

A 2018 study conducted in Vietnam revealed that although fishers reported their mesh sizes to be between 10-25mm, all the mesh sizes measured on their vessels were 10mm. This was far smaller than the minimum allowable mesh size of 20mm.

BOX 3 The role of trawlers in feed-grade fishing

Trawlers, which are commercial fishing vessels that catch fish by dragging a large net along the seabed, are the primary fishing gear used in FGF practices. In mainland China, Vietnam and Thailand, trawls are responsible for about 50% of total seafood production. Unlike many trawl fisheries outside of Asia, very little catch is discarded and an increasing amount is used as FGF. However, documentation on the volumes, species and body sizes of FGF catch composition is lacking.

The recent rise in the demand for FGF for animal feed, especially in the aquaculture sector, has allowed and even encouraged the continued operation of trawlers – despite the depletion of their original target fish species. This was also the case in Hong Kong, where trawlers continue to profit even as individually-marketed species, such as the commercially valuable hairtails and yellow croakers, diminished in population size due to heavy overfishing and lack of fishery management.
3.1 Methodology

Using the *Ecopath* with *Ecosim* modelling platform, our study examined changes in productivity and biodiversity of the fisheries in the ECS and SCS, as well as human-related factors such as employment, income, and food security over time.

Building on the research conducted in *Boom or Bust: The future of fish in the South China Sea*, ecosystem models were expanded in several aspects for this report. The study area was expanded geographically to include the East China Sea. The modelling period was also extended to the end of the century to provide long-term insights on the impacts of the various scenarios, spanning the years 2000 to 2100. Furthermore, additional fisheries management scenarios were considered under the two climate change scenarios, particularly to address the rise in FGF exploitation, resulting in a total of eight scenarios (Table 2).

These fisheries management scenarios, in order of most to least improvement over current fishing practices, are:

**Most improvement**
- Decreasing fishing effort by 50%
- Decreasing FGF landings by 50%

**Least improvement**
- Maintaining current levels of fishing (business-as-usual or BAU)
- Increasing fishing effort by 50%

These practices are assumed to be implemented for the first ten years of the modelled period, then held constant for the remainder of the period.

Two different greenhouse gas scenarios, representing potential climatic futures by 2100, were used in the models. The RCP8.5 scenario represents a business-as-usual, high emission scenario, which results in a 1370 ppm concentration of atmospheric CO₂ by 2100. The RCP2.6 represents a ‘strong mitigation’ scenario in which greenhouse gas emissions peak mid-century and decrease to a 450 ppm CO₂ concentration by 2100.

In 2021, the IPCC produced its 6th Assessment Report, providing a broader scope of climate change scenarios and projections as summarised in Box 4.

**Box 4 The world’s climate change trajectory**

The Intergovernmental Panel on Climate Change’s (IPCC) Sixth Assessment Report (AR6), published in August 2021, estimates that global temperatures have increased by 1.07°C from pre-industrial temperatures as a result of human activities. A continued warming of 1.5 to 2°C is expected by the end of the century unless significant reductions in greenhouse gas emissions are made. Under the very low emissions scenario (SSP1-2.6), a 1.0-1.8°C warming is expected by 2100, compared to the 3.3-5.7°C warming expected under the very high emission scenario (SSP5-8.5).

The impacts of climate change translate to an increase in mean global sea level of 20 cm from 1901 to 2018, with rates of sea level rise now at 3.7 mm per year compared to 1.9 mm per year two decades ago. Under the most optimistic climate mitigation scenario explored in AR6 (SSP1-2.6), sea level is expected to rise by 0.28-0.55 m by 2100, whereas a very high emission scenario (SSP5-8.5) projects a sea level rise ranging from 0.98-1.88 m by 2100. Continued global warming is also expected to intensify the variability of rainfall (i.e., more severe floods and droughts), increase the frequency of extreme heatwaves in marine and terrestrial environments, and reduce the effectiveness of ocean and land carbon sinks in sequestering CO₂ emissions.
The model resulted in three primary parameters by which the future of ECS and SCS fisheries were evaluated: **biomass, catch, and revenue** (see Box 5). These outputs were produced for ten of the most commercially prevalent functional groups, or groups of species with similar characteristics, on the Hong Kong market:

- Croakers
- Small demersals
- Large demersals
- Snappers
- Groupers
- Bigeyes
- Pomfrets
- Threadfin breams
- Cephalopods
- Shrimps

### TABLE 2 SCHEMATIC DIAGRAM OF THE EIGHT FISHERIES MODELLING SCENARIOS

Two climate change scenarios (mild and severe) were applied to four different fisheries management scenarios (I50, D50, FGF, BAU) to produce a total of eight scenarios. The models were run from 2000 to 2100.

<table>
<thead>
<tr>
<th>Climate change scenarios (n=2)</th>
<th>Fisheries management scenarios (n=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (RCP2.6) Low greenhouse gas emissions</td>
<td>Decrease fishing effort by 50% (D50)</td>
</tr>
<tr>
<td>Severe (RCP8.5) High greenhouse gas emissions</td>
<td>Decrease FGF landings by 50% (FGF)</td>
</tr>
</tbody>
</table>

*FGF denotes feed-grade fish; BAU stands for business as usual.

The biomass of marine organisms is particularly impacted by the effects of climate change. It is greatly reduced under the severe warming scenario, indicating a large reduction in functional group population sizes throughout the ecosystem. Under the severe warming (RCP8.5), severe reduction in biomass occurs under the severe climate change and increased fishing effort scenario (RCP8.5, I50) (Figure 3).

3.2 Changes in Biomass

Biomass, a measure of the total weight of organisms in an ecosystem, serves as an indicator of the state of a fish stock within the ECS or SCS at a given time. In general, fisheries biomass is highest when the most stringent management strategies are applied. Biomass is lowest when fishing practices are left unchecked and intensify over time. Climate change also has a notable impact on fisheries biomass, with much lower levels of biomass projected under the severe warming scenarios.

South China Sea

In all modelled scenarios, the future biomass of commercially valuable functional groups declines and will not recover to resemble present day levels. The magnitude of these declines is dependent on both climate change and fisheries management, where the most...
scenario, there are significant declines in all functional groups other than shrimps. This would result in a supply shortage of fish species imported from various SCS economies that are commercially valuable to Hong Kong, as well as jeopardize the food security and employment that SCS fisheries provide to millions of people in the region.

The large decreases in fish biomass in the SCS are largely due to the loss of suitable habitats in the face of warming ocean temperatures. As many species reach the limits of their thermal tolerance range, they seek more suitable habitats in cooler, northern latitudes outside of the SCS – mainly the ECS. This large-scale migration of fish, particularly those in the top of food webs, reduces predator pressures from organisms lower in the food webs. As a result, the projected reduction in all SCS fish functional groups between RCP2.6 to RCP8.5 scenarios is accompanied by a persistence and in some cases an increase – e.g. D50 scenarios) of shrimp and cephalopod biomass.

Under the RCP2.6 scenario, croakers, threadfin breams, and pomfrets become the dominant fish functional groups – particularly in scenarios with reductions to fishing effort (i.e., D50 and FGF). Given that these functional groups are currently overfished in SCS waters, the reduction in fishing effort allows their populations to recover.

Changes in fishing effort also lead to a shift in both the total fisheries biomass and the biomass of specific functional groups. Increasing fishing effort by 50% is projected to reduce the total biomass of SCS fish to less than half of present day levels, even more so under the severe warming scenario (RCP8.5).
East China Sea

Compared to present day biomass in the ECS, the impacts of climate change are evident but not as severe as in the SCS scenarios. As noted above, this is likely due to the northward migration of some fish species from tropical and subtropical waters, such as the SCS, into the ECS in response to warming ocean temperatures. This offsets some biomass lost from the ECS due to overfishing or climate change-induced die-off of pre-existing fish populations, resulting in the lower magnitude of biomass change seen in the models (Figure 4).

The importance of managing fishing effort is evident in the ECS model outputs: with a 50% reduction in fishing effort in the first ten years of the modelled period, or even a 50% reduction in FGF landings alone, the biomass of the ten functional groups in 2100 can exceed that of today, even in the higher emission scenario (D50).

However, though total biomass levels may remain relatively high, the relative proportion of each species (i.e., abundance) is projected to shift as a result of climate change. Threadfin breams and croakers are anticipated to undergo large decreases in biomass under the RCP8.5 climate change scenario, driven by factors such as loss of habitat, warming ocean temperatures, and lower availability of prey. In contrast, species with a better tolerance to warmer temperatures, such as shrimps and cephalopods, remain largely unimpacted by differences in climate warming scenarios.

The changes in species composition within the ECS and SCS ecosystems have a variety of knock-on effects for various functional groups. For example, biomass in the ECS under the high emission scenario is lowest under the BAU scenario rather than the I50 scenario. In the I50 scenario, small demersals are projected to have a significant increase, likely due to the removal of predator pressure as larger, carnivorous fish become smaller in number. This result highlights the complex interactions within trophic webs that may drive unexpected responses in species composition under the different scenarios.

As in the SCS, currently overexploited fish stocks, such as threadfin breams, bigeyes, and large demersals, benefit from reductions in fishing effort, as can be seen in the increases in their biomass in the FGF and D50 scenarios compared to BAU and I50 scenarios. Though the ECS has cooler sea surface temperatures than the SCS, the impacts of severe, RCP8.5 warming will lead to lower fish biomass as their habitat or oceanographic conditions become unsuitable for survival.
3.3 Changes in catch & revenue

South China Sea

Projected catches in the SCS decrease under all fishing and climate scenarios, with near collapse for almost all fisheries under the high emission scenarios (Figure 5). The decreases in catch are largely driven by the projected reductions in biomass, particularly under the more severe effects of climate change. Only shrimp fisheries are projected to survive in the severe warming scenario, likely due to the higher heat tolerance of shrimp species compared to other fish or invertebrate species. In the mild climate change scenario, relative proportions of functional groups such as cephalopods, bigeyes, and threadfin breams suffer large reductions.

In the severe warming scenario, the catch and revenues of the single dominant functional group, shrimps, are higher when there is no reduction in fishing effort (Figures 5 and 6). Given that shrimps are typically preyed on by other fish, the shrimp stocks are able to thrive as increased fishing effort removes more predators from the ecosystem.

However, this relationship does not hold in the mild climate change scenario, where even an unregulated fishing effort scenario (such as I50) results in the lowest catch and revenue. Increases in fishing effort deplete dominant fish functional groups such as threadfin breams, pomfrets, and bigeyes. These functional groups, which are current mainstays of regional seafood markets, are projected to be fished to near-extinction in the SCS. Therefore, even with an increase in fishing intensity, catch and revenue levels remain the lowest of all four scenarios.

This indicates that while fisheries may be more profitable when fishing effort is high, this is only a temporary effect. At a certain point, the overexploitation of fish stocks results in the forfeit of economic gains that could have been preserved with judicious management of fishing efforts (as in the D50 and FGF scenario).

**FIGURE 5** MODEL PROJECTIONS OF SOUTH CHINA SEA FISHERIES CATCH BY 2100

**FIGURE 6** MODEL PROJECTIONS OF SOUTH CHINA SEA FISHERIES REVENUE BY 2100

**Fisheries Management Scenarios:**
- **D50**: decreasing fishing effort by 50%
- **FGF**: decreasing feed-grade fish landings by 50%
- **BAU**: business-as-usual
- **I50**: increase fishing efforts by 50%
East China Sea

In contrast to the SCS, catch landings are projected to increase in the East China Sea when fishing effort is high, showing an inverse relationship with biomass. That is, higher catch levels and revenues that are seen in the BAU and I50 scenarios are associated with lower biomass levels. Similarly, when fishing effort is controlled under the D50 and FGF scenarios, a reduction in catch and revenue is observed.

The species diversity of ECS catch is projected to decrease by the end of the century, especially in scenarios that allow fishing effort to continue or increase from current practices (Figure 7). ECS catches are generally concentrated over a few functional groups (i.e., cephalopods, croakers, small and large demersals), making the industry even more vulnerable to future fluctuations in individual fish stocks. Notably, species of particular economic and conservation interest, such as the small and large yellow croakers, are reduced to a fraction of their present day catch levels.

In some cases, a reduction in fishing mortality and resulting recovery of fisheries biomass is accompanied by a growth in the value of the fish stock – particularly as previously overexploited populations reach a more sustainable yield level. The revenue associated with small demersals, for example, can be seen to increase along with biomass when fishing effort is controlled in the D50 and FGF scenarios or even kept stable in the BAU scenario (Figure 8). The growth in revenue and catch associated with small demersals, however, is also driven by the depletion of large demersals and other predator species that typically would control their population size. This highlights the dangers of overfishing larger predatory fish in order to reap gains from the subsequent proliferation of smaller prey species.

For most fish functional groups in the ECS, however, the overexploitation of fish stocks results in such scarcity that the market price of the fish is driven even higher. Thus, the increase in revenue observed in the BAU and I50 are a product of demand-driven inflation from undersupplied

![Figure 7: Model Projections of East China Sea Fisheries Catch by 2100](image)

![Figure 8: Model Projections of East China Sea Fisheries Revenue by 2100](image)
3.4 Ecosystem-level summary

The results of the scenario modelling for the ten most economically important functional groups on the Hong Kong market are summarized on an ecosystem level in Table 3. The projected changes in biomass and revenue between the years 2000 and 2100 are calculated for the entire SCS and ECS ecosystems.

The best-case scenario represents the highest level of mitigation to fishing effort (Decrease 50%) under the mild climate change scenario (RCP2.6). The worst-case scenario represents an increase in fishing effort without mitigation (Increase 50%) under the severe climate change scenario (RCP8.5).

The SCS is projected to experience a 22% reduction in fisheries biomass even in the best case, and a 93% loss in biomass in the worst case. This translates to annual economic losses of USD 6.7bn and USD 11.4bn respectively, and this is for ten functional groups alone. These results highlight the severity of overexploitation in the SCS, where even the best-case scenario will result in further decline and loss of economically-important fish stocks, such as sharks (see Box 6).

On the other hand, the best-case scenario model for the ECS shows a gain of 20% in biomass across the ten functional groups by the end of the century compared to present day. The worst-case scenario suggests a loss of equal magnitude, indicating the importance of both climate change mitigation as well as the management of fishing effort.

In the case of the ECS, a gain in biomass is associated with the reduction of fishing effort, thereby reducing revenues by USD 850mn. This relative loss, however, is crucial to ensuring the long-term sustainability of these fisheries. If fishing effort is left unchecked to pursue the short-term economic gains (as in the USD 890mn gain projected from the worst-case scenario), the ecosystem may eventually cross a tipping point to resemble SCS – one where overexploitation leads to unrecoverable economic and biological losses.

### TABLE 3  ECOSYSTEM-LEVEL SUMMARY OF CHANGES IN BIOMASS AND REVENUE THAT ARE PROJECTED TO IMPACT THE SCS AND ECS UNDER A BEST- AND WORST-CASE SCENARIOS (2000-2100).

Biomass and revenue are calculated based on the 10 most economically important functional groups on the Hong Kong Market

<table>
<thead>
<tr>
<th>Model Parameter</th>
<th>Scenario for comparison with present day*</th>
<th>SCS</th>
<th>ECS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change in biomass (%)</strong></td>
<td><strong>Best case:</strong> Mild climate change (RCP2.6) and decreasing fishing effort by 50% (D50)</td>
<td>-22%</td>
<td>+20%</td>
</tr>
<tr>
<td></td>
<td><strong>Worst case:</strong> Severe climate change (RCP8.5) and increasing fishing effort by 50% (I50)</td>
<td>-93%</td>
<td>-20%</td>
</tr>
<tr>
<td><strong>Change in revenue (%)</strong></td>
<td><strong>Best case:</strong> Mild climate change (RCP2.6) and decreasing fishing effort by 50% (D50)</td>
<td>-49%</td>
<td>-57%</td>
</tr>
<tr>
<td></td>
<td><strong>Worst case:</strong> Severe climate change (RCP8.5) and increasing fishing effort by 50% (I50)</td>
<td>-82%</td>
<td>+45%</td>
</tr>
</tbody>
</table>

- **SCS (South China Sea):**
  - Biomass: -1,490,000 t
  - Revenue: USD 6.7bn

- **ECS (East China Sea):**
  - Biomass: +645,000 t
  - Revenue: USD 850mn

- **Difference:**
  - Biomass: -1,555,000 t
  - Revenue: USD 5.8bn
Shark fins have historically been the most valuable seafood product imported to Hong Kong. Despite a 70% reduction in Hong Kong’s shark fin imports between 2009 and 2019, the city remains the biggest global hub for the shark fin trade and the largest per-capita consumers of shark fin.

Prior studies of the South China Sea have demonstrated a significant reduction in shark and ray populations due to bottom trawling, exacerbated by the demand for FGF. Modelling from Boom or Bust: the future of fish in the South China Sea showed that the catch value of sharks is projected to decrease by more than 30% by 2045 under a BAU fishing and high emission scenario. The same projections showed that a reduction in fishing effort has the potential to rebuild the biomass of shark populations; otherwise, the continued impacts of overfishing and climate change will greatly deplete the stock. Though the biodiversity and abundance of sharks in the SCS has already been on the decline, shark fisheries are continuing to expand their operations across South East Asia.

Similarly, updated model projections suggest that the biomass and revenue associated with sharks and rays in the SCS will decrease by 2100. Under the worst-case-scenario modelled (i.e., severe climate change and a 50% increase in fishing effort), sharks will be virtually extinct from the SCS – leading to an associated annual revenue loss of over USD 1.4 million. Even in the best-case scenario (i.e., mild climate change and a 50% decrease in fishing effort), biomass and annual revenue of shark fisheries cannot recover to present day levels.

In the ECS, shark species have historically declined, particularly because they are caught as bycatch in longline fisheries that target tunas. In 2008, 84% of Japan’s shark catch was made as bycatch from tuna longlines, and Korea’s shark bycatch made up of nearly 50% of tuna longline catches. As a result, the two ECS nations have made concerted efforts to halt the bycatch of sharks by instituting stricter licensing systems for shark bycatch-producing fisheries.

Our modelling shows that the ECS presently has low shark biomass across the ecosystem, reflecting the decades of overexploitation and removal as bycatch. However, under the best-case scenario, in which fishing effort is reduced by 50%, biomass is projected to increase significantly by 2100 and create total catch revenues of ~USD 667,000 annually. On the other hand, the modelled impact of severe climate change and increased fishing effort (i.e., worst-case scenario) results in total extinction of sharks from the ECS by 2100. These results further highlight the extent to which fishing effort and climate change can determine the fate of sharks in both the South and East China Seas.
4.1 The Rise of Feed-Grade Fishing in Asia

In light of the continuing depletion of the world’s fishery resources, aquaculture is perceived by many as the solution, since farming fish may appear to take the pressure off wild stocks. In reality however, the reliance of many farmed species on feed produced from wild fish stocks means that aquaculture is only part of the solution. In other words, it does not necessarily relieve pressure on wild fish stocks and may conversely contribute to the overexploitation of wild fish and invertebrate populations. Feed-grade fishing is considered by many to be detrimental to both current and future fish populations.

The countries bordering the ECS and SCS collectively consume the largest amount of the seafood in the world and are the biggest fishery and aquaculture producers. At present, over 70% of global aquaculture is fed aquaculture, with East Asia accounting for 62% of global aquaculture.

In many parts of the ECS and SCS, mariculture involving uncontrolled wild capture of juveniles for ‘grow-out’ and the intensive use of wild fish as feed intensifies the pressure on fish stocks. This is especially true for the feed provided to farmed carnivorous fish, such as salmon, croakers, and groupers, among other high-valued species. In both LMEs, FGF practices are dominated by several countries, mainly mainland China, Vietnam and Thailand (Figure 9).

In 2016, half of mainland China’s trawler catch consisted of FGF. The trawlers accounted for 35% of all mainland Chinese marine catch (~4.6 million tonnes). In both the ECS and SCS, mainland China is responsible for the majority of FGF landings – approximately 85% in the ECS and 57% in the SCS in recent years (Figure 11). Vietnam is also a major contributor to FGF landings in the SCS (~28% of total landings), as is Thailand (~10%). The remaining eleven SCS economies only account for about 5% of FGF landings.

The growth of FGF practices is often in direct competition with the traditional fishing industry. Many of the same taxonomic groups are caught for the FGF industry in both the ECS and SCS (Figure 12). Crucially, these groups include the same species that are mainstays of the Hong Kong and mainland China markets, where they are sold fresh for human consumption. These species include chub mackerels, Japanese anchovies, large head hairtails, silver croakers, and yellow croakers.
FIGURE 11  HISTORICAL FEED-GRADE FISH LANDINGS BY FISHING ENTITY IN THE ECS AND SCS FROM 1980 TO 2015

FIGURE 12  HISTORICAL FEED-GRADE FISH LANDINGS BY TAXONOMIC GROUP OR SPECIES IN THE ECS AND SCS FROM 1980 TO 2014. ‘OTHERS’ INCLUDE 203 TAXA FOR THE ECS AND 278 TAXA FOR THE SCS
4.2 Impacts of the rapidly growing FGF industry

The full impact of FGF fisheries is yet unknown due to the paucity of species-specific catch data for FGF landings in the ECS and SCS. There has been little reporting or assessment of the FGF stocks despite the large volumes at which FGF are caught, regardless of their species, growth stage, or size. Reports from research supported by organisations such as the Greenpeace and WWF, as well as ADMCF, have begun to contribute to this understanding.120

Feed-grade fishing practices not only threaten present-day fish stocks due to the high level of exploitation, but also jeopardize future populations by prematurely harvesting juveniles, including those of commercially important species.121 In addition to the impacts of climate change and improper fisheries management discussed prior, the prevalence of unregulated FGF practices could lead to an ecosystem-wide collapse of marine food webs.122

The FGF industry is also anticipated to have detrimental economic consequences for fisheries and fishing communities. FGF catch profits are derived from a ‘quantity over quality’ approach. All types of catch are indiscriminately harvested for use as aquaculture or livestock feed and do not need to be of high quality. In comparison, fish that are marketed for direct human consumption, i.e., sold at a marketable size, have a much higher value, particularly on a per-fish basis. The FGF industry is therefore sacrificing potential economic gains by harvesting fish with high individually-marketed values for sale as low-quality FGF.

The loss of fish available for direct human consumption to the FGF industry will also result in higher market prices for consumers as supplies dwindle.123 This presents particular hardship for lower-income communities that rely on fish as their main source of protein and for their livelihoods. Many of the farmed carnivorous fish and shrimp species that are available on today’s market not only require large volumes of FGF to produce, but also are only accessible to wealthier consumers. The Pacific bluefin tuna, silver seabream, and groupers are all high-value species that are highly dependent on FGF for the increasingly profitable aquaculture sector.124

4.3 Scenario modelling of potential futures

Using ecosystem modelling, the differences in net fishery catch sizes and revenues were estimated based on current feed grade fishing practices in comparison to sustainable practices that avoid catching juveniles and rebuilding present fisheries. Given mainland China’s dominance in SCS and ECS feed-grade fishing, this analysis focused on five coastal Chinese provinces: Fujian, Guangdong, Guangxi, Hainan, and Zhejiang.125

Studies that undertook port-side sampling and identification of fisheries landings in these five provinces found that the proportion of juveniles in catches ranged from 23% to 60%.126 The premature removal of juveniles from wild populations before they mature and reproduce contributes to the decline of stocks in order to meet the demands of fed aquaculture. Globally, most managed fisheries seek to reduce or eliminate the catch of juveniles as a fundamental measure to ensure sufficient reproductive capacity for population replenishment. We simulated average annual catch sizes and net revenues under two scenarios using Sea Around Us catch data:

- **BAU Scenario**: based on the continuation of current fishing practices for feed-grade fishing (FGF). The net revenue discounts the loss in future revenue caused by harvesting juveniles that could have been sold for direct human consumption as adults.

- **Rebuild Scenario**: based on the catch of only mature adult fish, where juveniles of each stock are caught only when they reach maturity. Unlike if they were captured for FGF, the juvenile fish that grow to marketable sizes can be sold at a higher per-unit price for direct human consumption. It is assumed that some of these juveniles will never reach maturity due to natural mortality.
In all provinces, the modelled fishery revenues and catch sizes are significantly higher under the Rebuild scenario in comparison to the present BAU scenario (Figure 13 and Figure 14). Revenue is predicted to be over ten times higher in the Rebuild scenario in some provinces, resulting from harvesting only adult fish and allowing juveniles to reach maturity.

The maturing time of juveniles generally ranges from one to five years. During the first year of the Rebuild scenario, catches and revenues are initially lower to account for this maturation time, after which the fish can be harvested. In subsequent years, the Rebuild scenario catch and revenue levels greatly outperform those of the BAU scenario. This one-year waiting time for juvenile fish maturation therefore has clear economic benefits that forego the immediate, but ultimately short-term gains from BAU practices.

While not explicitly considered in this analysis, there are also large benefits to increasing the number of mature fishes that are able to spawn and restock the population, rather than harvesting them before they are able to reproduce. This fisheries management strategy would be particularly beneficial to ECS and SCS fisheries, many of which have stocks that are overfished.\textsuperscript{127}
The scenario modelling carried out in this report suggests that reductions in fishing effort for the first ten years of the modelled period can have lasting positive impacts in restoring fish stocks for the longer term. In particular, the 50% reduction in fishing effort resulted in positive gains in ECS biomass for the 2100 outlook.

While the SCS is still projected to experience future losses in fisheries biomass, the magnitude of this loss can be greatly mitigated by lowering fishing effort. To preserve the ecological and economic longevity of Asia’s most valuable fishing grounds, it is crucial that action is taken on the following three main themes: initiating regional dialogues, addressing feed-grade fishing practices, and integrating climate change and fisheries management policies.

5.1 Initiate regional dialogues

Following the publication of the predecessor to this report, *Boom and Bust*, and other related research, several workshops were held convening SCS fisheries stakeholders. The SCS Fisheries Resources and Management Workshop in 2017, for example, brought together 25 participants from seven SCS fishing actors: mainland China, Malaysia, Taiwan, Vietnam, Indonesia, Thailand, and the Philippines. The workshop served as an apolitical opportunity for these fishing actors to build up a mutual understanding of fisheries management measures and discuss future collaboration.

Going forward, the results of this report can similarly be used to build on such dialogue as a basis for promoting collaborative multinational fisheries management across the region in a non-politicised manner. This could take place within and across multiple stakeholder groups through mediums such as journalist collectives, scientist coalitions, and workshops similar to the SCS Fisheries Resources and Management Workshop. In addition, reports of this nature serve as the foundational scientific knowledge base to support meetings amongst regional policymakers.

Without an effort to build a robust regional multilateral approach to address impacts of overfishing and climate change, a critical source of protein for millions in the region will be at risk. The regional convergence of policymakers and stakeholders will be instrumental in not only developing holistic management strategies, but also improving compliance with existing obligations, treaties, and conventions. If current activities are left unchecked, and as stocks decline and prices rise, disputes over these resources are likely to unfold.

5.2 Address feed-grade fishing practices

The continuous growth of the aquaculture industry is increasing the demand for fish-based feed products, leading to the proliferation of unsustainable feed-grade fishing practices. Results from our in-situ research and scenario modelling show that there are millions of dollars of unrealized economic losses at stake in supplying fish-based feed to the fed aquaculture industry. In particular, the capture of juvenile fish for use as low-quality aquaculture feed sacrifices the revenue from selling market-size mature fish for direct human consumption at much higher per-unit prices.

To address feed-grade fishing practices, it is therefore crucial to reduce or halt the indiscriminate harvesting of juvenile fish and small species of fishes and invertebrates, especially for use in low-quality feed for aquaculture. Furthermore, stakeholders of the aquaculture industry must have a greater awareness of the ecological and economic ramifications of utilizing fish-based feed. Simultaneously, these stakeholders should be encouraged...
by managers to seek alternative protein sources for feed. Alternatively, the aquaculture industry can consider farming species that do not require feed that is derived from wild fish sources, noting that any significant shifts in farming or fishing practices may result in shifted impacts elsewhere.

To facilitate policy change, a robust peer-reviewed situation analysis is considered critical to provide the necessary data and information to inform regional policy development and proposals. While the concern over FGF is acknowledged in some arenas, it is less well known and understood in others. The situation on the ground in some of Asia’s largest fisheries is not well-documented, if documented at all, and the scale and severity of this growing problem has not received the global attention it deserves.

In addition to regulating the use of FGF for aquaculture, the sustainable management of FGF also comes hand-in-hand with reducing trawling pressure as part of efforts to reduce overall fishing effort. This can take shape through measures such as trawl bans, closed fishing seasons that coincide with spawning seasons, or closing off spawning grounds to trawlers. Governments should also consider implementing economic incentives to support these measures or educational programs to raise awareness of the higher economic benefits that can be attained by avoiding juvenile harvests for FGF. Furthermore, engagement with fish traders and buyers can facilitate the negotiation of higher prices for larger sized fish for direct consumption.

5.3 Integrate climate change and fisheries management policies

The results of our research show the interdependence of climate change and fishing effort on the fate of globally important fisheries, such as those in the ECS and SCS. In light of the recent release of the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), it is undeniable that urgent action is required to mitigate anthropogenically induced climate change. The development of integrated climate-adaptive fisheries management and conservation plans is also crucial. This is particularly important for climate-sensitive fish stocks, which, in the absence of climate adaptation interventions could collapse despite the implementation of fisheries management strategies.

Despite the majority of fishers and fishing vessels in the ECS and SCS belonging to small-scale fisheries (SSF), SSFs have historically been neglected and marginalised in fisheries management policies and strategies. Insights from recent studies and workshops conducted with small-scale fishers globally reveal that SSFs are already experiencing the significant socio-economic impacts of climate change and overfishing in their communities. These fishers most commonly cited abnormally warm seawater temperatures, increases in the frequency and severity of high tides and strong winds, and decreases in fish availability as the main impacts of climate change on their fishing activities. Policies for addressing climate change and fisheries must therefore focus on understanding the adaptation capacity of small-scale fishers and communities, whose livelihoods, food security, and local cultures are dependent on the ECS and SCS ecosystems.

Further scientific research is needed to support the development of regional policies. Specifically, the impacts of climate change modelled in this report have not differentiated between small- and large-scale fisheries, which will not be affected in the same ways. Continued research in this area can help portray a clearer image of the future of this region’s food security and livelihoods. In addition, the FGF modelling conducted in our study can be expanded upon by examining the impacts that FGF for aquaculture will have on global fish supply and the implications for regional trade dynamics. Lastly, further research on the impacts of ocean acidification on marine invertebrates will be crucial in evaluating whether these species will be able to persist in the future as our models suggest.
The story emerging from the OceansAsia Project is one of a globally significant marine resource, shared by East and South East Asian nations, that is at risk of collapse if we do not act in the immediate future. The East and South China Seas, which hold critical social, economic, and ecologic value, are under threat by anthropogenic factors that are within our power to mitigate. Left unaddressed, the degradation of these LMEs will lead to enormous losses in food and nutritional security, employment, and trade on the order of tens of billions of US dollars, as well as the proliferation of social inequities and biodiversity degradation.

By telling this story, we hope to support a call for action to rebuild and protect the marine resources of Asia’s LMEs’ and address the commonly held misconception that aquaculture is ‘the solution’. In reality, aquaculture does not displace fishing or address the underlying causes of overfishing due to its reliance on FGF, conversely accelerating the overexploitation of fisheries. Our modelling shows that there are large revenue gains to be made from reducing or eliminating FGF practices to allow juvenile fish to mature for sale on markets for direct human consumption.

In summary, our research provides an important economic rationale for adapting current fishing practices to maximize potential economic returns, ensure food and nutritional security, and ultimately preserve the valuable ECS and SCS marine ecosystems. The short-term pursuit of economic gains can result in irreparable losses to fisheries resources, jeopardizing food security and resource equity for future generations. It further provides the impetus to facilitate multilateral cooperation in regional fisheries management in order to reduce current threats, rebuild fisheries, and manage future social-ecological and environmental risks.

To do so, multilateral cooperation is required to reduce fishing effort to levels at which the fisheries can be both sustainable and productive in the long-term. Our research emphasizes the urgency to act at a regional scale to mitigate human and climate pressures on the ECS and SCS marine ecosystems. National-level actions, such as the improved monitoring of fishing practices, are also essential for successful fisheries management. The implementation of effective policy and governance strategies are critical for ensuring the resilience of ECS and SCS ecosystems in the face of global changes. It is clear that the continuation of present unsustainable trajectories in ECS and SCS fisheries will not only affect global fishery production, but also hurt the social, economic, and human well-being of coastal communities.

Our scenario modelling paints a picture of seas spiralling into crisis, threatening Asia’s food security, biodiversity, and economic stability as a result of our current business and consumption practices. We currently lie at a junction beyond which swift and effective action can rebuild sustainable fisheries. Otherwise our continued inaction will lead us to economic, social and ecological peril. The choice is ours to sink or swim.

2. Ibid.

3. Ibid.

4. Ibid.


20. a. Ibid.


24. Ibid.

25. Small-scale fisheries in the SCS target fish from various shallow coastal ecosystems, including coral reefs, mangroves, and seagrass beds. Common gears used in small-scale fisheries include hook and line, Gillnet, fish corral, traps, spear, long line, bag nets, troll line, and cast net, among others.


REFERENCES AND END NOTES

30. a. Ibid.


31. a. Ibid.

b. Ibid.

c. Ibid.


33. Ibid.

34. Ibid.

35. According to the Food and Agricultural Organization of the United Nations, a Regional Fishery Management Organization (RFMO) is a mechanism through which States or organizations that are parties to an international fishery agreement or arrangement work together towards the conservation, management and/or development of fisheries. A RFMO is a body which has a management mandate and which adopt fisheries conservation and management measures that are binding to its members. The Western and Central Pacific Fisheries Commission (WCPO) is an RFMO that manage the dwindling and highly migratory fish stocks in the Pacific, and includes the South China Sea in its geographical scope. However, only Indonesia, and the Philippines are full members while Vietnam is a cooperative non-members.


41. Ibid.

42. Ibid.


48. Ibid.


58. Ibid.
53. a. FAO (2010) Status and potential of fisheries and aquaculture
52. a. Gazeau, F., Parker, L. M., Comeau, S., Gattuso, J., O’Connor,
51. 73. Teh, L. S. L., Cashion, T., Alava Saltos, J. J., Cheung, W. W. L., and
46. 74. a. Gazeau, F., Parker, L. M., Comeau, S., Gattuso, J., O’Connor,
45. 75. Sumaila, R., Zeller, D., Hood, L., Palomares, M. L. D., Li, Y., and
44. 78. Ibid.
91. Ibid.
92. a. Ibid.
97. Ibid.
98. Ibid.
99. Ibid.
100. Ibid.
101. Ibid.
106. Ibid.
109. Ibid.
111. Ibid.
REFERENCES AND END NOTES

114. Ibid.


119. Ibid.


133. Small-scale fisheries, or artisanal fisheries, are defined as traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, and mainly for local consumption. They contribute about half of global fish catches and employ more than 90 percent of the world’s capture fisheries. *(Food and Agricultural Organization of the United Nations).*


