**Food Security Contributions from Climate-Adapted Future Fisheries in Small Island Developing States**

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1. **Introduction**

The ocean is the main source of protein for roughly 20% of the world’s population (FAO 2018). The tropics have high levels of dependence on the productivity of marine fisheries, yet have some of the lowest potential for institutional adaptive capacity into the future, while also expecting the highest degree of fisheries productivity decline due to climate change in the coming decades (Cheung et al. 2013; Golden et al. 2016; Lam et al. 2016; Thiault et al. 2019). Small Island Developing States (SIDS), predominantly situated in the tropics, are at the forefront of many sustainable development challenges, all exacerbated by the threats posed by climate change. SIDS’ local food systems are limited; livelihoods are often limited by high-level of dependence on the health of natural resources, and food security is fragile and vulnerable to economic price shocks on the global market affecting trade (Belton and Thilsted 2014; FAO 2019).SIDS are prone to market and price volatility of imported foods due to their geographic isolation and high dependence on imports for food availability. Such economic vulnerability is exacerbated by nutrition-related public health concerns, including high rates of non-communicable diseases linked to a diet of imported processed foods (Charlton et al. 2016; Santos et al. 2019).

The 38 UN member states included in the SIDS group (Table 1) will experience population growth from ~67 Million today to ~90 Million by some estimates in 2050, growth of about 30% (UN DESA 2015). Considering the high level of SIDS’ dependence on the ocean for food, global fisheries decline is particularly worrisome. Greater fractions of food security from the sea globally are increasingly accounted for by seafood trade flows and aquaculture. Sustainable fishing practices in SIDS keeping oceans healthy would go a long way to support these nations in meeting several of their Sustainable Development Goals. Insidious and persistent, climate change’s effects on marine systems lead to the rearrangement of ecosystems and fish species populations (Pinsky and Fogarty 2012; Cheung et al. 2013; Hollowed et al. 2013), with measurable impact to economic and nutritional benefits humanity derives from the ocean (Blasiak et al. 2017). SIDS need efficient and effective climate-smart ocean governance, informed by science and enabled by political will, to enable their nations to preemptively adapt their national fisheries management to anticipated climate impacts in order to secure maximum potential food security benefits for a growing population.

Climate change has and will continue to play a significant role in many SIDS’ economies and fisheries governance with analyses resulted in expected economic and food security hardships (Allison et al. 2009; McIlgorm et al. 2010; Guillotreau et al. 2012; Gaines et al. 2018). Modeling human population growth, expected rise in seafood demand and consumption rates, along with modeling climate change impacts on fisheries suggests that meeting future needs hinges on strong leadership in governance and management to secure ecologically sustainable catches by mid-century (Merino et al. 2012; Blasiak et al. 2017; Pinsky et al. 2018; Free et al. 2020). In addition, often human fishing efforts lag in their tracking of shifts in the climate change-driven ecological and geographical shifts in fisheries. These lags in human fishing effort are thought to result from economic and regulatory constraints (Pinsky and Fogarty, 2012). If unaccounted for in fisheries management and adaptation mechanisms, the social-ecological aspects of lags in fisheries under climate change can perpetuate overfishing and marine ecosystem decline.

This paper aims to support adaptive and robust ocean governance in SIDS, contributing to stronger food security and healthier ecosystems into the future as well as momentum towards the achievement of SDGs. We present model projections for seafood consumption from today through 2050 with anticipated population growth. The modeled gap in future seafood availability with respect to present conditions is striking. Several scenarios for adapting local fisheries to climate change are offered for each country to illustrate how crucial adaptive management and institutional capacity are to meeting both ocean health and human food security objectives along the path to sustainable development.

1. **Methods**

*List of SIDS nations:*

The list was derived from UN Sustainable Development Goals Knowledge Platform. The 38 UN member states listed as Small Island Developing States are grouped in three categories: **Pacific** (Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tuvalu, and Vanuatu), **Caribbean** (Antigua and Barbuda, Bahamas, Barbados, Belize, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago), **Atlantic, Indian Ocean, and South China Sea** (Bahrain, Cabo Verde, Comoros, Guinea-Bissau, Maldives, Mauritius, Saō Tome and Principe, Seychelles, Singapore).

*Seafood consumption data:*

Food Balance sheets developed by the FAO were used to estimate the supply of seafood for domestic utilization (Watson 2017; Klein et al. *in prep*). The supply for domestic utilization is quantified as the sum of production and imports less exports plus changes in stocks. "Freshwater Fish" items were removed from the dataset, leaving demersal fish, pelagic fish, marine fish, other crustaceans, and cephalopod item categories. The amount of seafood imported to a country was calculated as described above. The amount of seafood available for consumption within a country was then calculated as the sum of the seafood supply for domestic utilisation and the seafood imported to that country (total seafood available for consumption = seafood imported + seafood supply for domestic utilization). This resulted in the amount of seafood available for consumption within a country always being greater than or equal to the amount of seafood imported (imported seafood/consumed seafood ≤ 1). If a country/year did not have domestic supply data or domestic supply was equal to 0, it was removed from the dataset.

A timeseries of seafood consumption per capita estimates were produced for 1961-2009 period. An average and standard deviation were determined for each country from the period of 2000-2009. The FAO dataset lacked data for Bahrain, Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Singapore, and Tuvalu. Seafood consumption per capita for these countries was available for 2007-2009 period from the U.S. National Oceanic and Atmospheric Administration (NMFS 2012).

*Population Projections:*

Population growth projections were obtained from UN DESA (UN DESA 2015). Three different scenarios from those projections were used in this study. Scenario A is ‘*no change*’, assuming constant fertility and constant mortality for the 2015-2050 period. Scenario B is ‘*low fertility variant’*, assuming low fertility 2015-2050. Scenario C is ‘*high fertility variant’*, assuming high fertility 2015-2050.

*Seafood Demand Projections 2021-2050:*

The total projected need for seafood in the SIDS for 2021-2050 was estimated by multiplying population models by the average per capita seafood consumption rate for the 2000-2009. The different population growth models served to provide an uncertainty envelope for the seafood demand projections, along with proper error propagation.

*Future Local Catch Under Different Climate Scenarios:*

Country-level projections for fisheries’ catch through 2050 under different carbon emission scenarios and different fisheries management scenarios from a recent study (Free et al. 2020) were juxtaposed against the modeled seafood demand to evaluate what combinations of climate-adapted fisheries management and carbon emission scenarios would yield fisheries able to sustain productivity that would most significantly close the potential food security gap anticipated for SIDS. Free et al. (2020) found that fisheries yield is likely to decline in equatorial areas and increase in higher latitudes, in general in all carbon emission scenarios. The fisheries management scenarios in Free et al. (2020) tested realistic adaptation shifts that would allow the managers to recalibrate regulations at 5, 10, and 20-year intervals. Institutional nimbleness exhibited in adaptive fisheries management can offset a significant amount of climate change impact on fisheries to continue delivery of food provisioning services (Free et al. 2020). In this study, we took the 10-year ‘realistic’ adaptation model results from Free et al. (2020) to different climate scenarios to see how effectively the food security gap could be filled in the future by climate-smart ocean governance and better fisheries management capacity to regulate and enforce reforms that contribute to a shared prosperity for nature and people, for ecosystems and human health.

1. **Results**

**Table 1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Small Island Developing States** | **2021 Seafood Demand (in 1,000s kg)** | **2050**  **Seafood Demand (in 1,000s kg)** | **% Growth in Demand** | **Vulnerability Index (Blasiak et al. 2017)** | **Seafood Contributions from Realistic Adaptation at 5-year intervals (Free et al. 2020)** | **Seafood Contributions from Realistic Adaptation at 10-year intervals (Free et al. 2020)** |
| **Atlantic, Indian Ocean, and South China Sea** |  |  |  |  |  |  |
| Bahrain | 22,006 ± 227 | 26,927 ± 2,453 | 18.3% | 0.483 (#56) |  |  |
| Cabo Verde | 8,794 ± 2,314 | 11,413 ± 3,358 | 22.9% | 0.467 (#61) |  |  |
| Comoros | 21,559 ± 886 | 38,061 ± 5,544 | 43.3% | 0.674 (#14) |  |  |
| Guinea-Bissau | 3,798 ± 1,693 | 6,783 ± 3,162 | 44.0% | 0.602 (#24) |  |  |
| Maldives | 59,774 ± 12,562 | 75,922 ± 18,374 | 21.2% | 0.868 (#4) |  |  |
| Mauritius | 27,166 ± 2,624 | 25,760 ± 4,023 | -5.5% | 0.398 (#84) |  |  |
| Saō Tome and Principe | 5,754 ± 310 | 10,130 ± 1,649 | 43.2% | 0.675 (#13) |  |  |
| Seychelles | 5,771 ± 350 | 5,876 ± 779 | 1.8% | 0.585 (#28) |  |  |
| Singapore | 283,969 ± 3,788 | 305,796 ± 31,577 | 7.1% | 0.358 (#96) |  |  |
| **Caribbean** |  |  |  |  |  |  |
| Antigua and Barbuda | 4,904 ± 503 | 5,778 ± 886 | 15.1% | 0.493 (#52) |  |  |
| Bahamas | 13,496 ± 653 | 15,860 ± 1,874 | 14.9% | 0.465 (#62) |  |  |
| Barbados | 5,055 ± 847 | 7,594 ± 1,612 | 33.4% | 0.396 (#86) |  |  |
| Belize | 11,486 ± 548 | 10,997 ± 1,382 | -4.4% | 0.607 (#21) |  |  |
| Cuba | 99,891 ± 17,042 | 89,259 ± 18,074 | -11.9% | 0.414 (#78) |  |  |
| Dominica | 2,386 ± 368 | 2,364 ± 459 | -0.9% | 0.511 (#45) |  |  |
| Dominican Republic | 119,111 ± 10,373 | 145,205 ± 22,943 | 18.0% | 0.478 (#58) |  |  |
| Grenada | 4,130 ± 812 | 4,209 ± 987 | 1.9% | 0.501 (#49) |  |  |
| Guyana | 25,460 ± 6,816 | 26,753 ± 8,084 | 4.8% | 0.507 (#46) |  |  |
| Haiti | 36,238 ± 9,070 | 46,410 ± 13,127 | 21.9% | 0.700 (#11) |  |  |
| Jamaica | 75,383 ± 10,172 | 72,577 ± 13,450 | -3.9% | 0.547 (#34) |  |  |
| Saint Kitts and Nevis | 1,928 ± 120 | 2,233 ± 292 | 13.6% | 0.565 (#30) |  |  |
| Saint Lucia | 6,155 ± 814 | 6,657 ± 1,173 | 7.5% | 0.394 (#89) |  |  |
| Saint Vincent and the Grenadines | 1,865 ± 72 | 1,861 ± 245 | 10.8% | 0.479 (#57) |  |  |
| Suriname | 9,418 ± 531 | 10,556 ± 1,408 | -0.2% | 0.432 (#72) |  |  |
| Trinidad and Tobago | 21,262 ± 4,238 | 19,889 ± 4,589 | -6.9% | 0.394 (#87) |  |  |
| **Pacific** |  |  |  |  |  |  |
| Fiji | 32,710 ± 1,159 | 33,709 ± 4,579 | 3.0% | 0.590 (#27) |  |  |
| Kiribati | 9,271 ± 161 | 13,767 ± 1,623 | 32.7% | 1.000 (#1) |  |  |
| Marshall Islands | 1,018 ± 12 | 1,382 ± 242 | 26.4% | N/A |  |  |
| Micronesia | 4,798 ± 65 | 5,996 ± 852 | 20.0% | 0.909 (#2) |  |  |
| Nauru | 251 ± 3 | 253 ± 27 | 0.9% | N/A |  |  |
| Palau | 1,536 ± 18 | 1,871 ± 203 | 17.9% | N/A |  |  |
| Papua New Guinea | 149,628 ± 1,808 | 241,656 ± 30,704 | 38.1% | 0.368 (#93) |  |  |
| Samoa | 9,795 ± 849 | 12,403 ± 1,987 | 21.0% | 0.811 (#6) |  |  |
| Solomon Islands | 21,308 ± 977 | 34,388 ± 5,071 | 38.0% | 0.901 (#3) |  |  |
| Timor-Leste | 472 ± 71 | 851 ± 219 | 44.5% | 0.553 (#33) |  |  |
| Tuvalu | 420 ± 5 | 472 ± 63 | 11.1% | 0.718 (#10) |  |  |
| Vanuatu | 9,691 ± 517 | 15,891 ± 2,036 | 39.0% | 0.819 (#5) |  |  |

1. **Discussion**
   1. Geographical variation
   2. Institutional adaptation required and necessary capacity-building
   3. The role of aquaculture in helping fill the gap
2. **Conclusion**
3. **References**

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