Climate Change and Bermuda

Part II
Impacts and Societal Risk

BIOS

Bermuda Institute of Ocean Sciences
by Dr. Mark Guishard

Introduction and Acknowledgments

BIOS is grateful for the support of the compilation of this report from an exclusive donor, HSBC.
Additional in-kind support was provided by the Bermuda Weather Service, a section of the Bermuda Airport Authority.

Part II of this report focuses on the impacts and risks to Bermuda due to climate and, in some cases, the responses to these effects that society has in place. This part of the synthesis report is necessarily interdisciplinary, not solely based on science, but also leveraging available data, reports and surveys of the relevant sections of society. Some aspects of this report are subjective and qualitative, using anecdotal data but, where possible, quantitative approaches are used.

Much of this report leverages work undertaken by colleagues and interns over the last decade. While a list of acknowledgements is provided, the author would specifically like to acknowledge work that has informed substantive sections of the text by (in alphabetical order) Caroline Alexander, Ximena Boza, Dr. Michael Johnston, Dr. Pinelopi Loizou, and Kendall O'Farrell. In addition, contributions and data provision from Ian Currie of the Bermuda Weather Service (BWS, a section of the Bermuda Airport Authority), all of the faculty at the Bermuda Institute of Ocean Sciences (BIOS), Dr. Brett Lefkowitz, Dr. Kevin Mayall of Locus Ltd., Dr. Irene Peñate de la Rosa, were central to the work conducted that supports this report. I also want to specifically thank Michelle Pitcher, Deputy Director of BWS and all of the staff at the BWS and the Bermuda Airport Authority for their support during my time writing this report. Gratitude for feedback and regular discussions also goes to Diane Gordon, Disaster Manager at the Bermuda Red Cross; Jeff Manson, SVP Underwriting and Head of Global Public Sector Partnership at RenaisssanceRe; and Steve Cosham, National Disaster Coordinator, Ministry of National Security, Government of Bermuda. A pro bono report supplied by the climate change and supply chain risk analytics firm, Correntics AG was gratefully received and utilized in the relevant chapter. Finally (but certainly not least!), Pamela Amaral, Ali Hochberg and Tiffany Wardman were invaluable to the review, proofing and formatting of the text, getting this report over the goal line. A table of all contributors follows.

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contents

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Cover image: satellite image of Bermuda courtesy of NASA.

Executive Summary
Exposures and Vulnerabilities to Storms and Floods

- Hurricane disaster risk in Bermuda is mitigated by natural defenses because of geography and topography, a strong building code, and a well-practiced real-time response capability.

- Wind hazard has increased over time, to the order of 5-7% more damage potential now than over the long-term average record. However, loss uncertainty (already large) also increases by 40-50%, almost an order of magnitude greater than the mean loss.

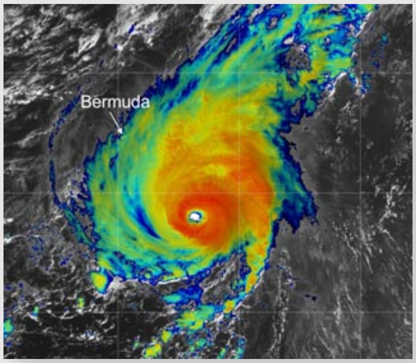
- Wind vulnerabilities have probably decreased due to removal of weak infrastructure and rebuilding to the current building code. This finding is supported by similar strength and duration storms causing less damage.

- Impacts to agriculture from changing storm activity have led to some adaptive practices amongst the local farming community. The later a hurricane occurs in the season, the greater the impact to local crop production and potential recovery.

- As climate change enables more water vapor to be available to produce larger rainfall extremes, the occurrence of flood rainfall thresholds being exceeded is likely to increase over time, putting many areas of the island under more frequent flooding impacts.

- While Bermuda is currently able to cope with 'today's' storm risk based on strong building codes and a decent disaster risk governance, improvements may be warranted to deal with increased hurricane risk and scenarios not yet faced by the island. For example, a category 4 storm with storm tide at or exceeding that of Hurricane Fabian (2003) is a more frequent likelihood. This year (2022) saw the close passage of a Category 4 hurricane (Fiona) that would have greatly tested Bermuda's disaster risk response, if it had impacted us more directly.

- Disaster risk governance currently suits our needs in terms of hurricane resilience, but as the 'storm climate' changes, the need to respond to impacts in the areas of local agriculture, health of the population (including psycho-social impacts), and infrastructure may also change.



The Effects of Heat and Droughts

- As heat indices increase over time, those who work outdoors will be more affected by heat-related conditions and illnesses.

- Those individuals working in such exposed professions (e.g., agriculture, landscaping, fishing, construction) are often in the lowest income brackets, and fewer than average are covered by health insurance. These aspects of wealth inequality point anecdotally to a reduced coping capacity for heat-induced illnesses amongst some outdoor workers.

- There are no obvious trends in the seasonal dry spells that Bermuda experiences annually; and freshwater consumption is more likely to be a contributing factor to water trucking demand than climate change. No formal definition of drought exists for Bermuda.

- Agricultural workers point to drought as being one of the contributors to reduced local crop production.

The Impacts of Sea Level Rise

- Although it probably represents the highest damage potential for Bermuda, storm surge has been less studied than hurricane frequency and wind speed extremes.

- Bermuda's most coastally exposed properties (e.g., at or below 1 m, or 3.3 feet, above sea level) show a dramatic increase in risk in the next 50 years. Property annual rental values (ARVs) exposed to coastal flooding jump from near zero now to as much as nearly $3 million in the next 50 years. This represents a relatively small number of properties, conservatively up to about 35 in number in the present analysis.

- Coastal and low-lying properties tend to be of a higher ARV on average, implying wealthier property owners (with greater coping capacity) are slightly more exposed. Some specific vulnerable portions of the community, such as those in assisted living facilities, may be at particular risk from sea level rise and more frequent coastal flooding.

- Sea level rise is likely to decrease the water quality of the fresh groundwater lenses over time. Extreme sea level events have been shown to increase the salinity of freshwater lenses fewer than six hours after the onset of the highest extreme water tide levels.

- The occasional high sea levels periodically impacting the groundwater quality are expected to increase in frequency at least 11-fold by 2050.

The Marine Environment

- Marine heatwaves and ocean warming trends can have an adverse effect on fisheries and coral reef ecosystems. Coral species each thrive within their own optimal temperature range that may be impacted by sudden increases in temperature, leading to bleaching events.

- Less acute impacts to the marine environment may be felt in decades vs. years from ocean acidification, including gradual impacts to shell- and structure-building species.

- Both ocean warming and acidification affect our 'natural sea wall's' ability to repair itself, and add to other human-induced stressors such as unsustainable fishing and marine pollution. Bermuda's coral reefs have been estimated to contribute on the order of $1 billion per year to Bermuda's economy (which has an official GDP of around $6-7 billion).

- The coral refugia hypothesis indicate some potential good news, as deep corals reside in cooler waters further down the sea mount, and may be well suited to replenish shallower aggregations of corals.

Risks to Supply Chain

- Bermuda has a concentration of upstream sources of agriculture and fuel (food and energy) in the markets and ports located primarily in the USA; 86% of our food supply comes from the USA. The value of food annually imported to Bermuda has more than doubled in the last 20 years. In 2020, Bermuda imported US $88 million worth of food.

- Far-field effects of climate change on upstream ports and destinations include disruption by storms and other climate extremes (e.g., east coast hurricanes, sea level rise) for port infrastructure, as well as local impacts.

- Adverse heat and drought will adversely affect upstream agricultural supply in likely future emissions scenarios. Significant drought exposure in the western US can affect availability and price of relevant food/agricultural imports.

- Imports of supplies (e.g., animal feed) and machinery needed for agriculture are likewise heavily dominated by, and dependent upon, delivery from US ports.

Tourism and travel

Safe and convenient travel to/from Bermuda

- Flight times from Europe will be adversely affected by changes in upper-level winds (the Jet Stream). Studies indicate that Jet Stream displacement supports longer flying times between Europe and North America which includes Bermuda.

- Notwithstanding the small-scale influences that govern day-to-day (as opposed to extreme) wind patterns, there should be limited-to-no impact on the flight times or availability from North America, on average, due to climate change.

- In addition, studies of aviation hazards at airports (e.g., wind shear, low visibility) may show some shifts in patterns over long periods of time. Local impacts will depend on local conditions. For example, sea level rise and seawater incursion onto the airfield may, in the future, cause flight arrival/departure delays.

- So, passengers may expect some longer, bumpier, journeys, increased weather delays and bumpier landings upon arrival.

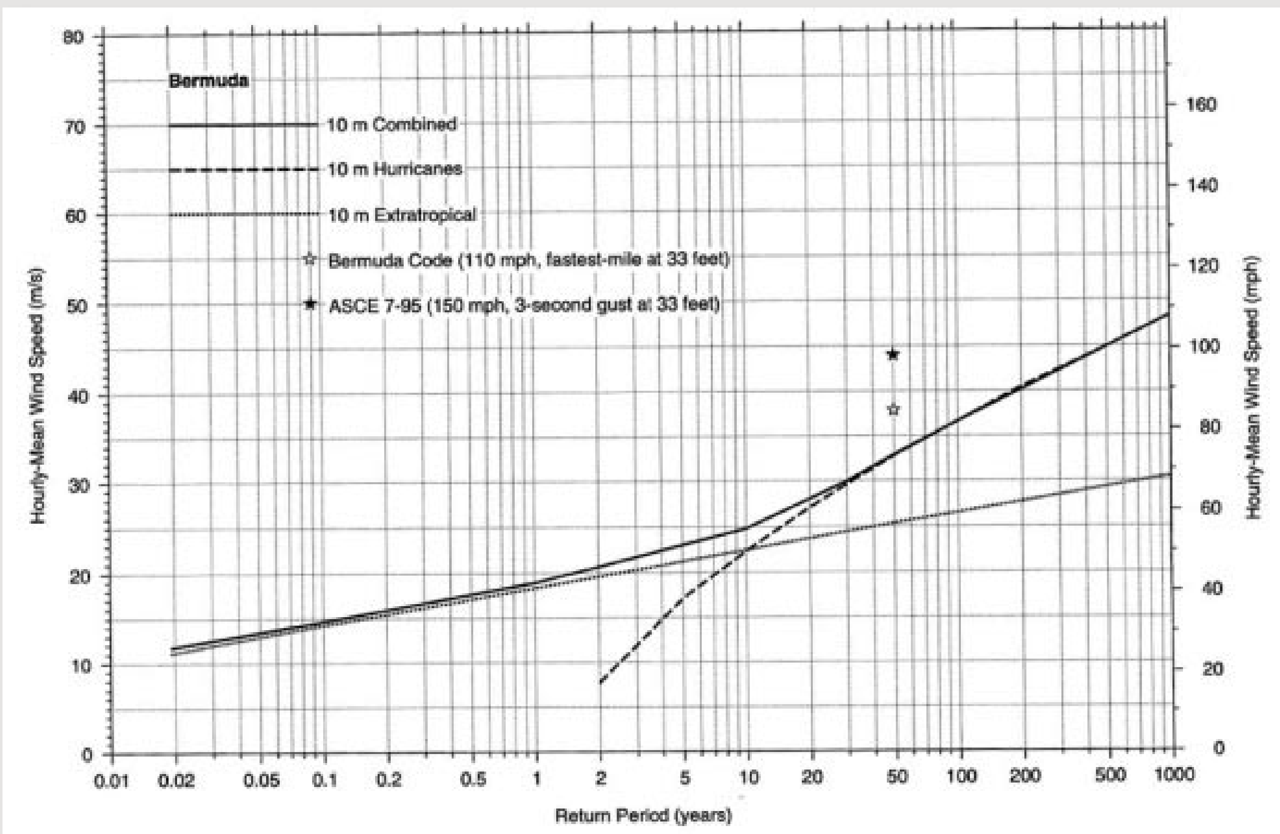
- **Activities and dining in Bermuda**
  Beaches and natural environment – sea level rise may be the biggest challenge with respect to beaches disappearing under what are currently extreme sea level rise events.

- Heat Index may go up, UV index may go down due to cloudiness, increased rainfall, higher rainfall extremes
- Wet beach days can be enough to ruin anyone's vacation, so we should incorporate more weather analysis and climate analytics into the development and marketing of activities in Bermuda. Winter rainfall is on the increase, and seasonal predictability of storms may be increasing. There is scope to develop tourism-derived impact-based forecasts and early weather and climate warnings that will inform tourism professionals locally and travelers alike.
- Impacts to food security will have a knock-on effect on affordable meal preparation for visitors.
- Affordability: complex effects of climate change (locally and globally) on supply chain risk will continue to challenge the attractiveness of Bermuda (already a comparatively expensive place to visit) as a destination of choice.
- Short-term opportunities exist to highlight and celebrate Bermuda's long history of resilience, the current efforts in response to climate change and strong efforts in the energy and transport sectors to drive down our local carbon emissions, while increasing sustainability. Long-term, the challenge is to maintain and increase those efforts.
- Opportunity: Success in climate risk financing may result in increased conference travel to Bermuda to discuss climate change impacts.
- Bermuda should be seen to be acting on local impacts of climate change, if it's to support more international efforts in climate risk finance.
- Ecotourism and 'regenerative tourism' are key offerings in a successful tourism market, and Bermuda has many opportunities in this regard.

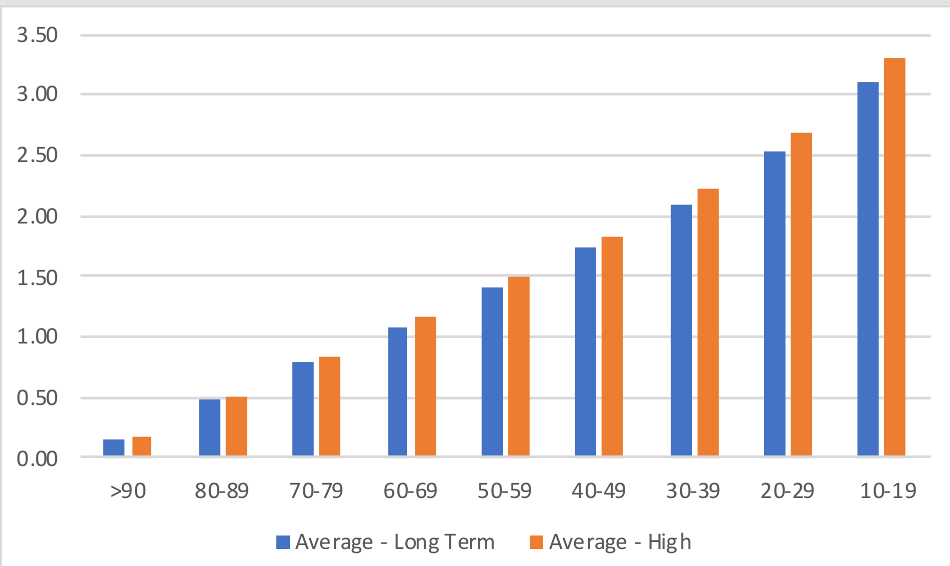
Exposures and Vulnerabilities to Storms and Floods
Wind damage potential

Bermuda's building code is well known to be strong, but what does this mean quantitatively? According to an engineering study presented in 2014 (Ho & Mara, 2014), the design of Bermuda's buildings is rated to withstand wind speeds that well exceed the statistical wind climate; in short, Bermuda's buildings are stronger than they need to be in the current climate, accounting for both winter storms and hurricanes. However, as has been outlined in Part I of this report, Bermuda's climate of storms has been changing, and is likely to continue changing, as the ocean warms and atmospheric patterns change.

A recent publication reveals that the costs of hurricane damage potential in Bermuda have increased by 5-7% in the last two decades compared to the previous baseline of the long-term record (Loizou et al., 2022) .This study uses the reinsurance industry approach of catastrophe risk modelling for assessing risk by quantifying hazard exposure and vulnerability to determine how much financial cost hurricane wind damage will incur. It uses historical events (in this case, Hurricane Fabian [2003]) to validate the model.

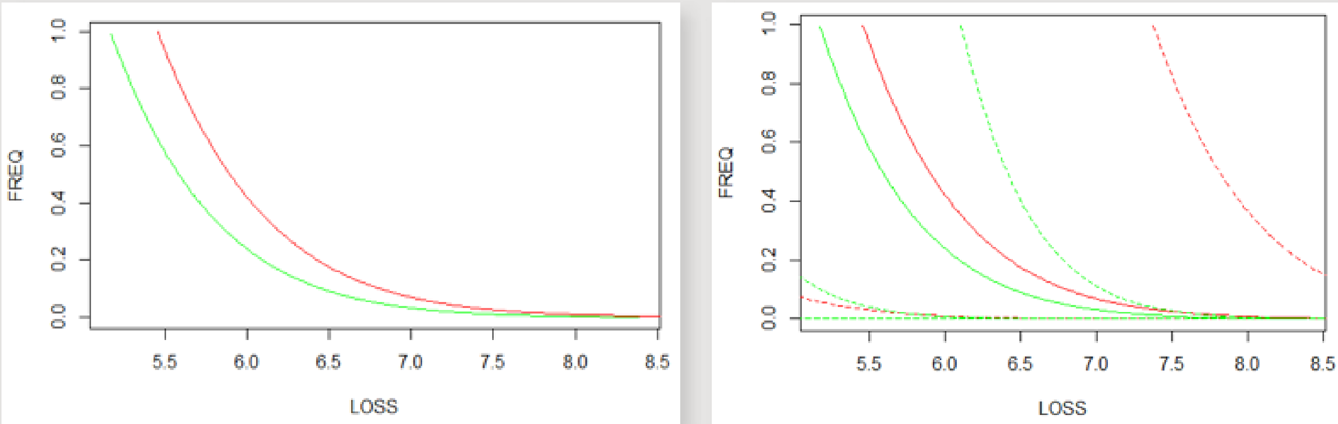


The graph above highlights the statistics of wind speed due to winter (extratropical) storms and hurricanes. The lines represent the highest wind speeds, averaged over an hour, that Bermuda is likely to experience based on historical records. The stars indicate the building code rating (wind speed that buildings in Bermuda are designed to withstand before failure). Source Ho and Mara, 2014



Annual Exceedance Probability (frequency % range) vs. average losses for 1877-2018 long-term (blue), and 1999-2014 'high rate' average (orange), in $Billions.

Percent frequency	Average Long Term	Average High	Average% increase
>90	0.16	0.17	6.16%
80-89	0.48	0.51	6.16%
70-79	0.79	0.83	6.33%
60-69	1.09	1.16	6.81%
50-59	1.40	1.49	6.44%
40-49	1.73	1.83	5.96%
30-39	2.09	2.22	5.97%
20-29	2.53	2.68	6.03%
10-19	3.11	3.30	5.97%



Left: Green = 1877-2018 average loss ($Bill), Red = 1999-2014 average loss ($Bill), Freq = Annual Exceedance Probability (%)
Right: same as top panel but including plus and minus 1 standard deviation (dashed lines).

Percent frequency	Return Period (Years)	Average Loss	High Frequency Loss	Percent change
1%	100	5.17	5.46	5.49%
0.40%	250	5.71	6.02	5.52%
0.20%	500	6.10	6.44	5.58%
0.10%	1000	6.45	6.81	5.62%

Data from (Loizou et al., 2022).

The results of this study show that the highest phase of hurricane activity on record is the most recent (see Part 1 of this report), and that the potential damage costs associated with this have increased by 5-7% across all probability events, relative to long term averages. A caveat of the results is that they are relevant for Bermuda's 2003 exposure (i.e., if one kept the infrastructure and its vulnerability to wind damage the same as it was in 2003). This also references a 'dummy' portfolio of Bermuda properties, based on their 2009 Annual Rental Value (ARV); this study multiplied ARV by 50 to get a representative property value. Hence, the raw numbers should not be used for pricing actual loss costs, but can be used for sensitivity analyses, as we have done here.

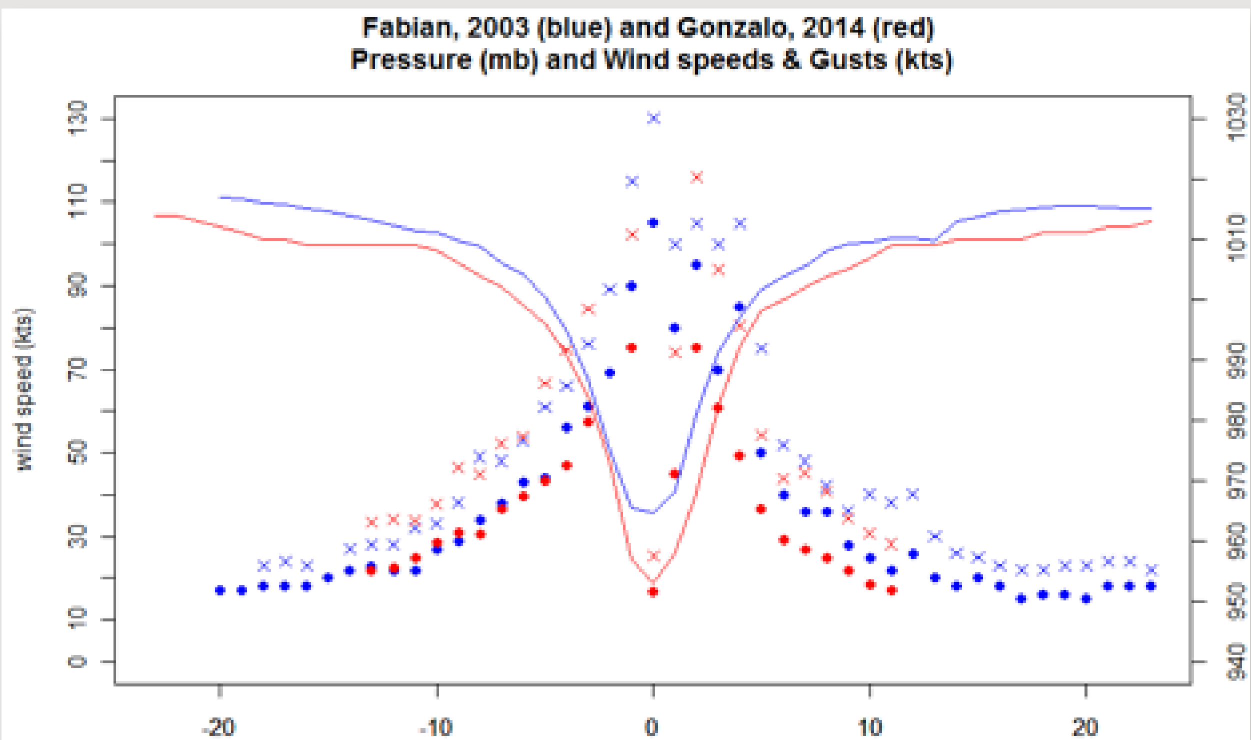
The increase in uncertainty is orders of magnitude greater. The standard deviation of the whole loss datasets for the full period 1877-2018 is $2.425 billion, increasing to $3.494 billion for the 'high phase' 1999-2014. The interpretation is that despite the seemingly straightforward result of an increase in loss, the uncertainties around these calculations greatly outweigh the increase. So, while damage potential increases by 5-7% across the return periods, loss uncertainty (already large) also increases by 44%, almost an order of magnitude greater than the mean loss.

Storms and Floods
Fabian, Gonzalo and more recent storms

Notwithstanding the findings of the catastrophe modelling study, vulnerabilities have probably improved since the time of the damage induced by Fabian (2003). The damage profile on actual losses has not shown any increase, despite damaging events being of similar magnitude in wind strength – for example, Hurricanes Gonzalo (2014) had a similar intensity to Hurricane Fabian, but did comparatively little damage.

There are of course differences, in that Hurricane Gonzalo's impact came after a storm (Hurricane Fay) that had the effect of removing all the easily damaged vegetation (Curry & Guishard, 2016; Guishard, 2015).

Interpretation – The wind hazard has increased under climate warming. While the initial conclusion may be that the damage vulnerability may have decreased since 2003, this finding should be treated with caution. Fabian represented a significant storm tide event that may not have been replicated by storms since then, due to highest surges not coming during high tide and the direction of the winds and wave fields have not yet been reproduced. Some of the damage profile assessed in the post-storm survey during Fabian may have been due to surge. Regardless, storm surge damage represents a huge part of the damage profile that was not captured in the study by (Miller et al., 2013).



Storm - relative Time (hours from passage). Data from BWS.

Storms and Floods
Power outages

Bermuda has one electricity provider, Bermuda Electric Light Company (BELCO). The main disruption to daily life that a storm may pose is a prolonged power outage. A BELCO spokesperson indicated that post-storm restoration times vary and are not necessarily linked to just storm intensity. Other contributing factors may include:

- duration and direction of winds above a threshold
- storm surge impacts to vaults or substations
- whether vegetation has been managed prior to a storm
- whether a dearth or abundance of rainfall in the preceding months has weakened vegetation
- resource availability (e.g., linemen)
- maintenance and/or hardening of the grid following previous storms
- investment in new technologies, such as smart meters, enabling more efficient deployment

It is worth noting the effect of vegetation and the vulnerability/resilience of infrastructure are not constant (Ramstrom et al., 2016), and are both indicated to be of critical importance to the characteristics of electricity outages stemming from storm activity, and subsequent restoration. In this analysis, we consider storms that likely have island-wide wind impacts vs. those that may be heavily localized (e.g., from severe weather or tornadic activity). Storm-related outages are summarized in the table below, based on media reports.

RG Magazine

Storms and Floods
Power outages

Storm	Year	Outages reported	Maximum Wind Speed* in Bermuda (knots)	Maximum Gust* in Bermuda (knots)	Maximum Surge in Bermuda (m)
Hurricane Igor	2010	28,700	79	102	0.54
Hurricane Gonzalo	2014	27,488	94	125	0.72
Hurricane Joaquin	2015	15,380	69	89	0.19
Hurricane Nicole	2016	27,431	87	111	0.87
Hurricane Humberto	2019	28,514	87	125	0.47
Hurricane Paulette	2020	25,222	72	97	0.73
Hurricane Teddy	2020	unknown	47	76	0.89
Tropical Storm Alex	2022	1,626	51	63	
Hurricane Earl	2022	1,550	51	58	0.35
Hurricane Fiona	2022	29,540	61	87	0.29

*Table: selected storms, outages and maximum wind speeds, gusts and storm surge experienced in Bermuda. * Maximum sustained wind/gust reported anywhere in Bermuda, regardless of elevation.*

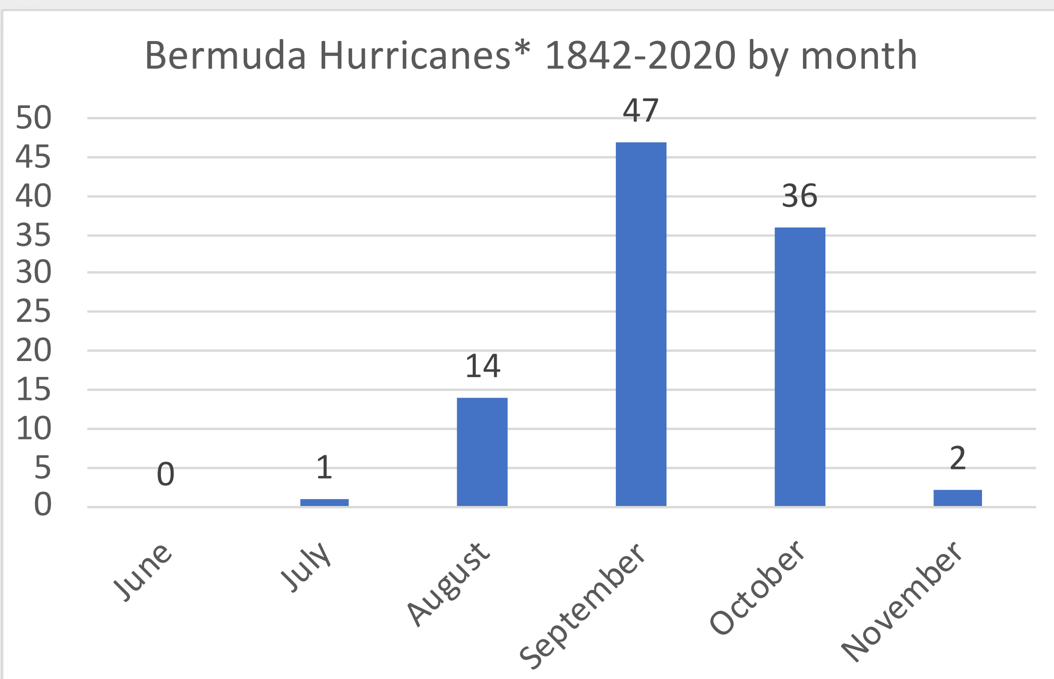
Note that in the data presented above, there is no clear relationship between the total number of electricity outages and the maximum wind speed, gusts or surge experienced in Bermuda, confirming the notion that climate-related variables are only one factor affecting electricity supply during or just following hurricanes. Hence, no clear climate signal can be anticipated due to changes in storm conditions. However, it would be reasonable to expect higher numbers of outages due to increased frequency of major storms in recent decades. The extent of outages and their restoration will be functions of the resilience of the systems in place that support production and transmission of electricity.

Storms and Floods
Impacts to agriculture

Any assessment of the impact of climate change and climate extremes on food supply must include local agriculture. Workers at four local farms, surveyed around the island during summer 2022, highlighted that storms are a main contributor to reduced local farm production. The Atlantic hurricane season runs from June through November, with the most active portion being September and October. While November through April is when various winter crops grow, the peak growing season begins in August and harvesting occurs through November. Farmers surveyed indicated that the impact of a tropical storm or hurricane depends on storm intensity and timing. Farmers described impacts from 'slight' to 'high levels of destruction' from hurricanes in recent years. Consecutive hurricanes Fay and Gonzalo in October 2014 were identified as creating high levels of destruction.

Farmers indicated that the worst agricultural impacts from hurricanes were from ones that hit before a crop is ready to be harvested, rather than just after planting. Hence, late season hurricanes are more impactful to local crop production. Impacts from early season storms may still allow time for crop re-planting. A late season storm's impact to the peak crop affects higher income earning potential for the farmer. The recent increased frequency of October storms will likely impact farmers more than September storms.

Not all crops are impacted in the same way; for example, root vegetables like sweet potatoes were indicated to be less damaged by storms compared to the above-ground crop of bananas. However, one farmer mentioned that potato crops were more susceptible than other cold weather crops to the impacts of winter gales, due to salt burning.



Distribution of hurricanes by month. September and October are the months with the greatest hurricane record. Over the past 10 years, there have been more October storms. Source: Bermuda Weather Service

Animal products such as milk, meat and eggs are less impacted by storms because the animals generally survive, with the main loss being the inability to access animals during the storm, and ancillary operations affected by electricity outages. Heat seems to be more of an impact to the cows themselves, who "like the colder weather better than the heat" (https://www.royalgazette.com/other/news/article/20191011/humberto-leads-to-blue-milk-shortage/).

Strong hurricanes can also impact infrastructure such as greenhouses. Losses are compounded if greenhouse destruction leads to a loss of seedlings. The photographs below show a destroyed greenhouse and structural damage to the Bermuda Government's Agricultural Service Centre (ASC) due to hurricane damage in the last decade.

The impacts of hurricanes on the farms' economics are a disruption to the 'cash flow' for farmers and require farmers to input more money into their operations to get back to a state of similar production. Farmers take 100% of the economic loss on themselves due to a lack of crop insurance options. The lack of crop insurance makes hurricane losses potentially crippling to farmers unless they 'self-insure.' Farms do this by hedging their losses with farm strategies or simply by having savings they can draw on in times of emergencies. Spending on new seeds, new fertilizer/pesticide inputs, more labor hours, potential loss of infrastructure, along with the loss of product, and set back of future production, all make hurricanes very expensive for farms. The price of crop insurance in Bermuda, due to the high risk, make it not economically viable for farmers. None of the sampled farmers in Bermuda had crop or livestock insurance.

Hurricane-induced electricity outages on farms affect the ability to pump water for irrigation and to keep chilled any produce in storage. Owning and using generators is one way farms have adapted to losing power in the wake of a storm.

One way in which the ASC supports farmers is through their chill room storage, pictured here. However, the ASC lacks generators, so when they lose power, normally for a few days, they instead minimize cool air losses by limiting the opening of chill room doors to stretch out the residual refrigeration. According to one farmer, crops can get spoiled in that time frame. Based on feedback from



Destroyed greenhouse (left). Source: Tony Amaral, Amaral Farms. Flooded fields after a storm (center). Roof Damage (right). Government of Bermuda Agricultural Service Center (2022).

surveyed agricultural workers, there are plans for a new ASC facility but a lack of funding is preventing building plans from moving forward.

Hurricanes may also disrupt the supply of agricultural labor, as workers are focused on the clearing of post-storm debris and rebuilding, if necessary. Debris cleaning is described as an extensive and time-consuming task that often results in overtime pay for workers. Following debris clearing is preparation of fields for replanting. This process normally takes weeks because the ruined crops are often used as fertilizer that must decompose before planting can begin.

Chill room filled with potato harvest. Government of Bermuda Agricultural Service Center (2022).

All farmers surveyed shared the perspective that there is no alternative after a hurricane other than starting again. The decision is made is to replant seeds, which can set farmers back three to four months. Some of the interviewees stressed that this mindset is essential given how many challenges there are to farming in Bermuda. Likewise, the ASC's policy for hurricanes was similar: clean up the flooding from the roof leaks and deal with the problem at hand.

All interviewees expressed there is reprieve in the timing of hurricanes because they generally hit in early fall, mainly in September and October, before the main crop is too developed. That said, the destruction can still be significant. No farmers mentioned concern over the increased frequency/intensity of hurricanes with respect to climate change; however, multiple interviewees separately indicated they felt the storms had been getting stronger over the past 50 years.

Some farmers indicated they will make adaptive changes outside of their normal production in reaction to extreme climatic events like hurricanes.

Existing adaptation strategies include:

- planting a larger variety of crops (broccoli, cauliflower, etc.) to hedge their bets. For example, there was an indication that sweet potatoes are better crops in the winter because they do not get burned by the salt water swept up in winter gales and hurricanes. Also, there was some focus on more greenhouse crops, grafts and ornamentals for ease of growth, greater variety and more profitability.
- changes in timing to the planting of crops such as potatoes
- new growing methods, such as hydroponics
- growing more economically secure crops, such as those on permanent embargo, and herbs, which are difficult to import
- one interviewed farm did not plan updates based on climate variables, but planned to make operational changes as an adaptation to the changing market. Of course, market variables may have indirect effects from climate change.

The farmers who indicated plans for adaptive changes perceived they would increase their resiliency in general, while decreasing crop failure, increasing production, and/or increasing cash flow.

Storms and Floods
Disaster risk governance

The Emergency Measures Organization (EMO) consists of representatives from departments and Ministries within the Government of Bermuda, and is chaired by the Minister of National Security, with a view towards disseminating crucial information to the public in the lead up to, during, and after natural disasters. Despite its important role in emergency management, the EMO is not a legislated body.

Most of the climate-related activities undertaken by the EMO are responses to tropical storms and hurricanes in the Atlantic. When a hurricane forms in the Atlantic, the EMO maintains contact with the Bermuda Weather Service (BWS, a section of the Bermuda Airport Authority), which monitors the forecasted trajectory of the storm. The EMO typically calls a meeting once the BWS issues notification of a hurricane threatening the island. During the meeting, the EMO and its attending agencies decide when to initiate a reduction of government services and activate emergency preparedness procedures. It is important to note that each agency is responsible for developing and activating its own emergency plans. Given the interdependence of each department on others' actions, public transportation and schools will often unofficially set the timeline by determining the latest safe time for government services to operate. A series of cascading decisions results from these timeframes. For example, the release of children from school requires parents to be available, and both groups must be able to travel home on public transportation. Any departments that need to reduce services must account for these factors before doing so, and allow sufficient time for their employees to safely transit home, or to their duty stations. Actions for recovery after the event are also discussed.

In 2014, a unit of the Ministry of National Security was established to coordinate the activities of the EMO, facilitate inter-agency communications and ensure that appropriate responses are conducted. In addition to natural hazard response, the Disaster Risk Reduction and Mitigation (DRRM) Unit has other functions under the Ministry of National Security, such as coordinating necessary precautionary and response measures for events with large numbers of attendees, such as international sporting events, and preparing (and exercising response plans) for a number of island-wide crises. Examples of their work beyond natural hazard response include exercising emergency plans for the airport, cruise ship evacuation contingencies, and fuel-related incidents (https://www.gov.bm/articles/disaster-risk-reduction-and-mitigation-team-end-year-report-%E2%80%93-2018). The 'DRRM team' comprises seconded public officers with expertise from the Bermuda Police Service, HM Customs, Bermuda Fire and Rescue Service and the Royal Bermuda Regiment.

In general, the combination of this response system and Bermuda's inherent resilience works very well to enable safety of the populace, mitigate impacts to the economy, and facilitate a swift response after the event (usually a hurricane). It should be noted that this governance and response framework has not been realistically tested by a short-notice natural hazard such as a tsunami or a tornado.

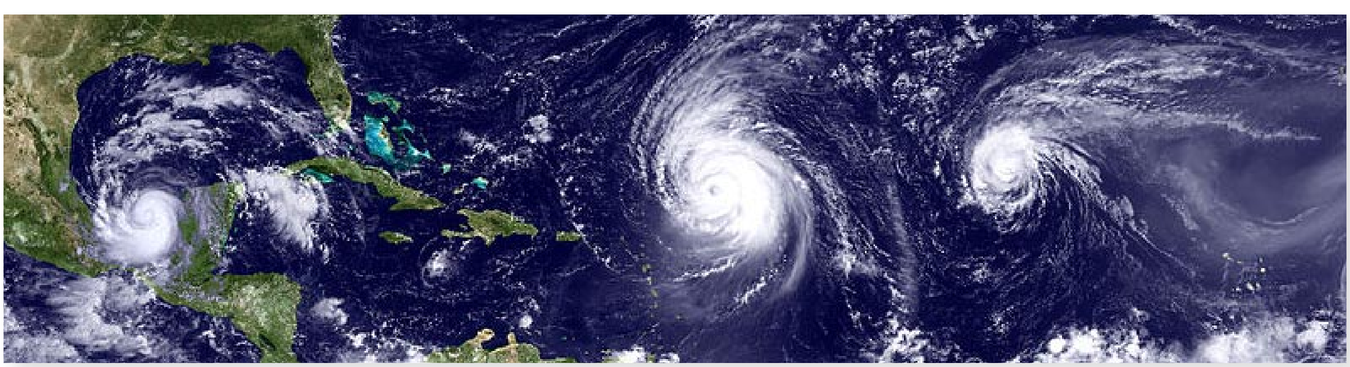
The recent increased frequency of hurricane passages in the past 20 years, noted in previous chapters, necessitates more frequent convening of the EMO and review of disaster preparedness measures. The author has been involved with EMO meetings directly since 2006, and notes that they have met more frequently in response to hurricanes in recent years.

The 2022 hurricane season, during which Bermuda had 3 'close calls' from hurricanes, provides a useful recent context for examination of the island's risks and resilience.

Storms and Floods
Case studies | The 2022 hurricane season

Hurricanes Earl and Fiona both passed near Bermuda in September 2022 and provide useful context for a critical examination of the risks we face from tropical cyclones, as well as our resilience to their effects. These storms and other high rainfall events in 2022 also provide a relevant backdrop against which to investigate the local impacts of rainfall flooding. By studying Bermuda's response to these events, we can gain valuable insight into longer-term resilience and areas for improvement.

In Part I of this report, we examined how the hazard of tropical storms and hurricanes is changing over time, with warming ocean temperatures (including the ancillary impact of reduced European pollution on Atlantic sea surface temperatures) and changing atmospheric patterns, such as wind shear, increasing Bermuda's hurricane frequency and intensity in recent decades. The extent to which these changes continue, or whether we have simply entered a 'new normal' of lasting increased hurricane activity remains to be seen. In this section, we will explore the ways in which Bermuda has reacted and responded to this changed reality of what basically amounts to being prepared for significant storm impacts annually.

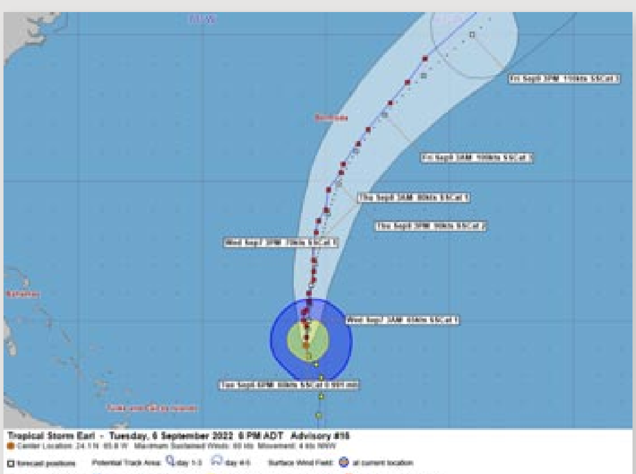


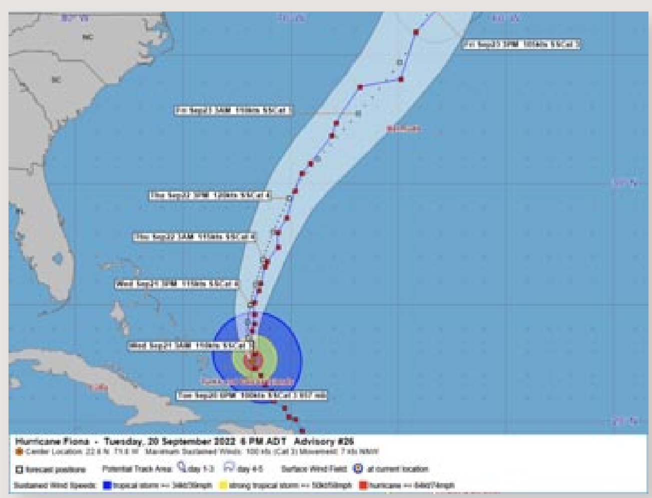
Storms and Floods
Tropical Storm Alex, Hurricane Earl and Hurricane Fiona, 2022

In many regards, Alex was the early season practice, Earl was the dress rehearsal, and Fiona was the main event. The hazards of each of the storms were well forecast by weather models and accurately represented by international and local prediction agencies. Forecasting of such events has improved vastly over the decades. While marginal events that may not pose much of a threat can still be tricky to forecast, it is reasonable to point out that tropical cyclones (tropical storms and hurricanes) that are poised to make a major impact are well-represented by models and forecast agencies.

Of particular concern during Fiona's approach was the potential impact of storm tide on vulnerable rest homes and the contingency plans for those locations. Coastal exposure to ocean hazards and sea level rise will be explore in more depth in the next section. Thankfully, the impact to rest homes was minimal in this instance, but it highlighted a growing need to assess risks to low-lying infrastructure associated with critical service provision across all sectors. The Government of Bermuda is currently undertaking such a review of coastal exposure, which will complement this report's synthesis of coastal risks (Ministry of Home Affairs, 2022).

Given Bermuda's general resilience to life-threatening hazards, we turn to the less dangerous and the more disruptive aspects of hurrican activity in Bermuda.





Data sources: NOAA, US National Hurricane Center

Storms and Floods
Business interruption and economic impacts

Government service suspension and the overtime that follows a storm in the recovery phase can be a drain on resources:

- Royal Bermuda Regiment embodiment means additional pay for soldiers on standby.
- EMO personnel must be on hand 24/7 to ensure emergency calls are fielded, coordinate responding services in a cohesive manner, and communicate regularly to the public, both directly and via the media.
- The BWS doubles up on shifts to ensure the forecast and local conditions are reported on routine and adjusted times, while public-facing communications are increased in frequency.
- BELCO personnel must work overtime to restore power for customers post-storm.
- Emergency and essential service personnel are on heightened alert through the storm and must remain available, even as most of the island shelters in their homes.

Once the storm has passed, pressure is exerted on many of these services to get Bermuda 'back up and running' as quickly as possible. In the cases of Hurricanes Fiona and Earl in 2022, this was deemed to be very successful.

This is true by anecdotal and objective measures. The peak of the Hurricane Fiona's winds with gusts in excess of 100 knots (115 mph) was between 5 and 7 a.m. ADT on Friday, 23 Sept., 2022 (BWS). At that time, BELCO's published electricity statistics indicated that 29,540 customers were suffering outages. The airport had been proactively closed to air traffic at 9 p.m. Thursday evening. While roads and bridges were not closed, residents were urged to stay off the roads by 10 p.m. Thursday night. Businesses and schools announced their closures for Friday in advance, anticipating the need for residents and operations to shelter during the night and morning, then recover during the following day.

Within 48 hours (12 p.m. Sunday, 25 Sept., 2022), the number of BELCO-reported outages had dropped to 896. The announcements that roads were now safe to traverse went out at approximately 3 p.m. Some services even opened on Friday as early at 2 p.m., especially restaurants and bars (already suffering lasting impacts from the pandemic).

It is reasonable to assert that Bermuda bounces back quickly from storm impacts, so that 'normal life' resumes in a short amount of time. However, this comes at the costs of remuneration, stress and fatigue of personnel.

All of that said, there is always room for improvement. (Collins et al., 2022) found that a majority of hurricane prone residents surveyed in Puerto Rico and the US Virgin Islands had a negative perception of public shelter options, with ¾ finding the "risks of enduring a hurricane to be less than those posed by public shelters." Locally, where infrastructure is expected to be stronger, this sentiment is likely to be even more pronounced. Interviews with attendees of the Government-provided shelter during Hurricane

Fiona's passage indicated that volunteer and staff of the shelter outweighed attendees 3 to 1 (36 staff to 12 attendees). Concern was raised that there are only proactive options available to residents in Bermuda's central parishes. The COVID-19 pandemic procedures put further restrictions on numbers that shelters would realistically be able to accommodate with social distancing requirements, as well as the additional personal protective equipment needed. COVID-19 pandemic restrictions were found to decrease the public's decisions to attend a shelter (Collins et al., 2022).

The personnel and selfless volunteers that staff the shelter in advance of a storm, and the ancillary services that support it, provide a vital and commendable service to the community. Given the increases in hurricane extremes that climate change poses, there may be a perceived need to bolster the shelter capacity in Bermuda to accommodate more people, including those with specific vulnerabilities such as health or mobility problems, in addition to their need for shelter assistance.

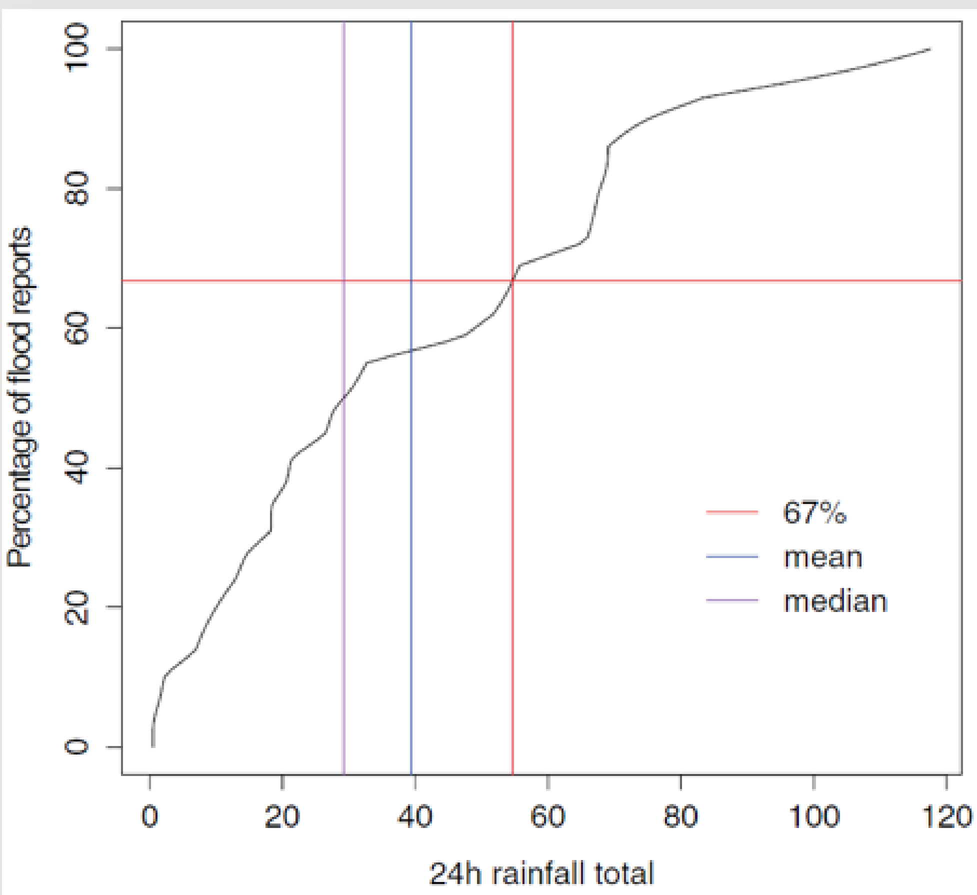
Finally, the psychological stresses and mental health concerns stemming from storm impacts are not trivial. Studies into mental health impacts of disasters reveal the hidden impacts that are faced by populations (Schwartz et al., 2017).

In a study presented at the 2021 session of the regional Hurricane Committee, Dr. Alexis Lorenzo Ruiz of Cuba stated that, "The increasing consequences and severe impact of the biological-psychological-social-spiritual and environmental nature of disasters at the beginning of the 21st century is no longer exclusive to the countries of the underdeveloped Third World, but also to the vast majority of countries, since nothing and no one is exempt from it. The psychosocial impact was related to material losses, damage to homes, and psychological reactions, fundamentally anxiety and worries. Human behavior in meteorological disaster situations in Cuba [included] a tendency towards manifestations of transitory acute stress, with particularities in different population groups, without becoming established as typical of post-traumatic stress given the processes of prior preparation, recovery and readaptation."

Storms and Floods
Rainfall and flooding

Another aspect of storms under climate change is that they will produce more rainfall. This has implications for areas in Bermuda to flood due to heavy downpours. Part I of this report explored anecdotal evidence for shorter-term heavy rainfall events becoming more frequent. It is worth pointing out here that Bermuda does not have any river systems that give rise to life-threatening fluvial (river) flooding. Nonetheless, pluvial (rain-induced) flash flooding has been an issue in well-known problem areas. Flash-flooding is defined by Webster's dictionary as "a local flood of short duration generally resulting from heavy rainfall in the immediate vicinity." Different jurisdictions further attribute flooding to timeframes and/or water levels. No definition for flooding or flash flooding exists for Bermuda. It is reasonable to say that Bermuda experiences 'nuisance' flooding that is disruptive but not life-threatening.

Well-known areas susceptible to nuisance flooding include Bakery Lane, Woodlands Road, Bernard's Park and Dundonald Street. These locales are very low-lying areas in Pembroke with little drainage available. They are also all virtually at sea level near a draining creek or a marsh. There are, of course, other areas of Bermuda that have rain-induced flooding issues, and the main disruption is



Flood reports and 24hr rainfall (2005-2015)

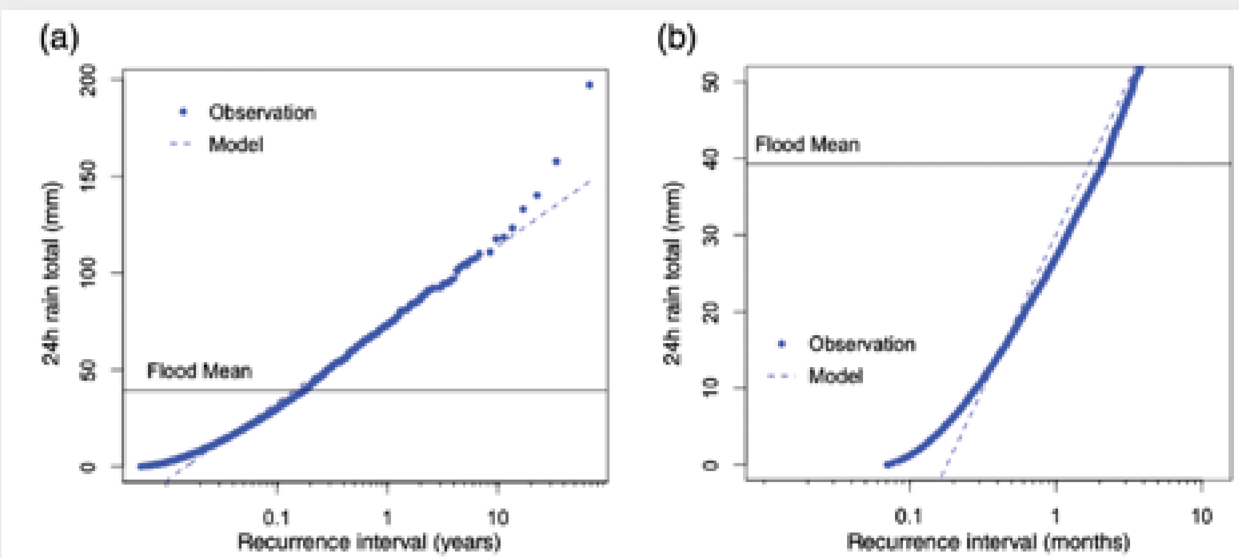
(Johnston et al., 2018) further found that the return period of such a flood-threshold rainfall event is about two months, based on long-term observational records at LFWIA (1949-2015), and a resulting model of 24-hour rainfall accumulations.

to road traffic. In the case of Bakery Lane, in addition to road traffic concerns, there are number of businesses whose ground floors are situated at the bottom of the flooded area.

There are no flood gauges in Bermuda; however, reports in the press have made a suitable proxy for a 10-year survey of flooding events. A study completed in 2016 compiled these anecdotal flood reports and used them as a basis for analysis, along with rainfall records from the BWS (Johnston et al., 2018). The study revealed that, on average, the rainfall amounts recorded at LF Wade International Airport that coincide with flooding events have a mean threshold of 39.3 mm (1.55 in). So, on average, a recorded or forecast rainfall event reaching or exceeding that magnitude would be a reasonable basis to assume these areas (and others) are likely to have experience flooding. It should be noted that these findings are only for the period 2005-2015, for which adequate press reports of flooding were available.

The effects of road flooding include disruption to traffic, especially notable during the morning and afternoon rush hours; potential erosion of weakened roadside infrastructure, such as retaining walls; and exacerbations of potholes in the roadways themselves. In most cases, the road flooding eventually reduces via drainage and/or evaporation in a matter of minutes to hours. However, in some cases (notably the areas named above), poor drainage means a reliance on pumping water away from the area to a different watershed or, as in the case with Bernard's Park, raising the level of the road passing through.

One only needs to do an online search for 'Bakery Lane, Bermuda' to find photographs of flooding events. The impacts of these floods, while not life-threatening, have nonetheless been described in one instance as follows for the Bakery Lane area (https://bernews.com/2015/11/demand-government-action-canal-upkeep/):



"As a result of the severe flooding that occurs every time it rains, the businesses and residence have been impacted as follows:

- Approximately 500 employees of the Mill Creek businesses cannot arrive or leave work due to flooding that can sometimes be three feet deep
- Cars of the employees and resident require significantly more maintenance due to the engine damage from the flooding
- Each business is losing between $13,000 and $40,000 per day on flooding days
- The disabled resident is confined to his home and cannot leave the area"

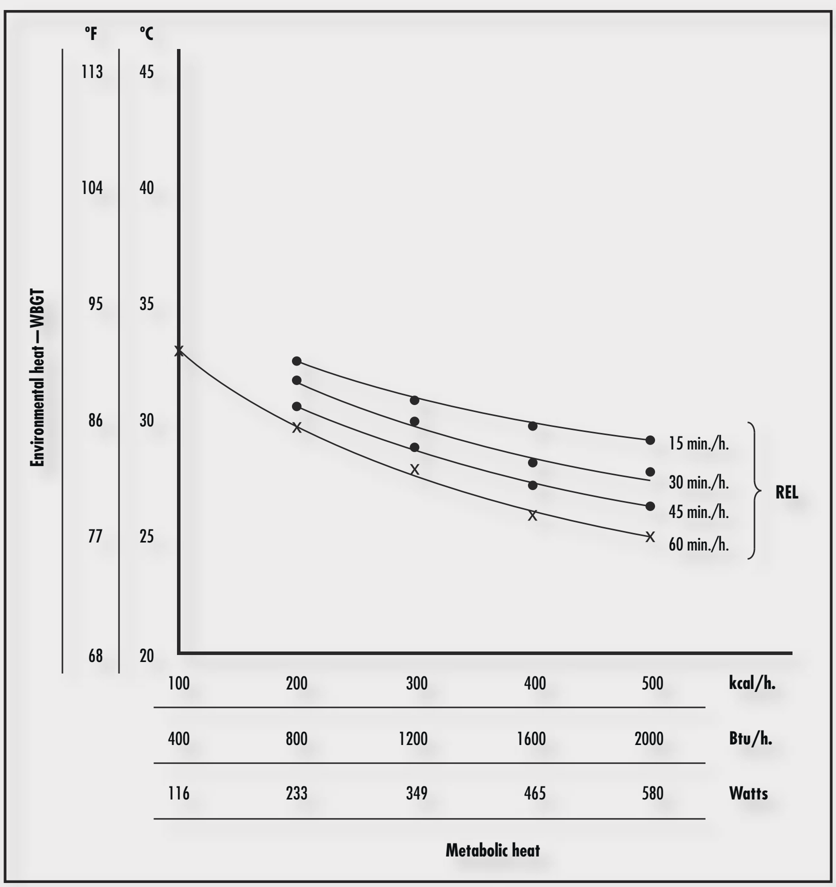
One effect of long-term climate warming is the creation of more water vapor to 'feed' such heavy rainfall events. Reiterating a finding from Part I of this report, theory indicates that a 1°C average surface air warming gives rise to 7% more water vapor in the atmosphere (Trenberth et al., 2003). For the most severe events, the rainfall may be worse, with rainfall rates in hurricanes projected to increase by as much as 20% under global warming modelled scenarios (Knutson et al., 2010). It is worth noting that Hurricane Nicole (2016) produced 135.6 mm (5.35 inches) of rainfall, more than three times the average threshold amount that would cause a flood event in Bermuda. The occurrence of flood rainfall thresholds being exceeded is likely to increase over time, putting many areas of the island under more frequent flooding impacts.

The Effects of Heat and Droughts
Heat stress

Part I of this report outlined how adverse heat conditions (quantified by heat index) are gradually rising during the hottest times of the year. One of the disproportionate societal impacts of climate change is how exposure to extreme heat may be affecting those least able to cope with it. This is specific to the labor force.

Heat stress is the net heat load from outside temperature and humidity (heat index), bodily (metabolic) heat, and clothing (Park et al., 2017) and denotes the impact of heat on peoples' health. The level of heat stress that will cause illness depends on the individual's heat tolerance. Heat tolerance is dependent on energy expended in work, duration of work, the workers' clothing, air and vapor permeability levels, and hydration status (Acharya et al., 2018). A worker's susceptibility to heat-related illness also includes indirect factors such as age, drug use (including cigarettes and alcohol), medicine use, amount of sleep, and Body Mass Index (BMI - Acharya et al., 2018). Acclimatization can be reached after repeated exposure to elevated heat indices, which will decrease the vulnerability of the worker to heat-related illnesses. Construction workers were found to need three to four weeks of exposure to fully acclimatize.

Despite the diversity of features involved and the range of individual heat stress vulnerability, some studies suggest a heat index threshold of 29.4°C (84.9°F) as an indicator for consideration of heat-related illness mitigation measures (Tustin et al., 2018).



Graphic shows recommended heat stress exposure limits for healthy, acclimatized workers (using average male height and surface area). No significant differences were noted between men's and women's reactions. Metabolic heat represents energy spent in workers' physical activity. (Source: (Jacklitsch et al., 2016).

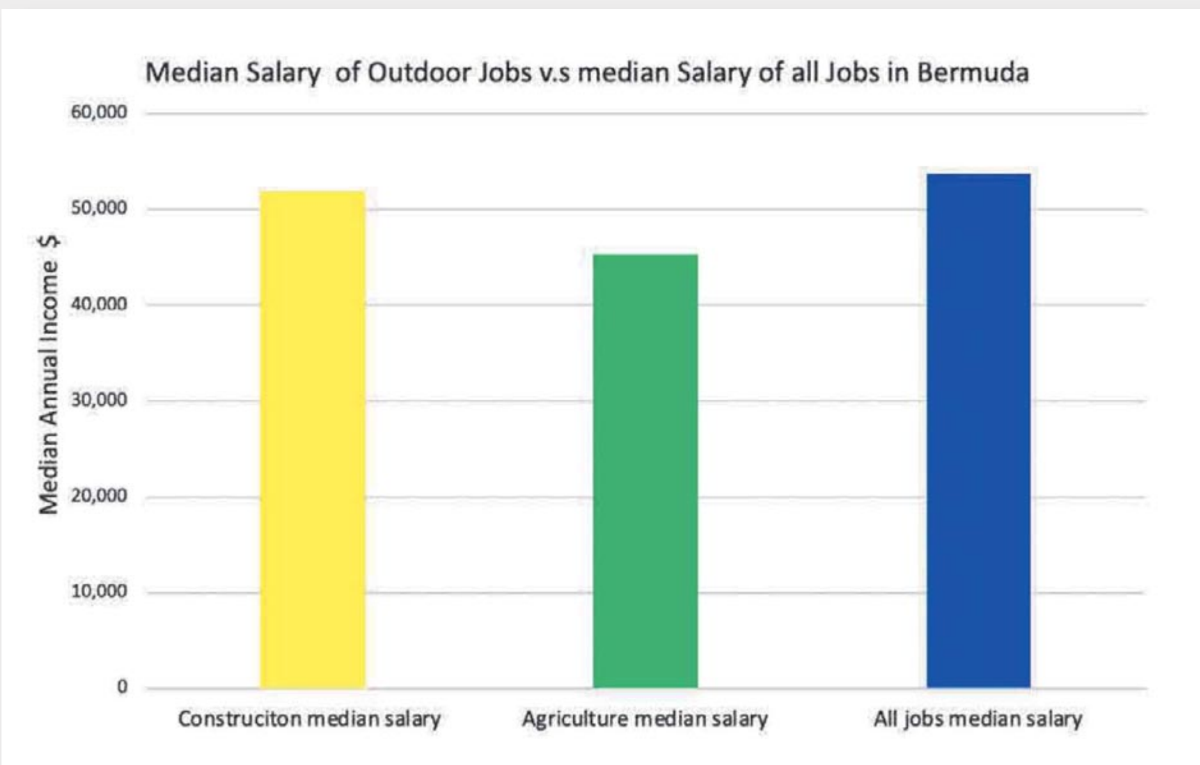
The Effects of Heat and Droughts
Bermuda's labor force

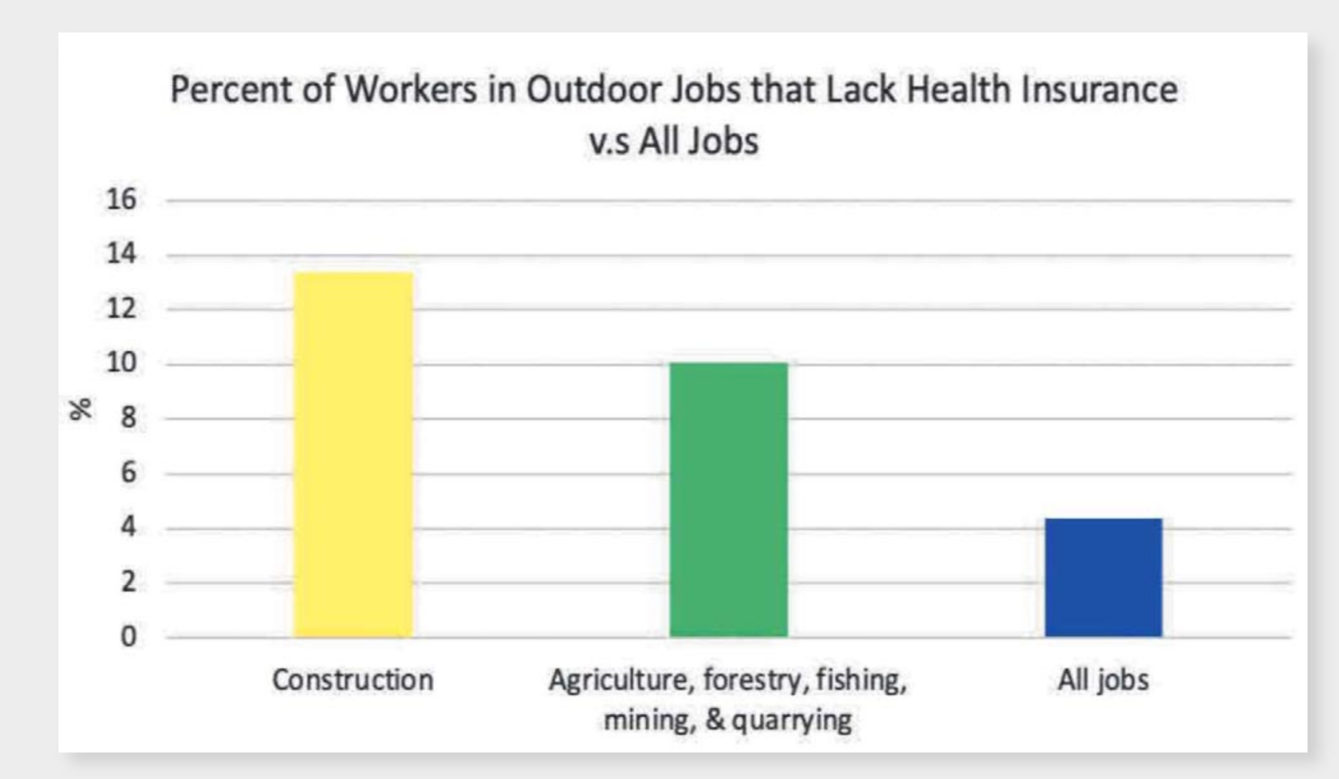
All else being equal, outdoor workers' exposure to adverse heat conditions will increase in future. In other jurisdictions, the highest heat-related illnesses occur in the construction industry (Acharya et al., 2018). Other relevant outdoor professions in Bermuda are agriculture/fisheries and landscaping. In 2016, there were 656 skilled agricultural/fishery workers and landscape gardeners, and 3,045 construction workers (Government of Bermuda, 2017)– a total of 3,357 workers who are potentially exposed to heat stress. Other occupations where some part of their work is outside, such as tour guides, are not included in this count.

Outdoor workers are typically paid lower than the baseline (median) income. Median salary in Bermuda is $53,716; agricultural workers are paid $45,309 median salary; and construction workers are paid $51,838 median salary (Government of Bermuda, 2017).

Therefore, heat risk is due to a) the natural exposure of outdoor workers in Bermuda and b) the vulnerability of their generally lower pay. Income is related to health insurance, that may in turn decrease vulnerability to lasting impacts of heat-related illnesses.

The insurance status of the exposed groups contributes to their resilience. Of this group, 66 agricultural/ fisheries workers and landscapers (10%) lack health insurance, and 408 construction workers (12%) lack insurance, compared to the total lack of health insurance that is 4.6 % among all jobs (Bermuda Department of Statistics, 2016). Percent of workers that lack health insurance is depicted in figure 7 to the right.





Heat and Droughts

Aridity

In Bermuda, each property owner is legislated to be responsible for their own water supply (M. Rowe, 1984). Drinking water supply is provided by rainwater harvesting, with each residential property built with a rooftop catchment area and, typically, an underground water cistern (both of which are linked to the building's square footage). Water conservation has long been a feature of responsible consumption and many Bermudians have grown up learning to take short showers, not leave the water running when brushing one's teeth, etc. The advent of modern conveniences such as dishwashers and washing machines means that the prospect of water conservation is generally a more challenging proposition.

Anecdotally, each year sees mention of a seasonal drought affecting water supply, necessitating water truckers selling treated freshwater from the groundwater table. There is no formal definition of drought in Bermuda. The seasonal nature of the dry periods mean they are naturally part of Bermuda's climate as opposed to the unusual phenomenon that the word 'drought' typically connotes. There are no obvious trends in the longer-term rainfall patterns that would lend themselves to more or less frequent dry spells. Theory would indicate greater evaporative rates associated with warming temperatures, leading to greater aridity; however, this may be tempered by increased water vapor available to augment heavy downpours (Karnauskas et al., 2016). Anecdotally, heavy downpours do seem to be on the rise in Bermuda, as indicated by the increasing number of thunderstorm days (see Part I). Hence, the recharge of the water lenses and heavy rainfall events may offset seasonal dry spells, even if they do become more prolonged. As with other

aspects of climate, the trends in rainfall and aridity are greatly outweighed by the year-to-year variability. Therefore, the water supply system that Bermuda currently utilizes is not likely to predictably change in the near term under climate change.

Nonetheless, the future of the rainwater harvesting system is more complex than simple projections of less or more rainfall. In fact, it is the type of rainfall event which is also critical for the overall practicality, dependability and effectiveness of the rainwater harvesting system. With rising temperatures, it is likely that rainfall will become more intense, as the water carrying capacity of the atmosphere is increased by 7% for every 1°C increase in temperature (Trenberth et al., 2003). This would be beneficial for rainwater harvesting. However, if there are extended dry periods, but with a similar or increased total volume in rainfall, this may still result in residential water supply issues. Longer periods of intense rainfall may fill tanks to their capacity, preventing the capture of all available rainwater. If this is followed by a prolonged dry period, tank water may reach critical levels and require trucked water from freshwater lenses to augment supply (Rowe, 2011). The challenges that sea level rise will present to the freshwater lens (see separate chapter) will also influence Bermuda's water supply in the longer term.

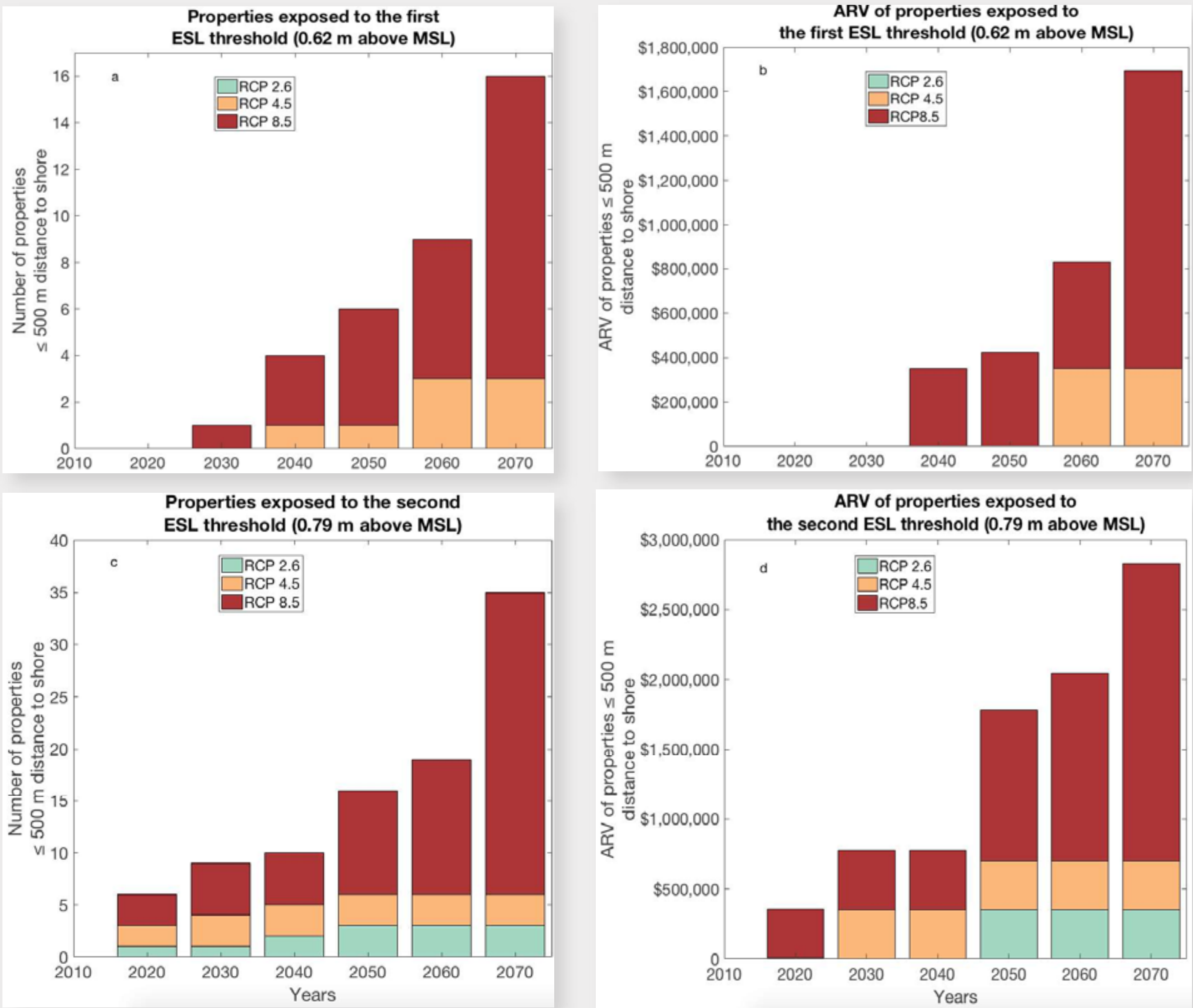
The Impacts of Sea Level Rise
Coastal exposure

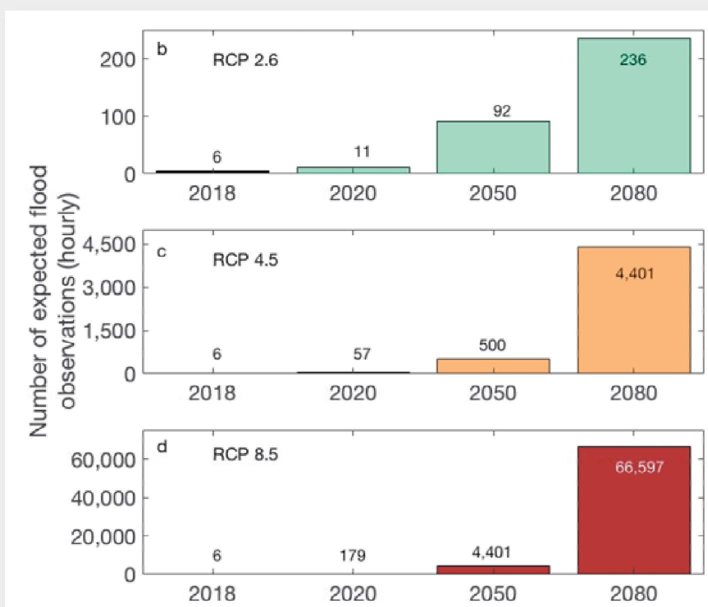
The risk exposure to property inundation is increasing in Bermuda due to rising sea levels, leading to a growing exposure of properties at risk. An exposure assessment was conducted by examining sea level data from the St. George's tide gauge from 1989 to 2018 (~29 years); historical hurricane data; the 2009 list of property values and elevations from the Government of Bermuda; and mean sea level (MSL) projections in three different emissions scenarios (representative concentration pathways, or RCPs, of 2.6, 4.5, and 8.5, which correspond to global average temperature increases of 1.9-2.3°C, 2.0-3.6°C, and 3.2-5.4°C above pre-industrial levels) through the 22rd century (Kopp et al., 2014).

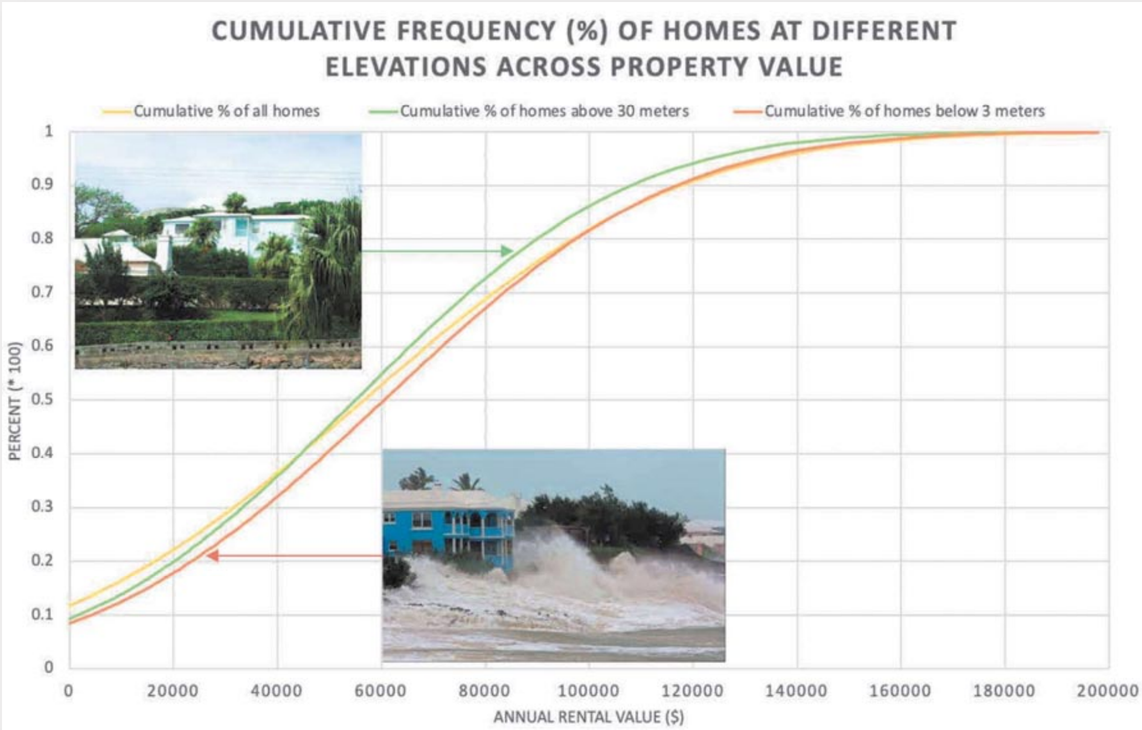
Details and discussion about the frequency and magnitude of extreme sea level (ESL) events in Bermuda are presented in Part I of this report. Events at or exceeding 0.62 m and 0.79 m above today's MSL were found in 2.5% and 0.1% of all measurements respectively and, accordingly, these are treated as 1st and 2nd extreme water level thresholds for the study.

The number of properties and their ARV exposed to the first and second ESL thresholds above MSL were analyzed through time. Three case studies of properties at different elevations (0.91 m, 1.03 m, and 1.21 m above MSL) were also chosen to analyze the frequency of seawater inundation these properties experience. Overall, there is a gradual increase in the number of properties exposed to both ESL thresholds through time, and more property value will be at risk in the future. Moreover, the three case studies indicate that properties at all elevations will experience more frequent inundations through time and among RCP scenarios (2.6 and 8.5 the least and the most, respectively), indicating successively higher probabilities of future flooding over the projected period.

The number of properties exposed to the 1st threshold of flooding (≥0.62 m above today's MSL) is initially zero (good news for today's flood risk), but increases to 16, with an ARV over $1.6 million, in fewer than 50 years. The number exposed to the higher elevation flood threshold of 0.79 m or more above today's MSL is necessarily higher. The projections indicate that if the water had reached that higher threshold by 2020, there would have been up to five properties exposed to that level. By 2070, that number jumps


Properties exposed to the first ESL threshold (0.62 m above MSL)
a
RCP 2.6
RCP 4.5
RCP 8.5
Number of properties ≤ 500 m distance to shore
0
2
4
6
8
10
12
14
16
2010
2020
2030
2040
2050
2060
2070
ARV of properties exposed to the first ESL threshold (0.62 m above MSL)
b
RCP 2.6
RCP 4.5
RCP8.5
ARV of properties ≤ 500 m distance to shore
0
$200,000
$400,000
$600,000
$800,000
$1,000,000
$1,200,000
$1,400,000
$1,600,000
$1,800,000
2010
2020
2030
2040
2050
2060
2070
Properties exposed to the second ESL threshold (0.79 m above MSL)
c
RCP 2.6
RCP 4.5
RCP 8.5
Number of properties ≤ 500 m distance to shore
0
5
10
15
20
25
30
35
40
2010
2020
2030
2040
2050
2060
2070
Years
ARV of properties exposed to the second ESL threshold (0.79 m above MSL)
d
RCP 2.6
RCP 4.5
RCP8.5
ARV of properties ≤ 500 m distance to shore
0
$500,000
$1,000,000
$1,500,000
$2,000,000
$2,500,000
$3,000,000
2010
2020
2030
2040
2050
2060
2070
Years


Number of expected flood observations (hourly)
b
RCP 2.6
0
100
200
6
11
92
236
2018
2020
2050
2080
c
RCP 4.5
0
1,500
3,000
4,500
6
57
500
4,401
2018
2020
2050
2080
d
RCP 8.5
0
20,000
40,000
60,000
6
179
4,401
66,597
2018
2020
2050
2080



Cumulative frequency of homes across ARV.

to 35 (with a combined ARV of nearly $3 million) under the worst emissions scenario. It is worth noting that ARV is not representative of the true property value and is a metric used by the Government to calculate land tax brackets. Nonetheless, the property dataset is freely available online and provides a comprehensive tool for conducting exposure assessments.

A different perspective this is even more illustrative. A property at just over 1 m elevation above today's MSL is found to be exposed to about six instances (hourly observations) of coastal flooding. The same property may see as many as 4,400 hourly instances of flooding by 2050 in the worst modelled scenario, but at least by 2080 under more conservative emissions. Beyond that stage, the model representation of flooding may be treated as unphysical (there are only 8,760 hours in a standard year) meaning, essentially, that such a property should be treated as being underwater more often than not.

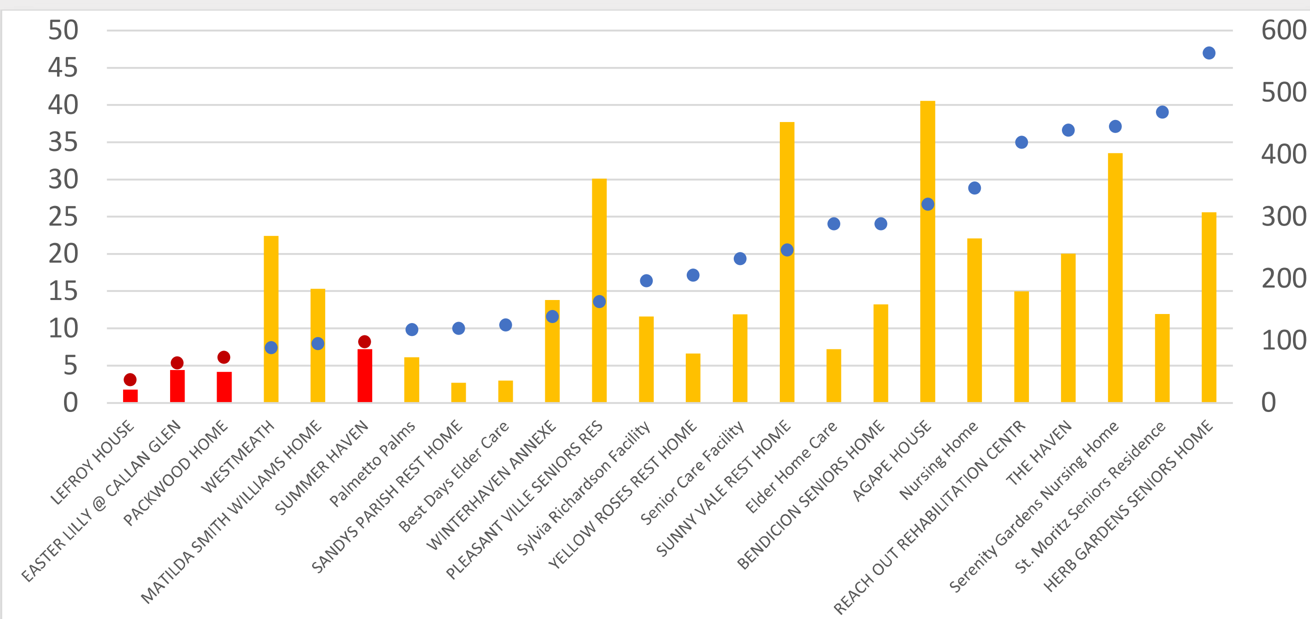
We further categorized all properties within 500 m of the coast by their elevation and treated all properties below 3 m (10 ft) above sea level as the most exposed to coastal inundation, while all properties above 30 m (100 ft) were considered to be more prone to hurricane wind hazards. An examination of the distribution of 'flood exposed' properties today reveals that there is a lower proportion below an ARV of $100,000 than the island-wide distribution. The conclusion this leads to is that, on average, those properties that are coastally exposed have a higher ARV. If we assume that high ARV is a good proxy for wealth, this implies that owners of coastally exposed properties are wealthier than average and, therefore, may have a better coping capacity against coastal inundation (through insurance or other protective measures).

The Impacts of Sea Level Rise
Vulnerable population highlight

Seniors are vulnerable to coastal flooding and storms in multiple ways: loss of assets and health vulnerability. The concept of heightened impact due to a lack of diverse assets applies especially to senior residents in Bermuda. Seniors here are identified as being "house rich, cash poor" (Government of Bermuda, 2005). Since seniors' homes may constitute the bulk of their assets, they are more vulnerable to loss through property damage. Moreover, seniors are more vulnerable to health impacts from flooding and are less capable of relocating after disasters (Hutton et al., 2008). In sum, senior homeowners may be at more risk from property damage than other age groups in Bermuda.

In terms of health impacts, the most vulnerable subpopulation of seniors resides at assisted living facilities, due to their reliance on medical equipment, care and diminished ability to relocate. The four assisted living homes identified as being potentially exposed to coastal flooding are indicated by the red bars on the figure below (B. Lefkowitz, Personal communications, July 2022). These care facilities are exposed to coastal flooding now, or will be in the future because they are both coastal and low-lying. Despite the Westmeath and Matilda Smith Williams homes being at low elevations, they are inland and are not exposed to flooding.

The four homes exposed proximity to the coast is shown in the imagery (Google maps) below:

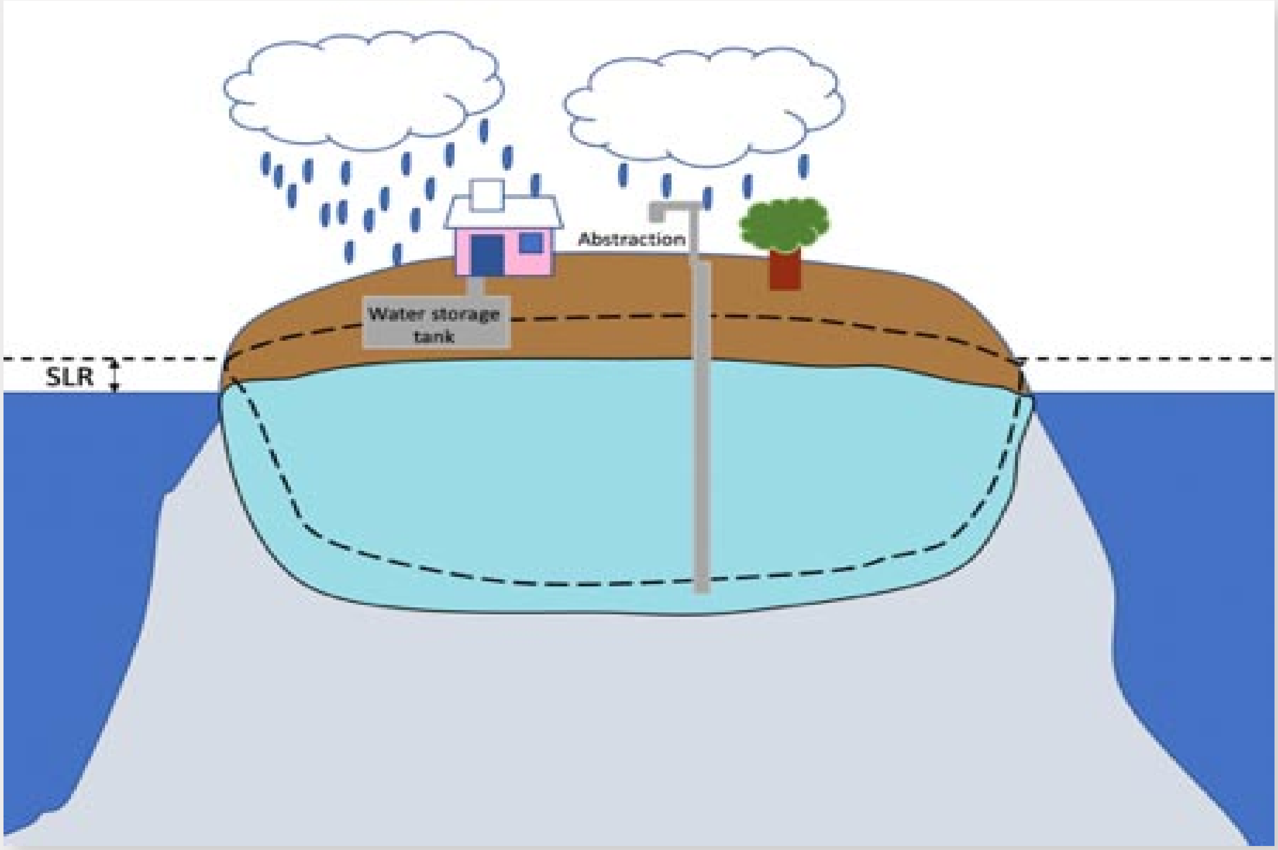


Elevations (dots, in meters) and distance from shore (bars, in meters) of all the assisting living facilities in Bermuda; with the facilities highlighted in red being the four homes that are already or expected to be impacted by coastal flooding. In collaboration with Dr. Lefkowitz, Health Disaster Coordinator, Ministry of Health Bermuda.

Here the exposure and vulnerability features of the homes is summarized:

1. Lefroy House (Government home) has 40 patients. The facility is flooded with a 0.5 m rise in water levels, while an increase to 1.5 m floods all access points.
2. Easter Lily at Callan Glen houses 10 residents. With a 1.5 m rise, the sole entry point flooded. At 4 m the home is flooded.
3. Packwood Home has flooded before. With a 1.5 m rise in water level, the facility and access roads were flooded.
4. Summer Haven (disabled and senior population) houses 18 patients. A 1.5 m rise in water level causes the only access road on the South Road to flood, which has occurred before. (B. Lefkowitz, Personal communications, July 2022).

Because these homes were identified as both at risk now and in the future under climate change conditions, the creation and updating of their emergency protocol was brought to the public's awareness.



Alexander, 2022: The impact of sea level rise (SLR) on the freshwater lens in Bermuda. Light blue represents the freshwater lens in the rock, while the black line represents the saltwater-freshwater interface. SLR and its impact is denoted by the dashed black line. The primary water sources of rainwater harvesting from rooftops and subsequent storage in tanks under the house as well as abstraction are shown. Other elements of the hydrological system in Bermuda are omitted, such as cesspits. Not to scale.

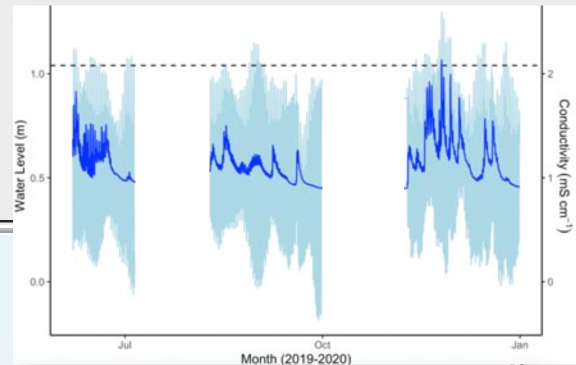
The Impacts of Sea Level Rise
Sea level rise and groundwater quality

A study was recently completed that focused on the effect of extreme sea level events on local ground water quality, and inferred impacts of long-term sea-level trends. As the freshwater lens floats over seawater within the bedrock, sea level rise will also force the water table upwards, reducing the overall freshwater carrying capacity of the lens. This could result in increased salinity (reduced water quality) of the lens at points where abstraction occurs. A schematic representation of this is presented above.

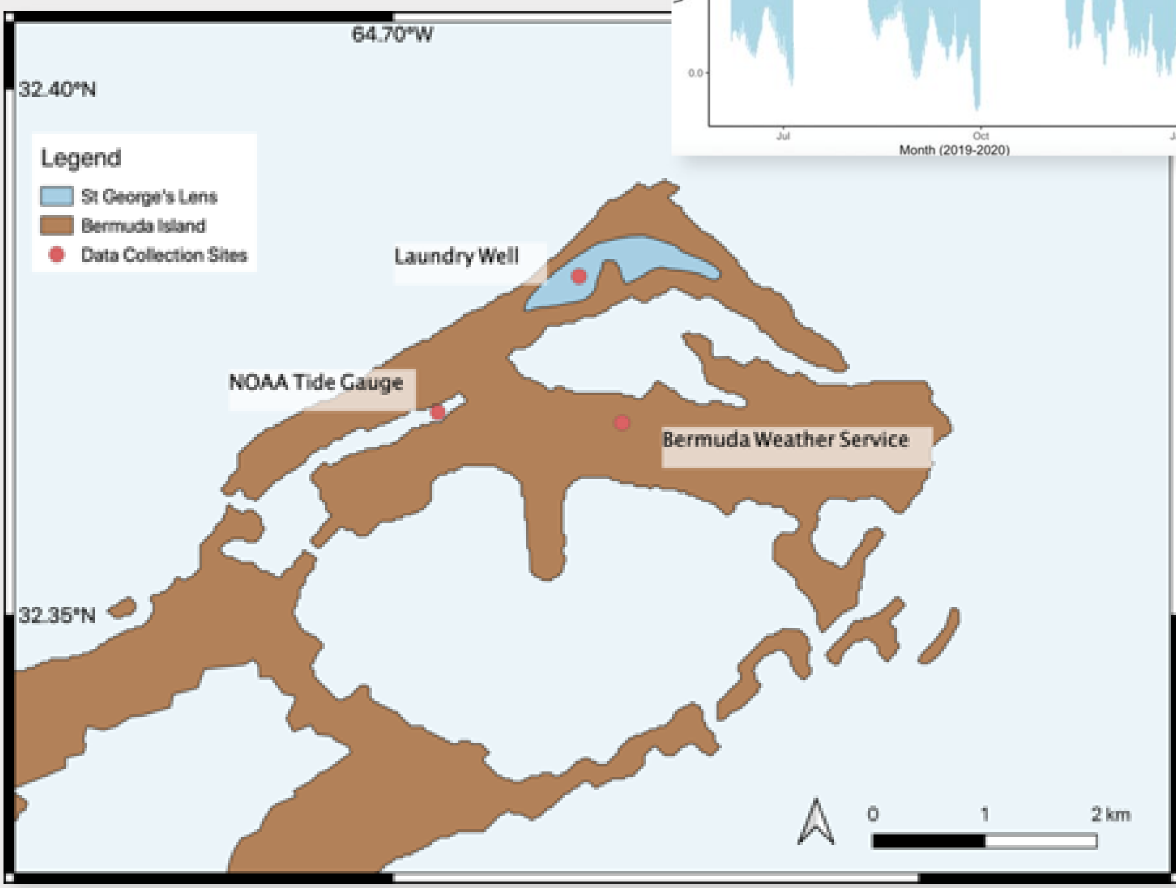
The study focused on St. George's groundwater, which does not have the complicating factor of abstraction wells impacting the water table, hence it is as close to a 'untouched' Bermuda freshwater lens as one can find. It had the added advantage of being in close proximity to a number of environmental data collection points (see map below).

Results (shown below) indicate that after short (estimated five-hour) lags, extreme sea level events in 2019 and 2020 produced salinity spikes in the St.

Time series of salinity and five-hour lagged water level from June 2019 to January 2020. Dashed line is the line at which water becomes too saline and must undergo reverse osmosis to be of potable standard. Light blue represents the water level data, and the dark blue line



Data collection sites for the various data sources, listed in Table 1. Daily rainfall accumulations are recorded by the Bermuda Weather Service (BWS) at the L.F. Wade International Airport at 0600 UTC using rain gauge measurements. Current position of the tide gauge shown, prior to 1994 it was located off the North Coast of St. George's island (Permanent Service for Mean Sea Level [PSMSL], 2019). Laundry Well transducer was a Van Essen Instruments 10m 80mS/cm CTD Diver.



George's lens water. Some of these sea level extremes are discussed in more detail in Part I of this report.

The threshold extreme sea level for this salinity groundwater contamination was 1.17 m above today's MSL. Under the most conservative estimates, the frequency of this threshold being reached is estimated to increase 11-fold by 2050.

Given that this study was conducted for a relatively untouched groundwater table, the effects on the Central Lens (from which groundwater is being abstracted and treated to supplement individual residential fresh water supply) are likely to be similar, but exacerbated by ongoing drawing of water from that system. However, it is worth noting that data were not available to test this hypothesis.

Fire coral bleaching, Skroggins Bay, Somerset, September 25th, 2022. Photo courtesy Magnus Henagulph.

The Marine Environment
Introduction

Bermuda's coral reefs, and their health and abundance, are major supporting elements of the marine ecosystem and the services it provides. (Sarkis et al., 2013) estimated the economic value of Bermuda's coral reefs is on the order of $1 billion per year, including associated ecosystem services such as tourism, fisheries and coastal protection. This can be taken in the context of being additional to Bermuda's Gross Domestic Product (GDP), which is on the order of $7 billion per year (World Bank 2021 data: https://data.worldbank.org/country/BM). While coral reefs do not represent the totality of the marine environment, their health is an important economic indicator. Therefore, it is important to assess how reef health and function may be affected by climate change.

One of the two main indicators of climate change in the ocean is warming of the surface waters. Both increasing long-term trends (Bates & Johnson, 2020) and more frequent and intense extreme events (Hobday et al., 2016) have been detected, and represent a change in the hazard of ocean temperatures. In order to understand risks to coral reefs, we must explore how individual species react to these changes in temperature.

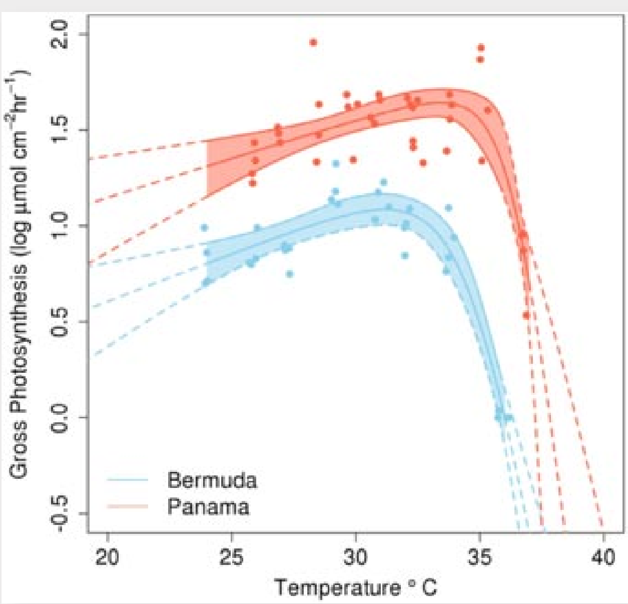
Coral is a symbiotic amalgam of plants (zooxanthellae, which give the coral its pigment) and animals (coral polyps) that reside within a limestone structure built over time. In this way, coral is simultaneously 'animal, vegetable and mineral.' One of the impacts when a coral species is overly stressed (e.g., by a marine heatwave) is that it may expel its zooxanthellae, leading to a characteristic white color in a phenomenon known as 'coral bleaching.'

Photographs above show successively bleached Fire Coral (from left to right) healthy, blotchy and bleached. Source: NOAA

(Silbiger et al., 2019) have constructed curves to assess the thermal tolerance of the boulder star coral (Orbicella franksi) in Panama and Bermuda. This function, if examined through the lens of catastrophe modelling, is similar in purpose and development to an engineering-based vulnerability curve for assessing the damage probability of properties susceptible to wind or surge.

From this analysis, one can see these particular coral species thrive best in a range of temperatures from about 24°C to about 35-37°C. The growth rates (or thermal performance) are calculated as a function of how well the corals photosynthesize (process sunlight and carbon dioxide into 'food' and oxygen).

Figure 2: From (Silbiger et al., 2019) - "Thermal performance curves of log(x+1) gross photosynthesis rates (µmol O2 cm-2 hr-1) from Panama (orange) and Bermuda (blue). Each dot represents an individual fragment (n = 28 in Bermuda; n = 44 in Panama) of Orbicella franski from 4 putative clones. Lines are medians ± 95% BCI drawn from the posterior distribution. The shaded regions are the temperatures where data were collected."



The Marine Environment
Exposure | maps of coral cover, species and biodiversity

A bleaching risk assessment would also need as inputs macro-assessments of coral coverage and species type. As an allegory to the 'property at risk' in a catastrophe risk model, the evaluation of the coral at risk from bleaching events is a crucial part of this exercise. Reef in situ surveys and laboratory experiments reveal rich detail on species behavior, habitats, and population structure (Goodbody-Gringley et al., 2018), and are vital for determining aspects such as thermal tolerance (Courtney et al., 2022). However, a reef-wide understanding of the functions and composition of the ecosystem is also desirable for the assessment of the extent of a species or system exposed to a hazard.

The Marine Environment
Loss | impact to ecosystem services

The availability and development of the data described in this document demonstrates the feasibility of a probabilistic assessment of the impact of major temperature-induced bleaching events on a coral reef ecosystem. The final piece of the coral bleaching risk assessment is an evaluation of the consequence of such events. The valuation of reef ecosystem services, such as provided by (Sarkis et al., 2013), can provide a unique perspective on the risks from impacts to coral reefs and, ultimately, a quantification of the economic consequence of bleaching events. This combination of system-wide assessments provides the necessary hazard, vulnerability and exposure data to evaluate the impact of marine heatwaves to a coral reef system. Further, the reef has real worth in terms of its function and services to the ecosystem itself that can be quantified. The value of the reef itself to society and the marine ecosystem enables a view of wider economic impact of bleaching (or underperformance) events. The final output of such a proposed model is envisaged to be an exceedance function revealing the probability of exceeding a loss threshold, either in dollars or productivity metrics, caused by marine heatwave-induced bleaching events.

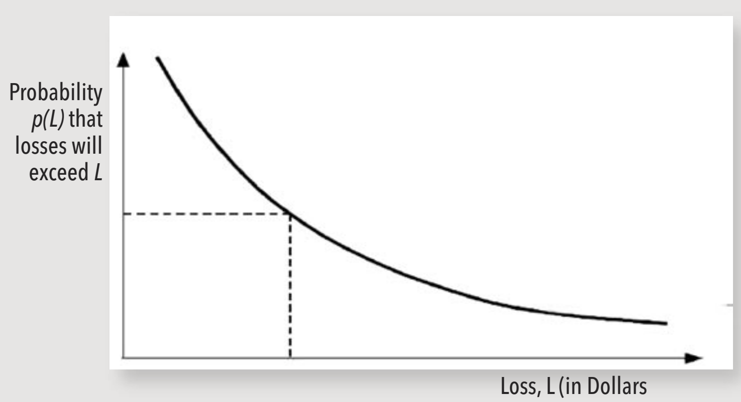
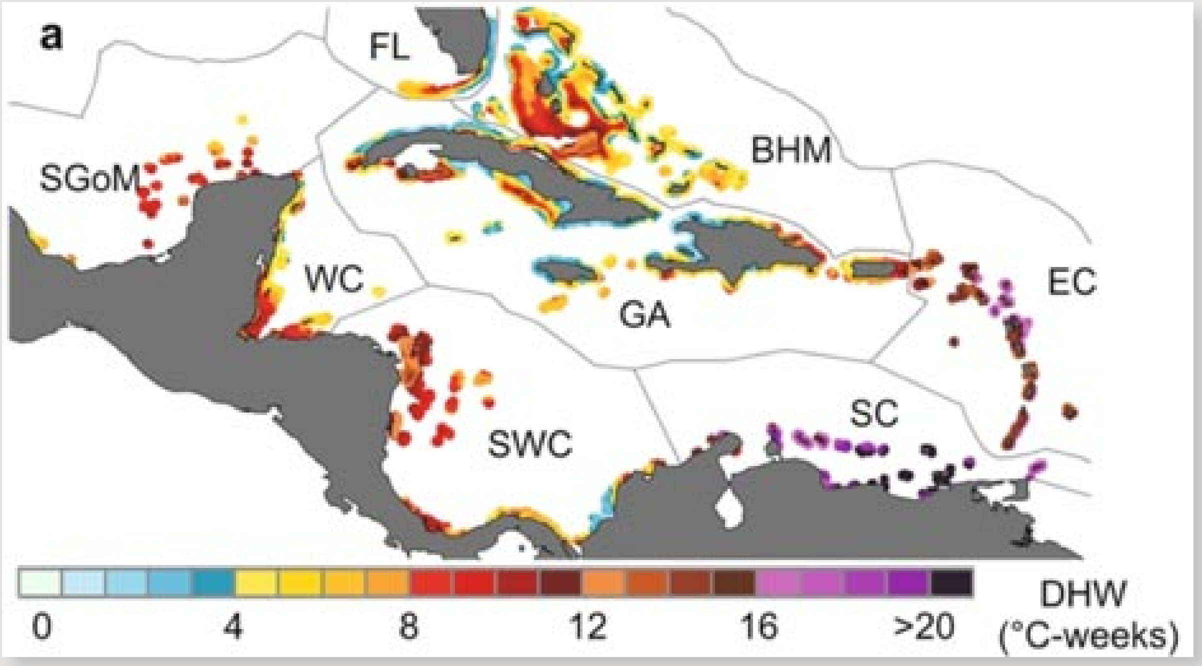
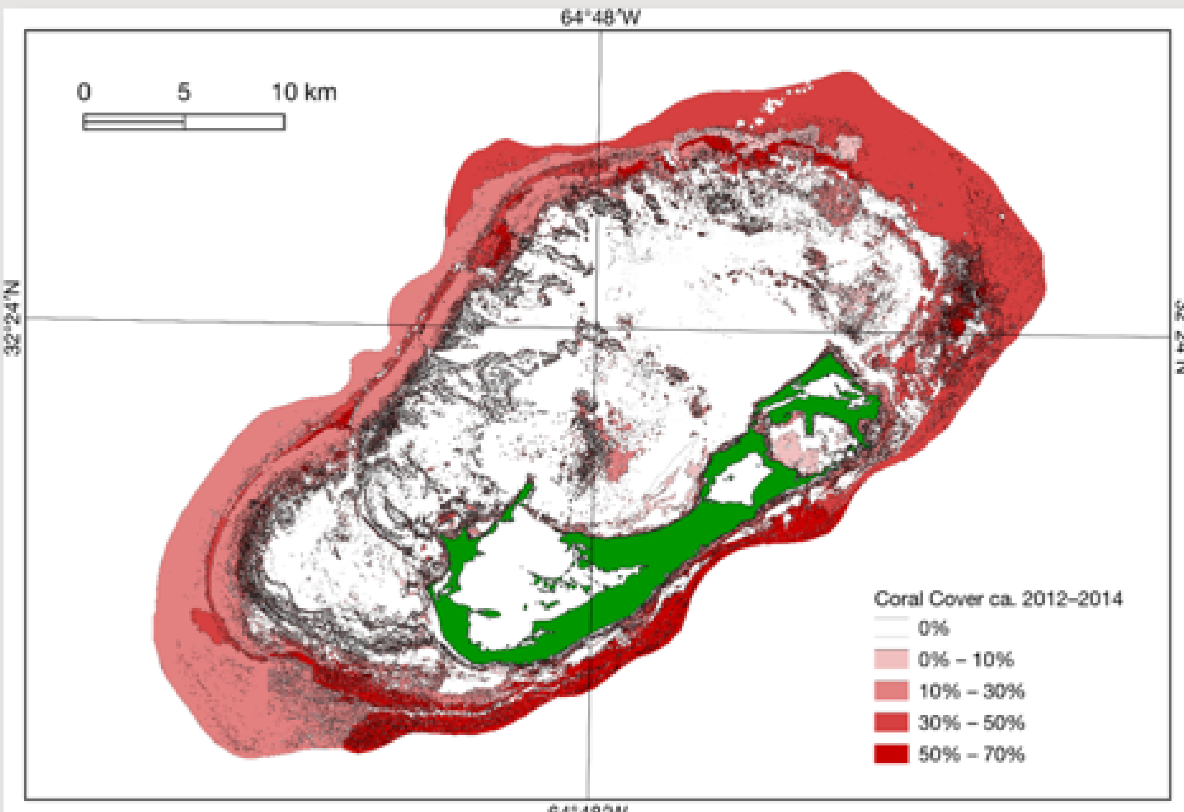


Figure 4. Schematic Exceedence Probability ('EP') Curve (Souch, 2017).

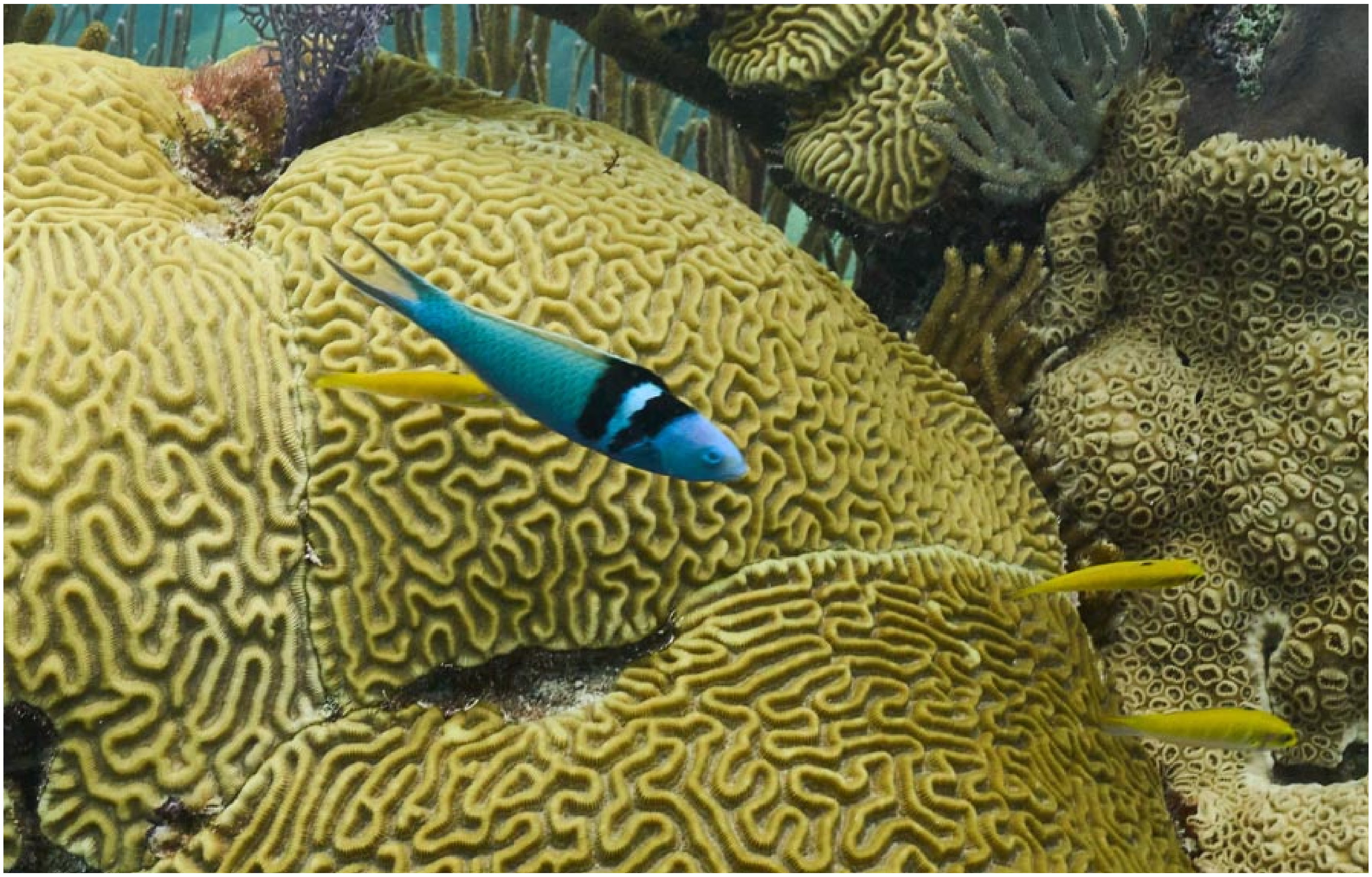
The vulnerability of coral reefs in Bermuda is an active area of research. Much of the scientific focus is on a hypothesis that Bermuda's deep (mesophotic) reefs, which reside at cooler temperatures down the seamount platform, may provide a refuge for coral species. Given that Bermuda is geographically better positioned than our neighbors in the Caribbean (in terms of cooler ocean temperatures), we have not suffered the widespread bleaching that they already have (Muñiz-Castillo et al., 2019).



Map showing heat stress values (Degree Heating Weeks – DHW) per pixel, 1985–2017, from Muñiz-Castillo et al., 2019 (their Figure 1a).



Map of Bermuda coral coverage (percentage cover) estimates for 2012-14. Courtesy of Dr. Eric Hochberg, BIOS.



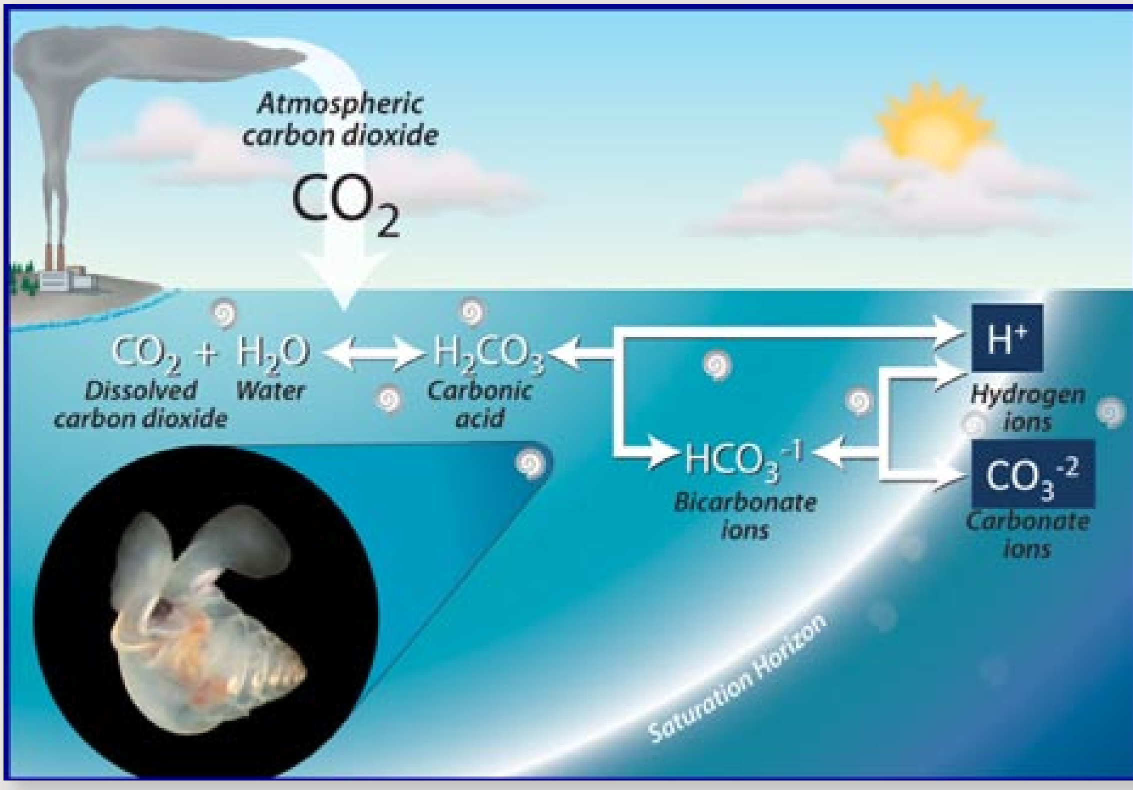
Therefore, there is cause for optimism that corals in Bermuda may be more thermally resilient than in other areas, due to a happy circumstance of geography and topography.

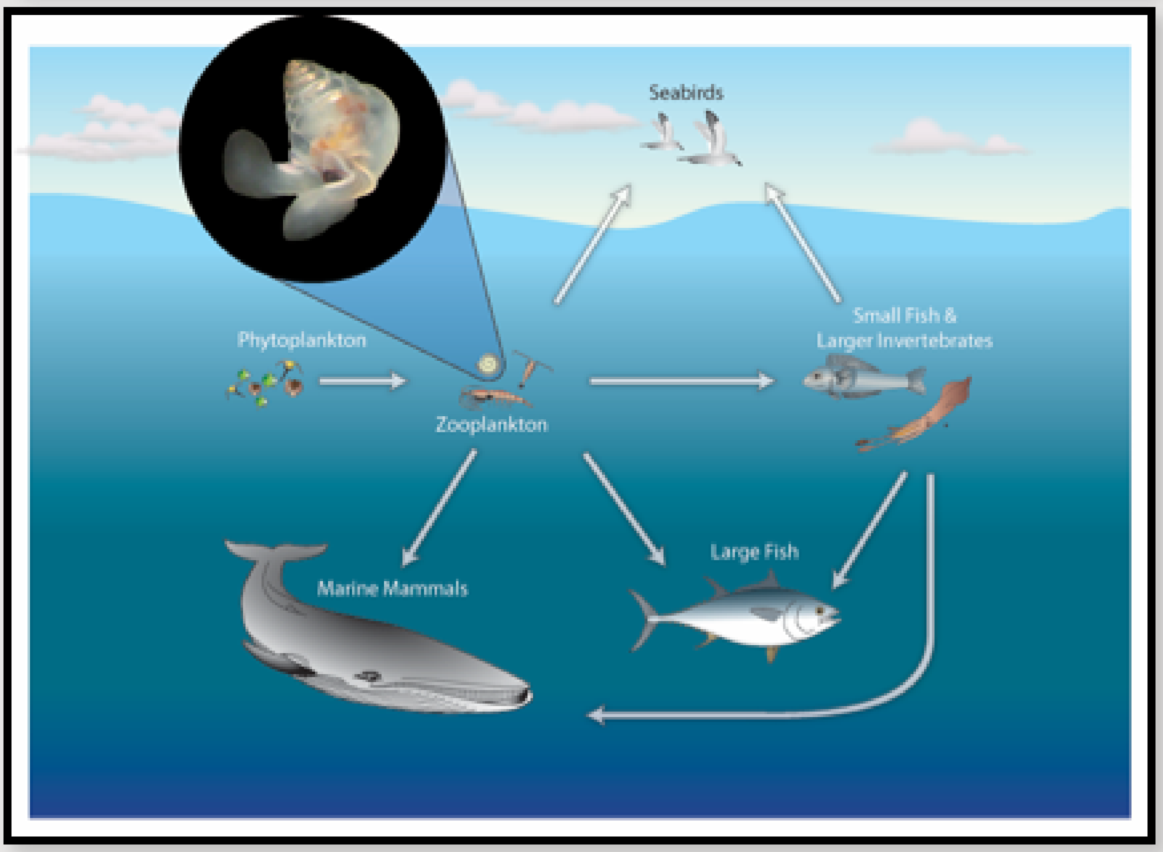
Another active area of research is to simply determine how much coral there is in the world. This is being mapped by satellite and airborne sensors, and the resulting map for Bermuda represents the 'exposure' piece of the risk puzzle.

The Marine Environment
Ocean acidification

In addition to the warming upper ocean, there is a gradual change in the chemistry of the ocean, as more greenhouse gases are absorbed by the surface waters. Specifically, the uptake of carbon dioxide (CO2) initiates a series of reactions that result in ocean waters becoming more acidic, and carbonate ions becoming less available (Bates & Johnson, 2020).

Over longer time periods, organisms that rely on carbonate ions to build their shells and structures, such as coral, shellfish, and some plankton, will more frequently experience osteoporosis (Maas et al., 2018), affecting their ability to grow and function. This reduced shell/skeleton integrity can disrupt marine food webs, biogeochemical cycles and fisheries.



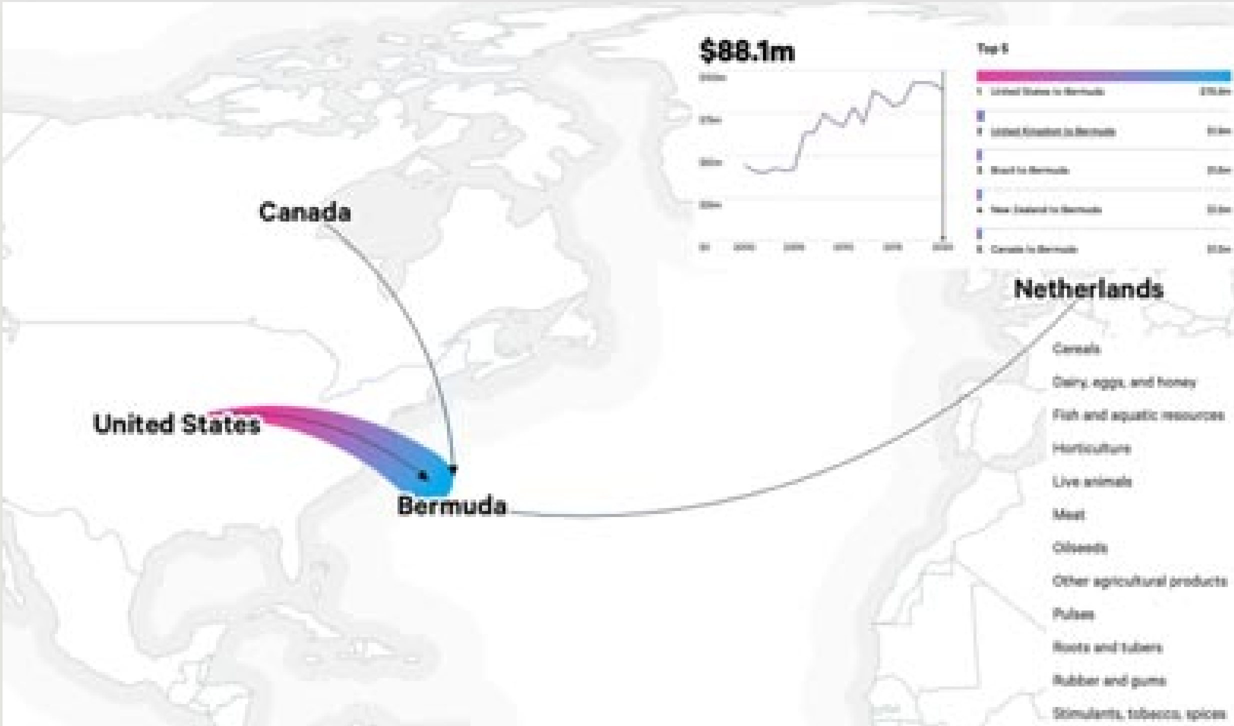


Graphics courtesy of Dr. Amy Maas, BIOS.

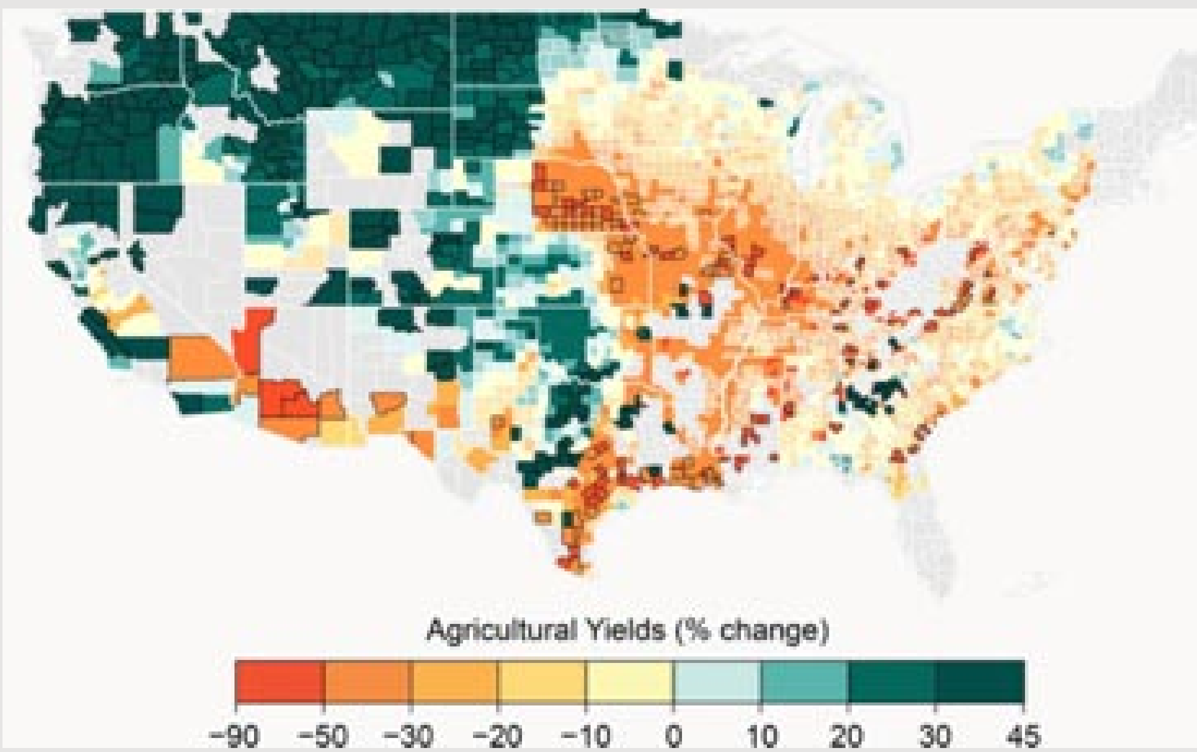
Risks to Supply Chain

The ability to import and grow food is the main critical factor in island-wide food security. Imported food significantly outweighs locally produced food. The last available metric states that 20% of produce consumed on the island is locally grown (Glasspool et al., 2008), while a surveyed farmer estimated that the number is now closer to 15%. All the dairy milk on island is locally produced between two farmers due to a permanent embargo on milk. Surveys indicate there is minimal local meat and egg production. Otherwise, for packaged and dry foods, Bermuda relies on the US for food imports.

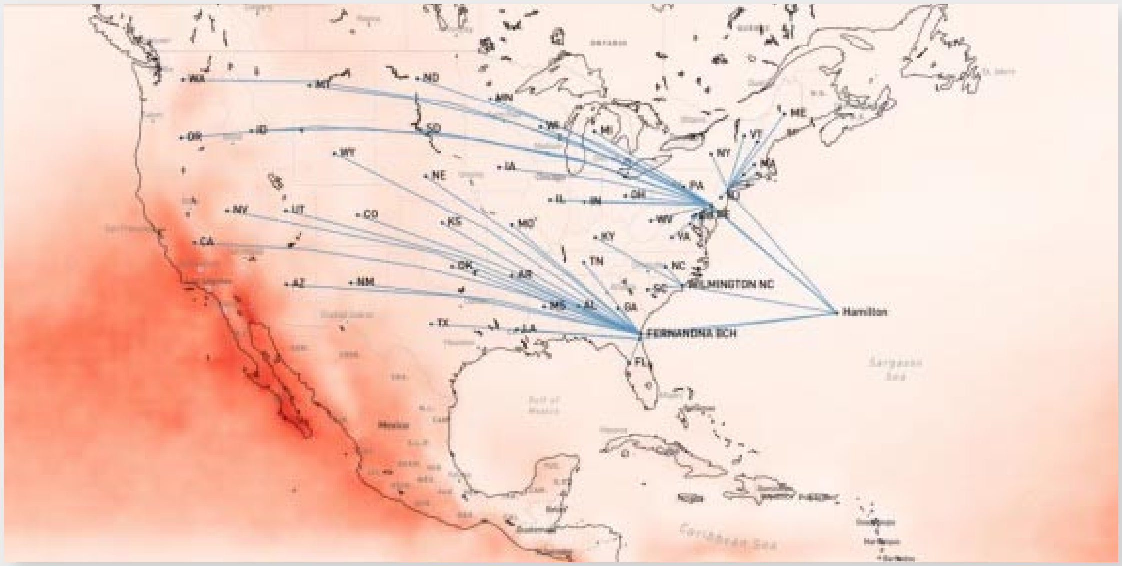
The impact of climate change on US food production is therefore directly relevant to Bermuda.



Map of exporters of agricultural goods to Bermuda. In 2020, the island imported USD$88.1 million dollars' worth of food, an increase from 42.4 million in 2000. Source: resourcetrade.earth



Percentage change in corn, wheat, soy, cotton yields under the RCP 8.5 scenario in 2080-2099 (Hsiang et al., 2017). The most productive areas are the most important regions to consider. These are California's Central Valley and the Midwest corn belt, both of which are anticipated to have yield declines in the future.



Number of Consecutive Dry Days (CDD) in 2050 under RCP 8.5 scenario. Significant drought exposure in western US can affect availability and price of relevant food/agricultural imports (source: Correntics).

A recent pro bono study by climate risk analytics firm Correntics confirmed this, summarizing the situation as follows:

"Extreme weather and chronic climate risks can lead to damage of critical supply chain infrastructure & transport disruptions; supplier disruptions, and; supply shortages.

Due to geographic dependencies and limited import diversification, there is a significant risk accumulation along Bermuda's essential supply chains. Major risks on the agriculture and energy supplies to Bermuda:

- Strong dependency on US exports (limited upstream diversification)
- Increase of temperature and precipitation extremes as a consequence of climate change may result in increasingly challenging conditions for agricultural production, especially in the western US with impacts on availability and prices.
- Main US East-coast and Gulf of Mexico ports and local (Bermuda) logistics infrastructure are exposed to tropical cyclones. In addition to hurricane induced damages with short term supply chain disruptions, the expected intensification of hurricanes in a warming climate along with long-term sea-level rise can pose severe challenges to low lying coastal port and transport infrastructure."

The anticipated decline in stable crops in the US will likely affect the availability and or prices of food in Bermuda. Stable crops like grains and soy are the most widely studied, but many more types of food are imported.

This weakness has been highlighted previously by food shortage scares; for example, in 2012 when Hurricane Sandy closed NJ ports for a week, the closing of NYC ports following 9/11, or when ships periodically break down causing delays

(Sinclair, T.J., Personal Contact, 2022). The increase in storms' frequency and intensity in Bermuda and along the US east coast (Hallam et al., 2021; Ting et al., 2019) could also impact shipping schedules.

It is important to note that nearly all of Bermuda's fertilizers and animal fodder are imported from the US as well (resourcetrade.earth). Moreover, other agricultural inputs and equipment must be imported.

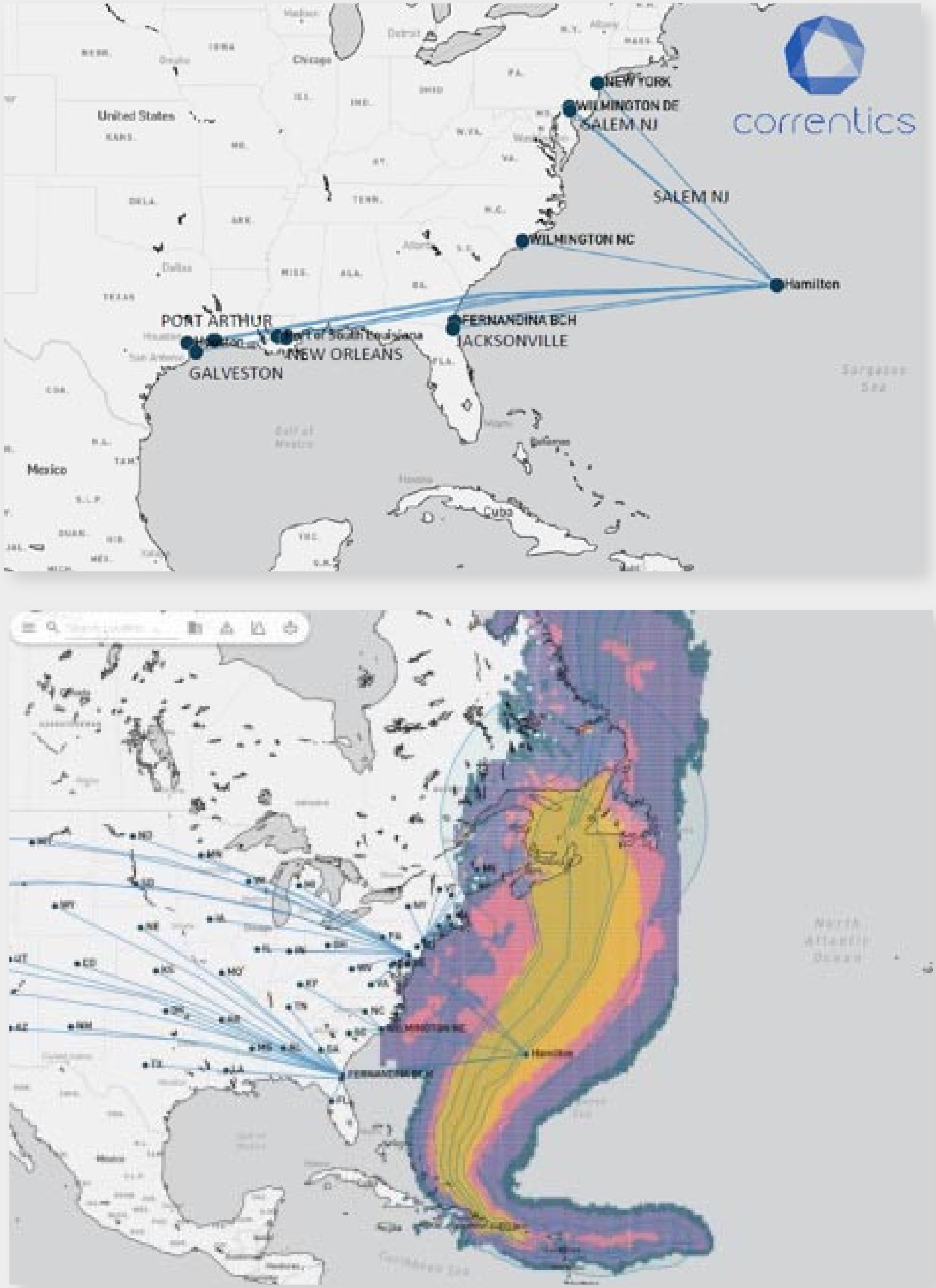
The science and governmental community have identified that local agriculture is an important piece of food security for the island particularly in consideration of climate change (Glasspool et al., 2008; Government of Bermuda, 2016).

One thing to note is that local produce can be more expensive than imported produce. Bermuda is an expensive place to farm, for similar reasons that it is an expensive place to live (e.g., the high cost of energy, labor, imported goods, high competition for land, and limited resources). The implication is that there is tension between food security in the context of price and food security in context of being globally autonomous. If Bermuda seeks to increase local produce production, this implication should be considered.

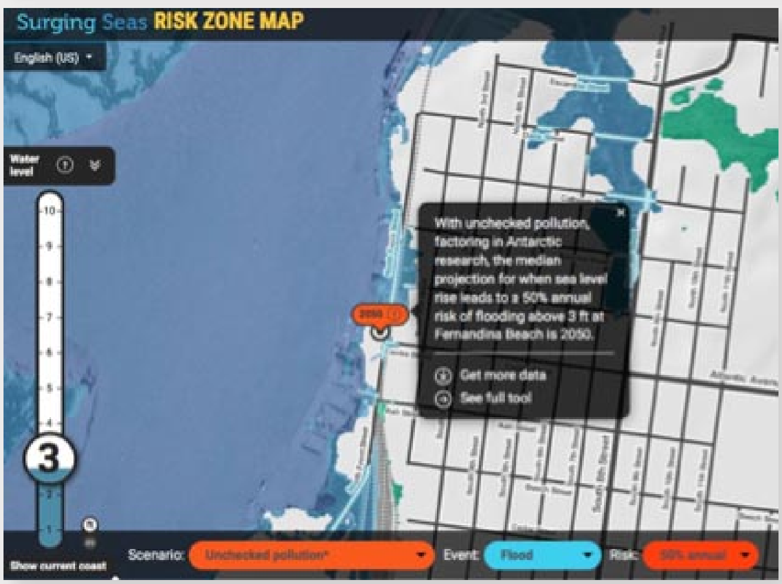
More broadly, infrastructure that forms the backbone of the shipping supply chain (not only for agriculture, but other goods and products, e.g., fuel for energy) is likely to be adversely affected by climate impacts.

A more thorough investigation is needed, but a simple review of sea level rise at some of these ports indicate effects that may be impactful to port operations in the coming few decades. Some of the detail on sea level rise and other climate impacts is presented in the chapter on sea level rise and storm surge, and effects on local port infrastructure may be inferred. However, a port assessment of climate impacts is advised.

Note: Aviation also forms a less significant portion of Bermuda's supply chain for goods, and climate impacts to aviation are presented under the chapter on Tourism and travel.



Top: Main US ports on US East Coast and Gulf of Mexico with relevance to exports to Bermuda. Bottom: Map including upstream destinations overlaid with the area affected by the impacts of Hurricane Fiona (2022). Source: Correntics



Top: Port of Fernandina, FL, source Somers Isles Shipping. Middle - Sea level Rise analysis, source: Climate Central: https://sealevel.climatecentral.org/ . Bottom: Bermuda's critical local logistics infrastructure for imports.

Tourism and travel
Aviation and air travel

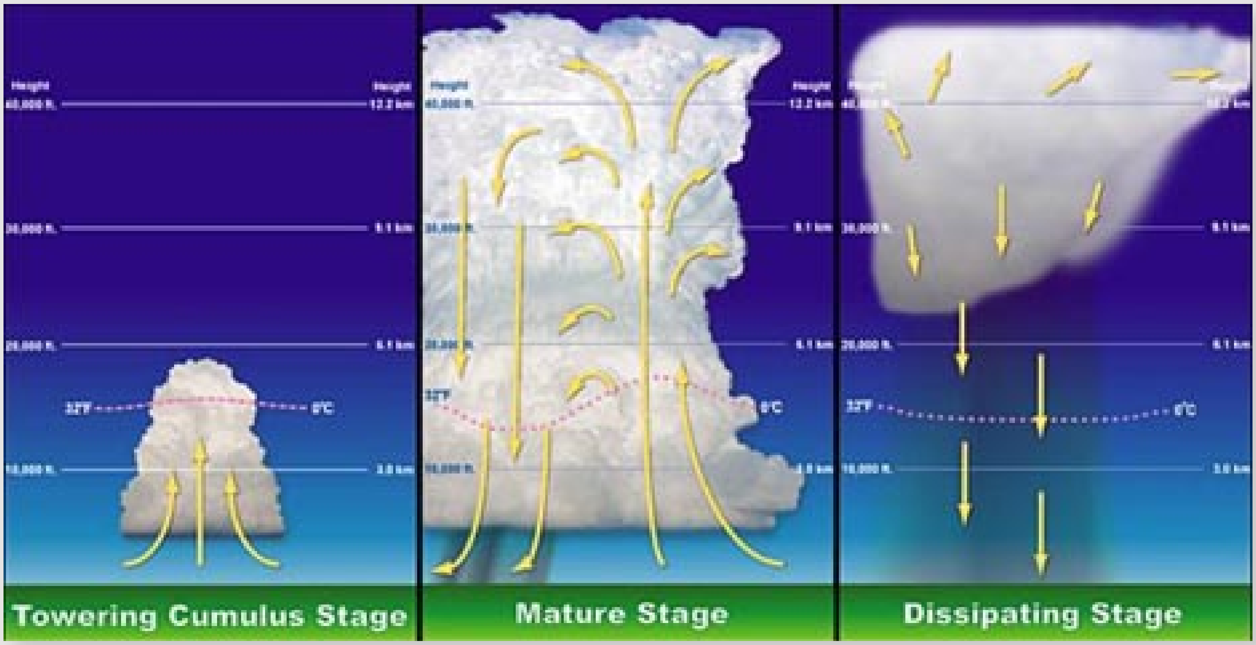
An exploration of the influences of climate change on international aviation requires an understanding of the background conditions that may influence en route flight planning and hazards at airports. A non-exhaustive survey of these considerations (and the influence that climate change may have on them) follows.

Disruptions to air travel are anticipated in a future state of the climate, due to more frequent weather delays, changing temperatures altering the weight requirements for take-off restrictions and sea level rise causing problems for many coastal airports (Puempel & Williams, 2016). The report also indicated that, while many climate factors may impact airports and aviation in future, more research is needed to resolve other small-scale effects, such as instances of thunderstorms and low-level wind shear at airports.

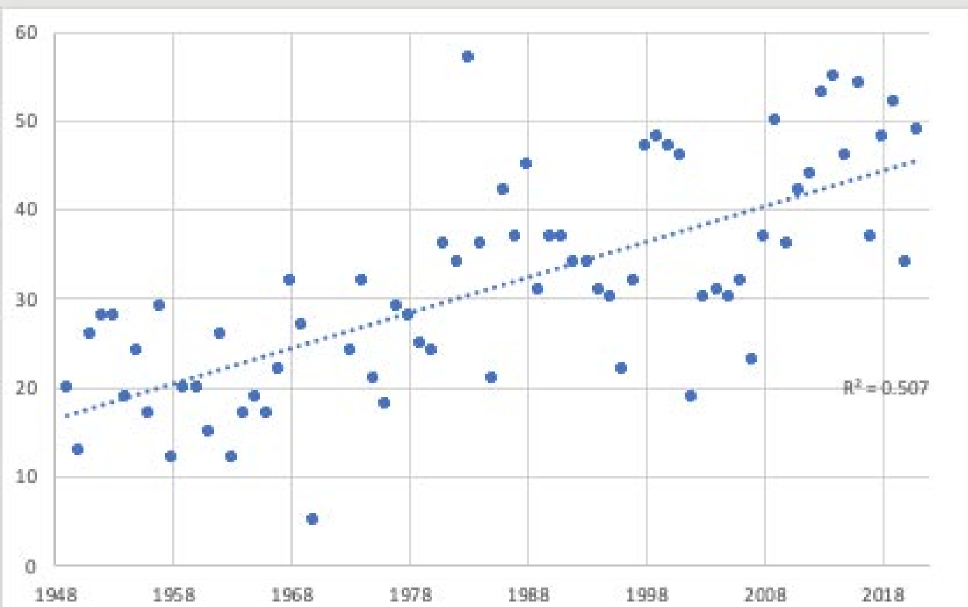
Thunderstorms, turbulence & low-level wind shear
Thunderstorms & lightning

The updrafts of air that develop thunderstorm clouds (cumulonimbus) can lead to sudden gains or loss of lift of an aircraft, with the consequence of light, moderate or severe turbulence being experienced. For this reason, and the unpredictability of the strength of such updrafts in real-time, pilots avoid flying near thunderstorms, and meteorological observers are charged by the International Civil Aviation Organization (ICAO) with noting the presence of cumulonimbus clouds at aerodromes (ICAO, 2018a).

In addition, lightning can pose a hazard to aviation operations and safety risks to ground-based aerodrome personnel undertaking necessary outdoor tasks. Other considerations include the presence of flammable fuels and the potential for damage to airport infrastructure. These risks are often managed by suspension of operations at an aerodrome, which can cause downstream impacts to air traffic, including delays and significant costs being incurred by airlines, passengers and airports (Steiner et al., 2016). The disruptions due to



Thunderstorm life cycle – graphic source: NOAA (https://www.weather.gov/zme/safety)



Number of days per year on which thunder was reported at LF Wade International Airport 1949-2021. Source: BWS.

lightning-induced 'ramp closures' are exacerbated by the low predictability of lightning behavior and the perception of inefficiency by air operators and passengers.

A trend that has been detected at LF Wade International Airport is an increase in the number of days on which thunder was reported annually.

Tourism and travel
Wind shear at airports

In contrast to high-altitude turbulence, low-level wind shear (LLWS) may occur in the flight path of approaching aircraft at aerodromes. Simply put, wind shear is a change in wind speed or direction within a short height or horizontal distance that can cause a sudden loss or gain in headwind. Headwind helps to generate lift for an airframe; LLWS can cause sudden and unpredictable rises and/or losses in altitude of an aircraft flying through it.

LLWS can be generated by thunderstorms in close proximity, larger-scale weather patterns such as fronts, rapid temperature change with height, and/or even topography (FAA, 2008). Under international standards, LLWS is required to be reported when it is evident below 500 m (approximately 1600 feet) above the ground (ICAO, 2018a).

Locally, a recent study (Wolffe, 2020) found that there were no obvious climate trends in the seven-year record of digitized low-level wind shear reports at LF Wade International Airport. One finding indicated that wind shear is likely most prevalent during winter wind events. If there are changes in the frequency and/or intensity of winter gales this might also imply changes in wind shear locally. However, wind shear can stem from several scenarios in the western Atlantic, therefore it is problematic to infer any trends from the existing records.

Tourism and travel
Clear-air turbulence and trans-Atlantic flight times

While the presence of turbulence is indicated by the presence of cumulonimbus clouds, clear-air turbulence (CAT) is invisible to pilots and instrumentation. CAT is not related to thunderstorm activity, and is present aloft near jet streams at cruising altitudes near 10 km (>30,000 ft) above sea level. Research conducted on the impacts of climate change to aviation indicate more turbulence disruption during flights by the period 2050-2080 under 'business as usual' emissions scenarios (Storer et al., 2017).

In addition, trans-Atlantic flight times are expected to change due to disruption of the mean jet stream position and strength (Williams, 2016). Williams' simulation study found shorter flight times between New York's JFK airport and London Heathrow by about half an hour, under business-as-usual emissions scenarios, due to a speeding up of the jet stream. For flights in the opposite direction, flight times are likely to be lengthened, likewise by about half an hour.

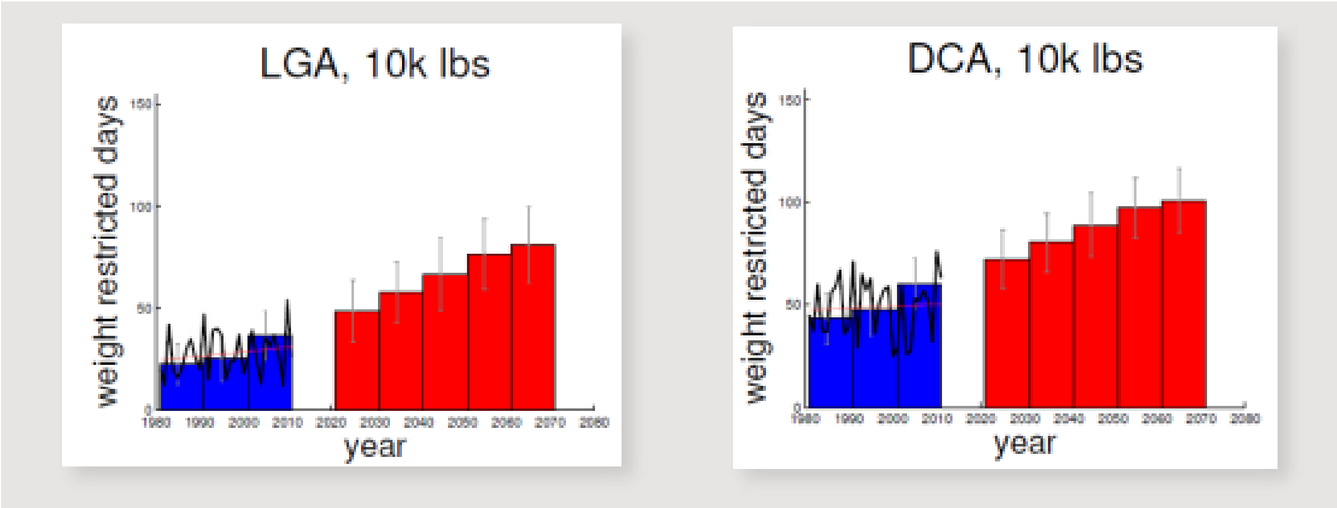
Tourism and travel
Temperature

Temperature affects the density of the air (hotter air means lower density) which, in turn, affects the performance of aircraft. The lower the air density, the less weight a given aircraft can carry for take-off or the longer runway is needed. In addition, high humidity can alter the performance of engines.

ICAO requires the publication of an aerodrome reference temperature, defined as "the monthly mean of the daily maximum temperatures for the hottest month of the year (the hottest month being that which has the highest monthly mean temperature)," averaged over several years (ICAO, 2018b). It is estimated that 1°C of reference temperature increase should result in an additional 1% of runway length being necessary (Ashford et al., 2011). The reference temperature for Bermuda's LF Wade International Airport is 30°C (Bermuda Airport Authority, 2022). The calculations reveal that a minimum runway length of 2,070 m (6791 ft) is required for this temperature. Thankfully, LF Wade has much to spare, with a published runway length of 2958 m (9705 ft). This goes well above the expected requirement for even an extreme warming scenario.

However, regional airports on the US East Coast that may be affected by greater weight restrictions in a warming climate will need to be considered, especially in the summer months. Coffel & Horton (2015) found that the number of 'weight-restricted days' is simulated to increase due to warming; with weight-restricted days defined as those on which flights must reduce their maximum take-off weight by 10,000 lbs due to a high air high temperature reducing aircraft performance at given airports. They found that for flights out of Washington DC's Reagan National (DCA) and New York's LaGuardia (LGA) airports, weight-restricted days may as much as double by 2050.

The impact of this may be more delays and disruption in general, especially for flights originating at airports with shorter airfields (the effect of temperature on performance is mitigated by having a longer runway). It may also affect flight planning: one way around this problem is that long-haul summer flights originating from hot airfields (e.g., Middle Eastern aerodromes) only depart during the cooler nighttime hours.



Tourism and travel
Coastal inundation risk

Sea level rise and storm surge basics were covered in Part I of this report, and this section will focus on the risk of seawater inundation to aviation assets at LF Wade International Airport.

In 2003, Hurricane Fabian caused a major storm surge tide event in Bermuda, with battering waves running over a large storm surge. The combined effect left large portions of the Causeway demolished, and the tragic loss of four lives. In addition, the airfield was also inundated with ocean water. Anecdotal evidence includes that crews clearing debris off the airfield noted that there were fish amongst the rubble. Some airfield instrumentation had a high-water mark about 1 m (just over 3 ft) above the ground at the site, which is estimated at 2 ½ m (8 ft) above sea level. So, over 3 m (11 to 12 feet) of storm tide is estimated to have occurred at that location.

Future coastal flood risk is represented here by Climate Central's Coastal Risk Screening tool, projecting the area to be below annual flooding levels in 2050.

Note that large swaths of the airfield, especially the southern and western shorelines are projected to be flooded annually by 2050. These include the 'Finger,' the south perimeter road (already frequently impacted by undermining during storms), and Kindley Field road near the Causeway, affecting road access to and from the airport terminal.

Tourism and travel

Tourism

The very thing that attracts visitors (our climate) is changing. This section will explore impacts and opportunities that climate change presents to the tourism sector in Bermuda.

Of course, one of the main tourist attractions to Bermuda is its beaches. Sea level rise will naturally start to reduce the beachfront, and this is already evident on some beaches. The extent of coastal retreat is dependent on the individual beach and coastal topography. In addition, some other coastal attractions, such as King's Square and the surrounding property in the Town of St. George's, located in Bermuda's own UNESCO World Heritage Site, are affected by 'sunny day flooding,' and are projected to be underwater each high tide potentially as soon as 2040.

Somerset Long Bay, October 2021

Tourism and travel
Opportunities for tourism

The Bermuda Tourism Authority's Annual Report for 2021 states, "Eco-tourism has become an important consideration for travellers who have come to demand the destinations they visit are eco-responsible with a demonstrated commitment to protect the environment."

Bermuda has a good story to tell with respect to resilience to natural hazards and sustainability. There's a long history of each (water supply, strong buildings, and environmental protection).

The history of sustainability goes back to 1620, when one of the world's first known legislated environmental protections prevented the overfishing of sea turtles. Bermuda's well-known strong architecture has long been touted as a source of protection against the worst hurricane damage, and our water supply regime is characterized by each property owner being responsible for their own fresh water.

Extreme weather events such as hurricanes can be very disruptive to a vacation or business trip. However, by most objective measures, Bermuda is a very resilient jurisdiction (this is explored more fully in the chapter on disaster risk). The fact that Bermuda is one of the most resilient locations to tropical cyclones in the world, is partly due to our high (and growing) experience with hurricanes. A popular internet meme makes light of the high degree of preparation in the face of hurricanes that Bermudians have, compared to other jurisdictions.

The existing resilience to storms could be leveraged in messaging to our visitors during the height of hurricane season. The challenge will

Left: Coney Island, November 2021. Right King's Square, 2017. Source: Bernews

be to continually demonstrate that high degree of resilience in the face of increasing hurricane risk.

More recently, the Bermuda Ocean Prosperity Programme and renewable energy efforts are two examples of planned progress in sustainability. Cultural awareness of climate change and the need to maintain/increase resilience and sustainability are represented by new activities such as the Bermuda Youth Climate Summit and publications including this report.

Burgeoning conference activities surrounding climate risk finance continue to grow, and there is hope that the increasing global interest in supporting climate change resilience will lead to more business tourism to the island.

All these facets of Bermuda's culture, including planned enhancements to sustainability, are reason to celebrate the island, and to tout its attractiveness to tourists as a climate-resilient destination.

There are many aspects that make a destination attractive and climate change may affect the decisions of tourists to come to Bermuda vs. another destination. These may include an ability for Bermuda to deliver safe and convenient travel to/from Bermuda, plus activities, including ecotourism and dining in Bermuda.

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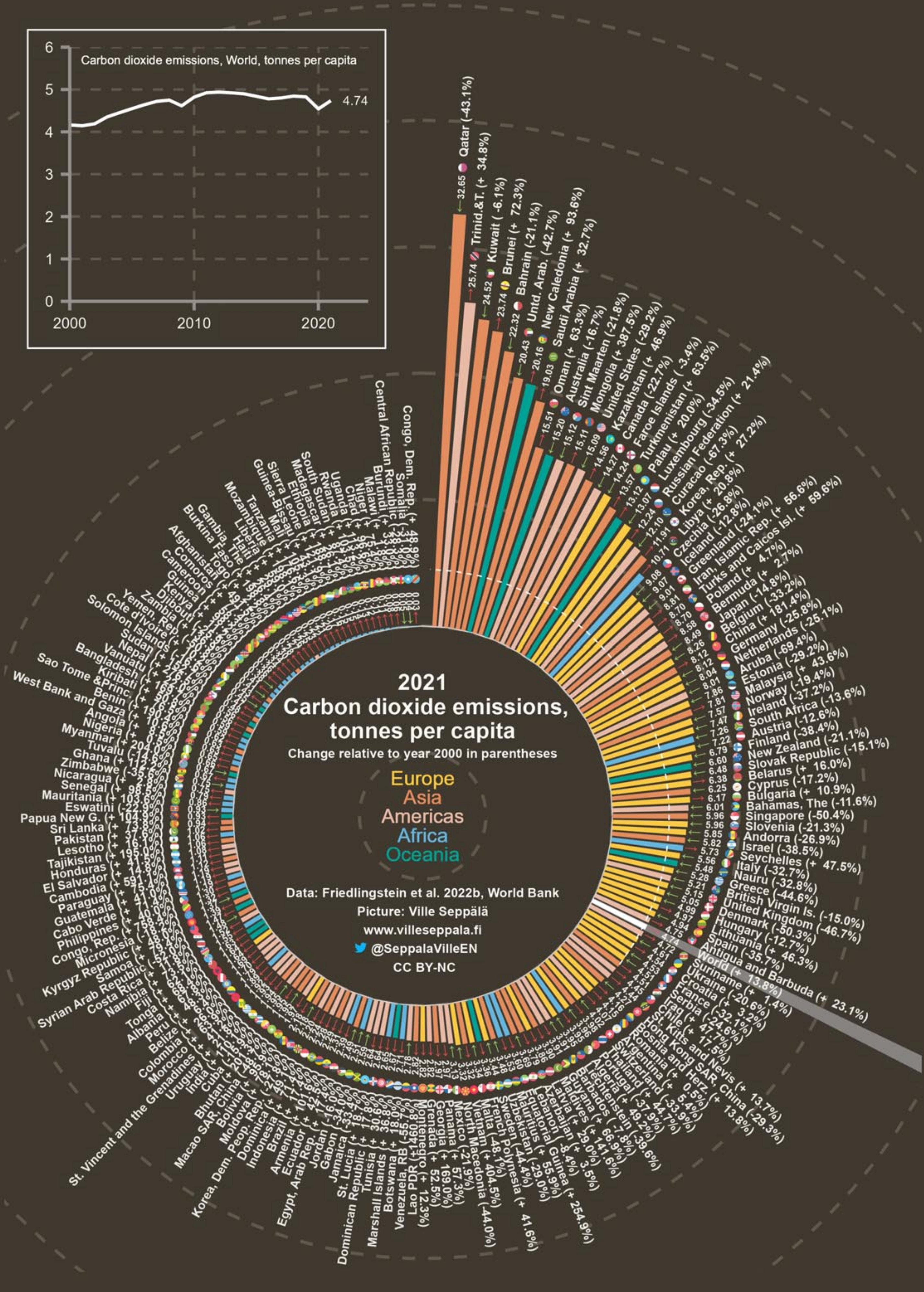
Afterword

This report is not intended to advocate for a particular course of action on climate change; it is designed to inform the decision process for individuals, policy-makers, and organizations. I am hopeful that deliberations on adaptation measures are particularly aided by this report. Nonetheless, while it goes beyond the scope of the set of studies synthesized in Parts I and II, it is clear that action on the mitigation of GHG emissions is also needed. As I have recently highlighted at numerous forums such as the Bermuda Youth Climate Summit, local residents annually produce nearly 10 tonnes of carbon dioxide per person (Global Carbon Project). This is not unusual for an island of our size and isolation. Due to shipment of materials to the island, and the reliance on burning fossil fuels for energy and transportation, small islands often have a high per capita output of greenhouse gases, compared to that of larger countries. In addition, the impacts to small islands are disproportionately high. So, we face a need to mitigate the climate change hazard by reducing our emissions; and also to reduce our vulnerability and exposure, by adapting to the rising potential for local impacts from changes in climate.

There are good economic, financial, and health reasons for reducing one's long-term carbon footprint, and also strong moral justifications. Bermuda is already a leader in some realms of sustainability and resilience. Our rainwater harvesting, centuries old legacy of marine protection, and provision of financial resilience against international disaster risk are all testaments to Bermuda's capabilities. However, a collaborative focus on improving our interactions with the natural world will continue to be needed, as climate change produces more impacts on our island home.

At the time of completion of this report, a wide-ranging survey on climate change in Bermuda was undertaken by Dr. Brett Lefkowitz, reaching approximately 1% of the total population. Recent local attitudes toward climate change and actions can be inferred from the preliminary results of the survey, presented in the Appendix to this report.



2021
Carbon dioxide emissions, tonnes per capita
Change relative to year 2000 in parentheses
Europe
Asia
Americas
Africa
Oceania
Data: Friedlingstein et al. 2022b, World Bank
Picture: Ville Seppälä
www.villeseppala.fi
@SeppalaVilleEN
CC BY-NC
Carbon dioxide emissions, World, tonnes per capita
4.74
Qatar (-43.1%)
Trinid.&T. (+ 34.8%)
Kuwait (-6.1%)
Brunei (+ 72.3%)
Bahrain (-21.1%)
Untd. Arab. (-42.7%)
New Caledonia (+ 93.6%)
Saudi Arabia (+ 32.7%)
World (+ 13.8%)

Appendix

Preliminary results presented below are from a survey presented to the general public, resulting in over 600 respondents. Full findings will be presented in "Threat Perception of the impact of Climate Change risks and Public Preparedness for resultant extreme-weather-events in Bermuda" (Lefkowitz, 2023 – in preparation).

1. Climate Change Knowledge, Beliefs, and Engagement

- Knowledge about climate change: Bermuda 68.44% of respondents report knowing " a lot" or "a moderate amount" about climate change.
- Climate change is happening: Bermuda 96.28% of respondents report that climate change is happening.
- Climate change is human-caused: Bermuda 70.74% of respondents report that climate change is caused mainly by humans.

2. Worry and Perceived Risks Regarding Climate Change:

- Worry about climate change: Bermuda 85.1% of respondents report they are either "very worried" or "somewhat worried" about climate change.
- Climate change will harm future generations: Bermuda 77.84% of respondents report that they believe climate change will harm future generations "a great deal".
- Climate change will be personally harmful: Bermuda 22.87% of respondents report that climate change will harm them personally " a great deal".
- Personal importance of climate change: Bermuda 62.23% of respondents report climate change is either "extremely" or "very important" to them personally.
- Climate change is a threat in the next 20 years: Bermuda 94.48% of respondents report that climate change is either a "very high", "high" or "medium" threat to people in their countries over the next 20 years.

3. Responsibility for Action on Climate Change:

- Who is responsible for reducing causes of climate change? Bermuda: 84.04% of respondents believe that the government should be doing more about climate change.
- Climate change as a government priority: Bermuda 78.37% of respondents report that climate change should be either a "very high" or "high" priority for the Government.

4. Energy and the Economy:

- Perceived economic impacts of action to reduce climate change: Bermuda 61.7% of respondents report that tackling climate change will improve economic growth and provide jobs.
- Increasing use of renewable energy: Bermuda 87.41% of respondents report that our Government should either support "much more" or "somewhat more" the use of solar panels and wind turbines as alternate sources of energy.
- Decreasing use of fossil fuels: Bermuda 75% of respondents report that our Government should continue to support the use of the same fossil fuels, like coal, oil and gas "much less".

5. Climate Activism

- Willingness to join an organized group for climate action: Bermuda 26.24% of respondents report either "participating in a campaign right now" or "would definitely join " a citizen's campaign to encourage the Government to address climate change concerns.

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