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Executive Summary

The specific aim of this analysis was to examine the impact of sea level rise (1.0, 1.5 meter by 2100; Sweet et al, 2017) at the Port of Honolulu to evaluate the potential risks to critical infrastructure from flooding through 2050 and 2070. This preliminary analysis is intended to identify key points of vulnerability due to SLR that may impact key food import infrastructure. Such identified points of vulnerability in the food system are intended to serve as key empirical reference points for developing new strategies for achieving food system resilience and ensure household and community food security in Hawai‘i in the context of anticipated sea level rise and the case of future natural disasters such as severe weather events. Key findings are the following:

Relative Risks By Year 2050 (1m SLR by 2100): The analysis indicates that only a few points of infrastructure are anticipated to be at risk by 2050 under an intermediate Sea Level Rise (SLR) scenario (i.e. 1m SLR by 2100). Any key infrastructure over 1m MHHW elevation is relatively protected and will likely not be significantly impacted by minor flooding. However, there are several points where impacts may begin to occur and are indicative of places where planning for adaptation should start. See *Map 1* below.

Relative Risks By Year 2070 (1m, 1.5m SLR by 2100): By 2070, the sea level rise and the frequency and level of inundation are significantly different. The severity of flooding will depend upon the extent of future sea level rise (SLR). Moderate impacts to critical systems infrastructure are anticipated under an intermediate SLR scenario (1m by 2100), and significant impacts under a higher SLR scenario (1.5m by 2100). Although these impacts are anticipated 50 years into the future, there is not a lot of time for planning and re-building key port infrastructure and/or relocating food storage infrastructure. There are several points with potential impacts

identified in the analysis that indicate clear impacts and thus justification for adaptation planning.[1] See *Map 2 and 3* (below).

Background & Introduction

According to the 2018 global report by the InterAcademy Partnership (IAP), comprising 130 national academies of science and medicine across Africa, Asia, the Americas and Europe, the current approach to food, nutrition, agriculture and the environment is unsustainable and must fundamentally change (IAP 2018). According to the IAP and other scientific consortia, global food systems are failing humanity and accelerating climate change (Willett et al. 2019). Transforming global and regional food systems, and changing dietary patterns are the key ways to improve human health and environmental quality while advancing climate change adaptation and mitigation (Shannon et al. 2015; Fanzo et al. 2021). The need for fundamental food system transformation is increasingly supported through a rapidly growing body of international scientific research (Rockström et al. 2020; Webb et al. 2020; Binns et al. 2021).

Even with significant and coordinated efforts to limit global greenhouse gas emissions and adhere to international policies and pledges, anthropogenic climate forcing is anticipated to exceed the upper threshold of 1.5C of warming two-fold by 2100 (IPCC 2018). Regions must thus prepare for the impacts of sea-level rise and more frequent and severe weather disasters that may negatively impact food security, critical supply chains and fisheries and result in the catastrophic loss of life, livelihoods, property and infrastructure (NCA 2014; Shannon et al. 2015; US EPA 2017; Sweet et al. 2017; FAO 2018; Mora et al 2018; IPCC 2018; Lenton et al. 2019; Melkonyan et al. 2019; Blunden & Arndt 2020).

With the possibility of significant destabilization of the Earth's climate system this century (Mora et al. 2013; Lontzek et al. 2015; IPCC 2018), there are increasing calls from scientists, NGO leaders and elected officials for immediate and significant investment in transdisciplinary an applied research, education, regional planning and policy efforts toward building more ecologically sustainable, resilient and equitable agri-food systems that are

[1] Results should be considered *conservative* (i.e. high probability of occuring) based on the following: a.) The above model is based on the still water level (SWL) and does not take into account compound flooding (i.e. there is no consideration of waves that could add an additional 20-30cms of flooding on top of the SWL. Also, the analysis does not account for flooding associated with an elevated water table because of sea level rise (SLR). This issue may also apply to stormwater runoff, depending on the elevation of the stormwater runoff outlets. b) Return level (RL) estimates for Honolulu harbor change rapidly across a very narrow band of elevation - 30 cms of SLR can make a significant difference (e.g. 1.5m versus 1.2m SLR above MHHW corresponds to a once in 100 years versus 2x each year RL; 1.3m versus 1.0m above MHHW corresponds to a once in 10 years versus every day RL). c) For infrastructure like piers, docks or quay walls, assuming the elevations level used in the model are based on 'top of the deck', disruption (or damage) would be expected to occur *sooner*, as water levels may not have to reach the top of the deck for things like floating docks to come up against the top (limit) of their collars, or floating fenders to approach a rollover scenario.

strategically aligned with municipal, regional and global sustainable development goals (Liebman and Schulte 2015; Delonge et al. 2016; Schipanski et al. 2016; SRC 2016; Seekell et al. 2017; FAO 2018; Hawaii Green Growth 2018; Loboguerrero et al. 2018; Niles et al. 2018; Vandermeer et al. 2018; Eyhorn et al. 2019; Klassen & Murphy 2020).

Similarly, the food system of Hawai‘i is failing the Native Hawaiian population (Look et al. 2020), is vulnerable to the impacts of severe weather driven by anthropogenic climate destabilization (ACD) (HIEMA 2019), and comes with significant economic and social opportunity costs (Leung & Loke 2008; Office of Planning 2012; Loke and Leung 2013; Kent 2016; Khan et al. 2018). With a residential population of over 1.4 million and 10 million annual visitors (pre-COVID-19), Hawai‘i is one of the most geographically isolated and food import-dependent populations in the world. Importing over 90% of its food[2] and fertilizer, and over 73% of its energy, the Hawaiian Islands are uniquely vulnerable to statewide and community food insecurity in the face of anthropogenic climate change, fuel price fluctuations and other economic and/or natural disturbances (Office of Planning 2012; Loke & Leung 2013; HECO 2018; HIEMA 2019). The just-in-time system of shipping food into Hawai‘i has few functional redundancies in key import infrastructure, with little state-led resilience measures or emergency food reserves in place for maintaining food security in the instance of significant natural or human-induced disasters (HIEMA 2019). Simultaneously, the post-plantation agricultural economy of Hawai‘i remains largely oriented toward agricultural biotechnology seed production, macadamia nuts, coffee and other specialty crops for external markets, with the diversified agriculture sector and regional food economy limited by a range of social, economic and political obstacles (Suryanata 2002; Kent 2016; Suryananta and Lowry 2016; Meter and Goldenburg, 2017; Khan et al. 2018; Miles and Heaivilin, unpublished data). High rates of poverty, food insecurity and significant health disparities have long impacted the Native Hawaiian (Look et al. 2020) and low-income communities while much prime agricultural land lies idle or slated for development (Melrose et al. 2015; Kimura et al. 2016; Coleman-Jensen et al. 2018).

Such conditions have been significantly exacerbated by the COVID-19 pandemic, with 48% of households with children reporting being food insecure (Pruitt et al., 2021). Legal cases over indigenous water rights and access to ancestral and quality farm land and housing remain unresolved for many communities, while concerns over the environmental quality, human health, economic stability and bio-cultural self-determination feature prominently in discourses about the future of food, agriculture and biocultural restoration in Hawai‘i (Goodyear-Ka‘opua et al. 2014; Kimura et al. 2016; Sproat 2016; Kohala Center 2017; Mawyer and Jacka 2018; Winter et al. 2018).

[2] Import dependency ratio varies considerably by commodity (Loke and Leung 2013).

The COVID-19 pandemic has further exposed this range of food system vulnerabilities and social costs, and has magnified the need for policymakers, educators, researchers, planners, citizens and practitioners to collectively advance economic diversification and food system resilience and equity in Hawai‘i and beyond (Rawe et al. 2019; Bene 2020).

The above raises critical questions as to the sustainability, resilience and social equity of Hawai‘i’s food system, and its ability to meet the long-term economic, ecological, cultural, public health and food security needs of its population under the conditions of stochastic shocks and the anticipated impacts of climate change (Office of Planning 2012; Kent 2016; NCA 2018; Binns et al. 2021). Moreover, to date, there has been little state-level strategic planning or public policy support enacted to enhance and protect Hawaii’s food and agriculture sector (especially with regard to food import and distribution systems) to optimize economic development and buttress against the anticipated impacts of ACD (Meter and Goldenburg, 2017; HIEMA 2019; Hawaii Climate Commission 2021).

Transforming Hawaii’s Food Systems Together (THFST)

The THFST initiative seeks to build statewide capacity and pave the way for a more robust, sustainable, and resilient food system, especially in times of crisis. The initiative harnesses the momentum for food system change emerging from the COVID-19 pandemic, documents key lessons learned, articulates policy and planning recommendations, and sets up the State of Hawaii to expand institutional purchasing of local and sustainably produced foods (THFST 2021). The project’s four principal knowledge products include the following: (1) social network analysis of power in the food system; (2) a Hawai‘i food system map of key processes and features of the agrifood system; (3) comprehensive state policy analysis and; (4) food system vulnerability assessments.

The food system vulnerability assessments aimed at defining key points of vulnerability to community and household food insecurity, were further broken down into 4 distinct assessment components: a. interviews[3] with key expert informants to identify key points of vulnerability to household and community food insecurity in Hawaii and lessons learned from COVID-19; b. a Port of Honolulu sea level rise (1.0, 1.5 meter) analysis evaluating potential infrastructure impacts from flooding at 2050 and 2070; c. an emergency food and feeding gap analysis to identify key points of weakness in the emergency food apparatus; d. quantitative survey of food system experts on key points of vulnerability to community and household food insecurity.

[3] Used to inform (d.) the quantitative survey of food system experts on key points of vulnerability to community and household food insecurity.

HNL Port Flood Vulnerability Assessment: Sea Level Rise and Food System Infrastructure Impacts at Years 2050, 2070 (1.0, 1.5 meter by 2100)

The specific aim of this report is to summarize the key findings of the Port of Honolulu sea level rise (1.0, 1.5 meter by 2100; Sweet et al, 2017) analysis evaluating the potential risks to critical infrastructure from minor flooding through 2050 and 2070. This preliminary analysis is intended to identify key points of vulnerability to food system infrastructure as a means of developing new strategies for building food system resiliency to ensure household and community food security in Hawai‘i in the case of a natural disaster.

Research Methods:

Data points of key food system infrastructure at Honolulu Harbor and other nearshore areas were identified with private sector stakeholder input (Chad Buck, HFA). Data points were overlaid onto the NOAA digital elevation model (DEM) and elevation values (in meters relative to MHHW) were extracted using geoprocessing tools in GIS. Elevation data of critical food system infrastructure at Honolulu Harbor were then compared to elevations and associated frequencies determined from several types of statistical analysis of data from the Honolulu tide gauge (below) to produce a range of estimates of relative risk (in terms of minor flood frequency) for each infrastructure point for the decades 2050 and 2070 under 1.0 and 1.5m by 2100 future sea level rise scenarios of Sweet et al. 2017. Results of the preliminary analysis were synthesized, and incorporated into a GIS layer with the points color-coded to symbolize project ranges in minor flood frequency.

The observational record from the tide gauge located in Honolulu Harbor provides the basis for these estimates. Return level estimates only apply to threshold elevations ranging from 0 to +1.5m (MHHW). Projections were derived from three methods of statistical analysis, and synthesized to form the following set of categorical retur level estimates: every day to 1 week every month; 1 week every month to 1 year; 1 week every 1 to 10 years; and 1 week every 10-100 years. Method 1 applied a Generalized Extreme Value (GEV) approach to extreme value analysis to calculate an event return level (the probability of an event occurring once in an n-year period) down to 1 year (Coles 2001). Method 2 involved the calculation of the *expected number of events* (ENE), a measure of the number of expected events (months/year) that will exceed a specified threshold (Obeysekera & Salas 2016). Method 3 was based on the work of Thompson et al. (2019), that employs a Beta-binomial statistical model to describe the number of days per year for which sea level exceeds a prescribed threshold. The synthesis of results from these three methods is intended to account for differences in the way that events are parameterized, integrating them so as to convey reasonable bounds in a way that can be easily understood by state agency and private sector end-users.

It is important to note that the type of minor flooding considered here is typically associated with high tides and other processes that elevate mean water levels over extended periods (e.g., eddies), that are rising with rising sea levels. It does not fully account for influences due to waves, nor does it account for compound flooding that might arise when elevated groundwater tables combine with heavy rains to produce localized ponding. Flooding associated with major events, such as tropical storms, is not considered here.

Key Findings:

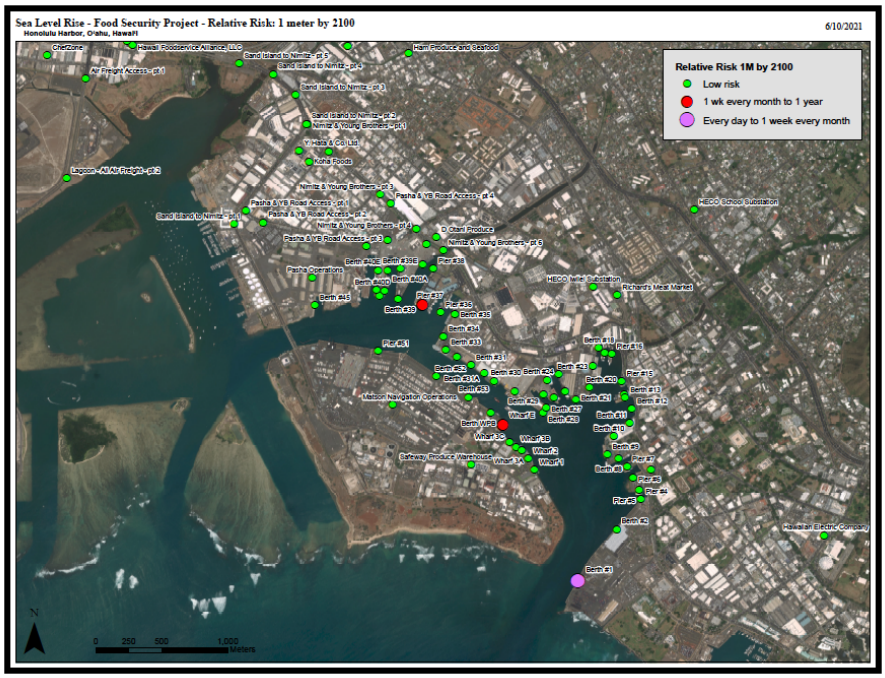
1. **Relative Risks by year 2050 (1m SLR by 2100):** Only a few key points of infrastructure are anticipated to be at risk by 2050 under an intermediate Sea Level Rise (SLR) scenario (1m by 2100). Any key infrastructure over 1m MHHW elevation is relatively protected and will likely not be significantly impacted by minor flooding. However, there are several points where impacts may begin to occur and are indicative of places where planning for adaptation should start. See *Map 1: Relative Risks 1m SLR by 2050.*

2. **Relative Risks by Year 2070 (1m and 1.5m SLR by 2100):** By 2070, the sea level rise and the frequency and level of inundation are significantly different. The severity depends upon the extent of future sea level rise. Moderate impacts to critical systems infrastructure are anticipated under an intermediate SLR scenario (1m by 2100), and significant impacts under a higher SLR scenario (1.5m by 2100). Although these impacts are anticipated 50 years into the future, there is not a lot of time for planning and re-building key port infrastructure. Again, there are several points with potential impacts identified in the analysis that indicate obvious places to start planning for adaptation.[4] See *Map 2: Relative Risks 1m SLR by 2070.*

3. **Maps:**

[4] Results should be considered *conservative* (i.e. high probability of occuring) based on the following: a.) The above model is based on the still water level (SWL) and does not take into account compound flooding (i.e. there is no consideration of waves that could add an additional 20-30cms of flooding on top of the SWL. Also, the analysis does not account for flooding associated with an elevated water table because of sea level rise (SLR). This issue may also apply to stormwater runoff, depending on the elevation of the stormwater runoff outlets. b) Return level (RL) estimates for Honolulu harbor change rapidly across a very narrow band of elevation - 30 cms of SLR can make a significant difference (e.g. 1.5m versus 1.2m SLR above MHHW corresponds to a once in 100 years versus 2x each year RL; 1.3m versus 1.0m above MHHW corresponds to a once in 10 years versus every day RL). c) For infrastructure like piers, docks or quay walls, assuming the elevations level used in the model are based on 'top of the deck', disruption (or damage) would be expected to occur *sooner*, as water levels may not have to reach the top of the deck for things like floating docks to come up against the top (limit) of their collars, or floating fenders to approach a rollover scenario.

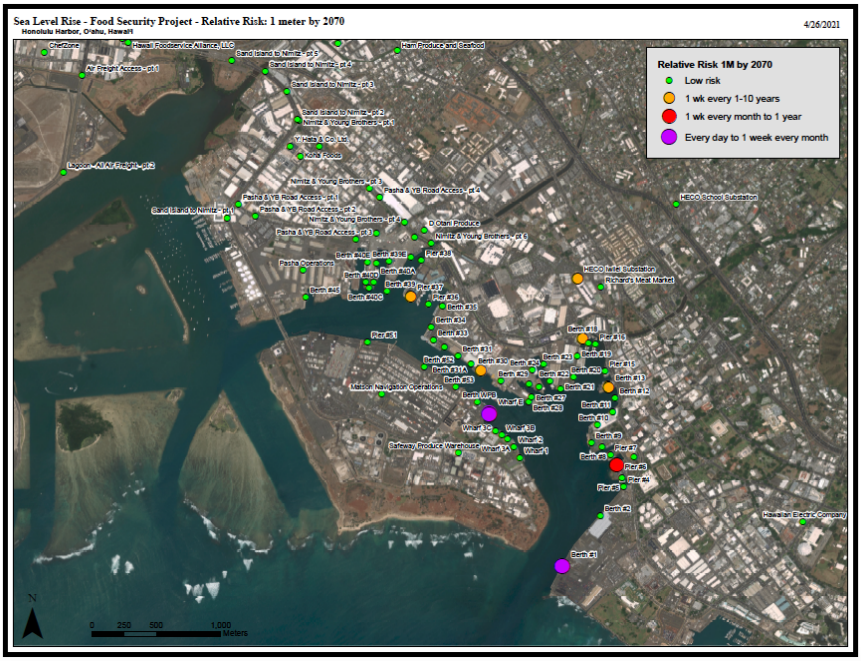
***Map 1:** Relative Risks by Year 2050 (1m SLR by 2100).*



Key:

- ***Low risk** - less than 1 week (7-10 days) of flooding (over several separate events) within a 100 year time period (on average).*
- ***Moderate risk** - at least 1 week (7-10 days) of flooding (over several separate events) within a 10 - 100 year time period (on average).*
- ***Moderately high risk** - at least 1 week (7-10 days) of flooding (over several separate events) within a 1 -10 year time period (on average).*
- ***High risk** - at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month to 1 year time period (on average).*
- ***Extreme risk** - every day to at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month (on average).*

***Map 2:** Relative Risks by Year 2070 (1m SLR by 2100)*



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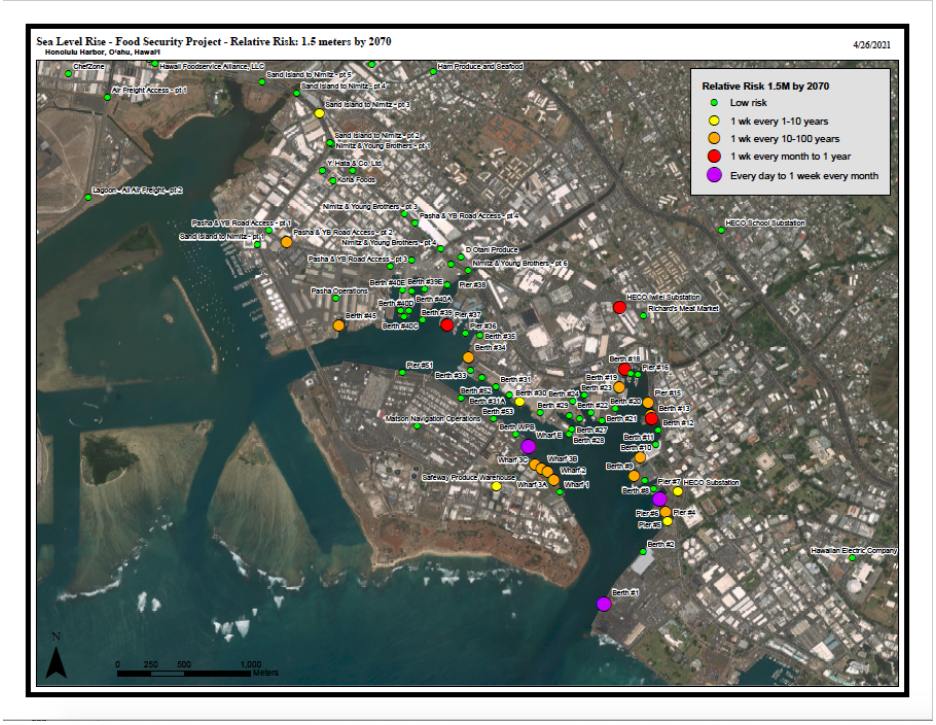
- ***High risk*** *- at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month to 1 year time period (on average).*
- ***Extreme risk*** *- every day to at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month (on average).*

Map 3: *Relative Risks by Year 2070 (1.5m SLR by 2100)*



Key:

- ***Low risk*** *- less than 1 week (7-10 days) of flooding (over several separate events) within a 100 year time period (on average).*
- ***Moderate risk*** *- at least 1 week (7-10 days) of flooding (over several separate events) within a 10 - 100 year time period (on average).*
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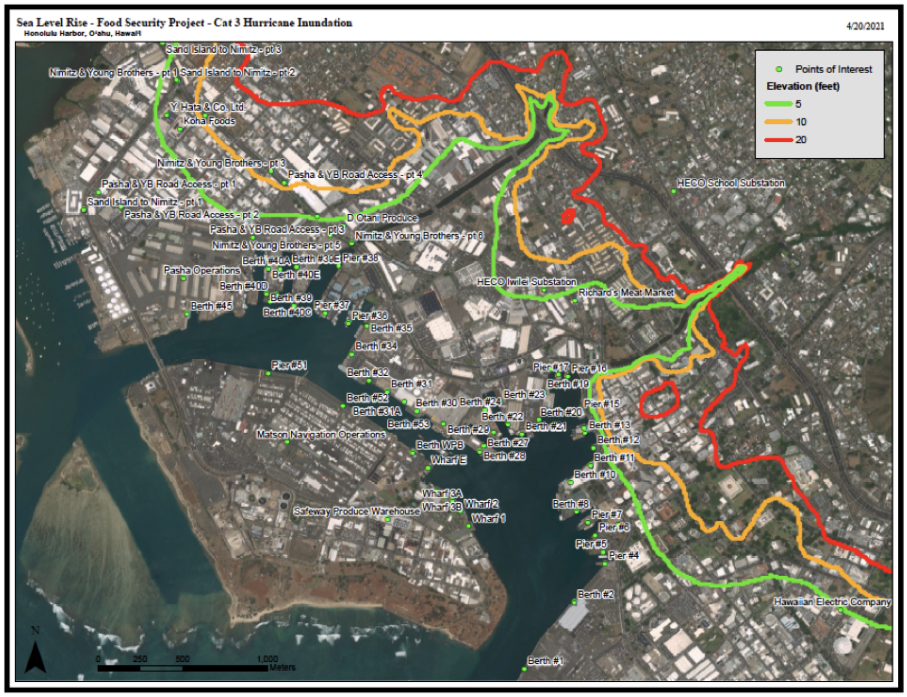
- ***High risk*** *- at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month to 1 year time period (on average).*
- ***Extreme risk*** *- every day to at least 1 week (7-10 days) of flooding (over several separate events) within a 1 month (on average).*

Map 4: *Estimates of Relative Risks: Flooding Levels Resulting from Category 3-5 Hurricane Reaching HNL Port.*



Recommendations:

- Need for an addition multivariable analysis to better account for flooding impacts due to a range of severe weather events (heavy rainfall, hurricanes, etc.);
- Need for planning and investment in alternate commercial and emergency food storage (via Public Private Partnerships) outside of areas anticipated to be impacted due to SLR.

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