A Resilient Path Forward for the Marine Transportation System: Recommendations for Response and Recovery Operations from the 2017-2019 Hurricane Seasons

Report by the CMTS Marine Transportation System
MTS Resilience Integrated Action Team

Foreword

This report is a product of the U.S. Committee on the Marine Transportation System (CMTS) MTS Resilience Integrated Action Team (RIAT). The RIAT was established in September of 2014 by the CMTS Coordinating Board (CB) to focus on cross-federal agency knowledge, co-production, and governance to incorporate the concepts of resilience into the operation and management of the U.S. Marine Transportation System (MTS). The RIAT is composed of twelve federal agencies that manage, operate, or have a significant interest in the MTS and its services. In October 2017, the CMTS CB requested that the RIAT review the impacts and compile best practices and lessons learned for federal agencies that operated within the MTS during the 2017 hurricane season. One of the recommendations from the 2017 report "*The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System"* was to review subsequent hurricane seasons to understand challenges, successes, and adaptations. This report is a follow up to the 2017 hurricane seasons report and is a product of the diverse perspectives of RIAT member agencies.

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U.S. Department of Transportation
U.S. Environmental Protection Agency
Maritime Administration
National Geospatial-Intelligence Agency
National Oceanographic and Atmospheric Administration
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Guide to Acronyms and Abbreviations

AMSC	Area Maritime Security Committee
ATON	Aids to Navigation
BAU	Business as usual
BTS	Bureau of Transportation Statistics
CART	Common Assessment and Reporting Tool
CB	Coordinating Board of the Committee on the Marine Transportation System
CMTS	U.S. Committee on the Marine Transportation System
COP	Common Operating Picture
COTP	Captain of the Port
DOD	Department of Defense
DOT	Department of Transportation
DHS	Department of Homeland Security
EEIs	Essential Elements of Information
EPA	Environmental Protection Agency
ESF 1	Emergency Support Function 1; jurisdiction – transportation
ESF 3	Emergency Support Function 3; jurisdiction – Public Works and Engineering
ESF 6	Emergency Support Function 6; jurisdiction – Mass Care, Emergency Assistance, Temporary Housing, and Human Services
ESF 9	Emergency Support Function 9; jurisdiction – Search and Rescue Annex
ESF 10	Emergency Support Function 10; Oil and Hazardous Materials Response Annex
ESF 14	Emergency Support Function 14; Cross-Sector Business and Infrastructure Annex

FEMA	Federal Emergency Management Agency
GAO	Government Accountability Office
GDP	Gross Domestic Product
GIW	Gulf Intracoastal Waterway
HSC	Harbor Safety Committee
IP	Office of Infrastructure Protection
MOU	Memorandum of Understanding
MTS	Marine Transportation System
MARAD	Maritime Administration
MTSRU	Marine Transportation System Recovery Unit
NAIS	Nationwide Automatic Identification System
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NRT	Navigation Response Team
RIAT	Resilience Integrated Action Team
SAD	USACE South Atlantic Division
SAW	USACE Wilmington District
SLTT	State, Local, Tribal, and Territorial
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard

Executive Summary

The U.S. Committee on the Marine Transportation System (CMTS) Resilience Integrated Action Team (RIAT) is a coordinating body of twelve Federal agencies that manage, operate, or are stakeholders of the Marine Transportation System (MTS). The RIAT was established to share knowledge, co-produce products and recommendations for policies and governance related to resilience of the MTS. In recent years, the MTS has been impacted by devastating hurricane seasons and the RIAT has endeavored to serve as a collaborative platform to amplify key findings and recommendations from these storms. To accomplish this, the RIAT convened member agencies to discuss some the challenges, successes, best practices, and recommendations for increasing resilience based upon reported experiences of absorbing and recovering from major hurricanes that impacted the United States and U.S territories in 2017, 2018, and 2019.

To gather post-hurricane interagency challenges, impacts, and successes, the RIAT held interagency data calls and hosted two workshops. The first workshop was in May of 2018 and focused on the 2017 hurricane season, specifically hurricanes Harvey, Irma, and Maria. The second workshop was in February 2020 and focused on the 2018 and 2019 hurricane seasons including hurricanes Florence, Michael, and Dorian. The workshops targeted participation from Federal agency personnel located in field offices and directly responsible for response and recovery actions to ensure accurate and in-depth discussions of their experiences. As a major caveat to this work, the Federal perspective provides only a portion of all response and recovery efforts as state, local, and industry stakeholders are critical to safe and effective response in coastal communities.

Resilience is a term that encompasses four general concepts: prepare, absorb, recover, and adapt. In general, emergency management is heavily focused on the "prepare", "absorb" and "recover" portions of this cycle. Consistently convening multiple agencies to share data, findings, and perspectives is a valuable addition to existing "after-action reviews" and provides a basis of knowledge on how the MTS "adapts" between hurricane seasons. Utilizing the four-step resilience cycle and timeline as a framework to gather input was a vital part of this work (Figure A).[1] By purposefully using these four steps to identify means of improving response and recovery, this report makes recommendations to both advance the understanding of how the MTS can be better prepared for future storms and understand adaptations between storms and hurricane seasons to enhance the resilience of the MTS.

[1] Rosati, J.D. et al (2015): "Quantifying coastal system resilience for the US Army Corps of Engineers", Environment Systems and Decisions 35:196-208.

A review of federal agency activities, challenges, success, and recommendations to improve MTS resilience was conducted for the 2017, 2018, and 2019 hurricane seasons. A comparison of these findings across seasons revealed emergent actions and adaptations. There are several key themes that demonstrate the ability of the MTS to adapt and improve response to storms:

- Enhanced cross-agency coordination,
- Improvements in data and information exchange, and
- Capitalizing on lessons learned from previous storms to pre-establish local knowledge and mechanisms for quick response.

Figure A. The cycle of the fundamental actions found in nearly all resilience definitions: prepare, absorb, recover, and adapt. (after Rosati et al. 2015)

While each hurricane season brought its own specific challenges, the hurricane response and recovery efforts by federal agencies and partners resulted in best practices and adaptations that were incorporated during proceeding storms. The following are recommendations identified from the RIAT's efforts to increase MTS resilience across hurricane seasons:

Preparation

- Budget for and hold regular trainings and drills to educate response and recovery teams about how to operate in different scenarios such as a virtual environment
- Establish important relationships and connections early and often, and document the chain of command for emergency situations
- Hold yearly exercises to understand the needs of the local area, and pre-identify storage areas and key infrastructure

Absorb and Recover

- Maximize seamless information sharing to the greatest extent possible both within and across Federal agencies through interagency teams and/or easily accessible data sharing platforms
- Regularly update accurate data as information continues to evolve during disaster events and keep it relevant to recovery coordination
- Utilize a flexible workforce that can continue operations during an emergency

Adaptation

- Hold proactive interagency after-action reviews focusing on what worked well, what challenges were faced, and to commit to implementing lessons learned and recommendations

- Develop an accessible common operating picture of vital information (survey data, port system requirements, dependent businesses)
- Document and communicate within and across agencies on the successes, challenges, and lessons learned following events

The MTS is a critical component of the national, regional, and local economies, facilitating the movement of U.S. goods and services within a domestic and global marketplace. The RIAT has attempted to foster a collaborative approach that enables federal agencies who manage hurricane response and recovery to share their findings and develop recommendations together that increase the resilience of the MTS. Not only are federal MTS agencies successfully responding to the challenges of coastal storms, but they also are adapting by utilizing lessons learned from past hurricane seasons to address vulnerabilities and improve their responses to future storms.

Introduction

The United States relies heavily on the Marine Transportation System (MTS) for commerce and security, to facilitate the movement of international and domestic goods, and to support continued growth, jobs, and productivity. The MTS is the primary mode of transport for international imports and exports. In 2018, vessels moved 41.9% of the value and 70.7% of the weight of U.S. international trade[2]. The value of the MTS extends beyond the movement of goods to the benefit of regional economies, by supporting $4.6 trillion of economic activity every year and generating jobs for more than 23 million workers in the United States[3].

The MTS is exposed and vulnerable to disturbances from a variety of natural and man-made hazards such as hurricanes, extreme precipitation and flooding, sea-level rise, temperature extremes, cyber-attacks, pandemics and terrorist attacks. The MTS is particularly susceptible to the impacts of coastal storms as encountered during the 2017, 2018, and 2019 seasons. The 2017 hurricane season was a record year for the U.S. and its territories with four of six major hurricanes making landfall in the U.S., impacting coastal communities and the infrastructure systems they rely upon. In 2018, the hurricane season recorded 15 named storms with two major hurricanes, Florence and Michael, making landfall. The 2018 season was followed by Hurricane Dorian in 2019 which devastated the Caribbean and put the mainland U.S. on high alert due to the uncertainty in its forecasted track. Each of these hurricanes exhibited distinct characteristics that created unique challenges and required MTS stakeholders to adjust response and recovery operations to better serve communities in need.

Since 1980, the frequency, number, and severity of weather- and climate-related disasters that could impact the MTS has been increasing (Figure 1), and as climate continues to change this pattern will likely continue. In the future, impacts are likely to be worsened by compounding factors like sea level rise and increased populations in vulnerable areas. Since the frequency and severity of disruptions is expected to increase with time, a comprehensive approach is required to identify current and future risks and vulnerabilities to the MTS and to develop strategies to become more resilient.

[2] Hu, P. S., Schmitt, R. R., Sprung, M. J., Chambers, M., Friedman, D., Gilmore, M. M., ... & Smith, D. (2020). Port Performance Freight Statistics in 2018: Annual Report to Congress 2019.Bureau of Transportation Statistics. Washington, DC.

[3] United States Coast Guard (USCG). 2018. Maritime Commerce Strategic Outlook.

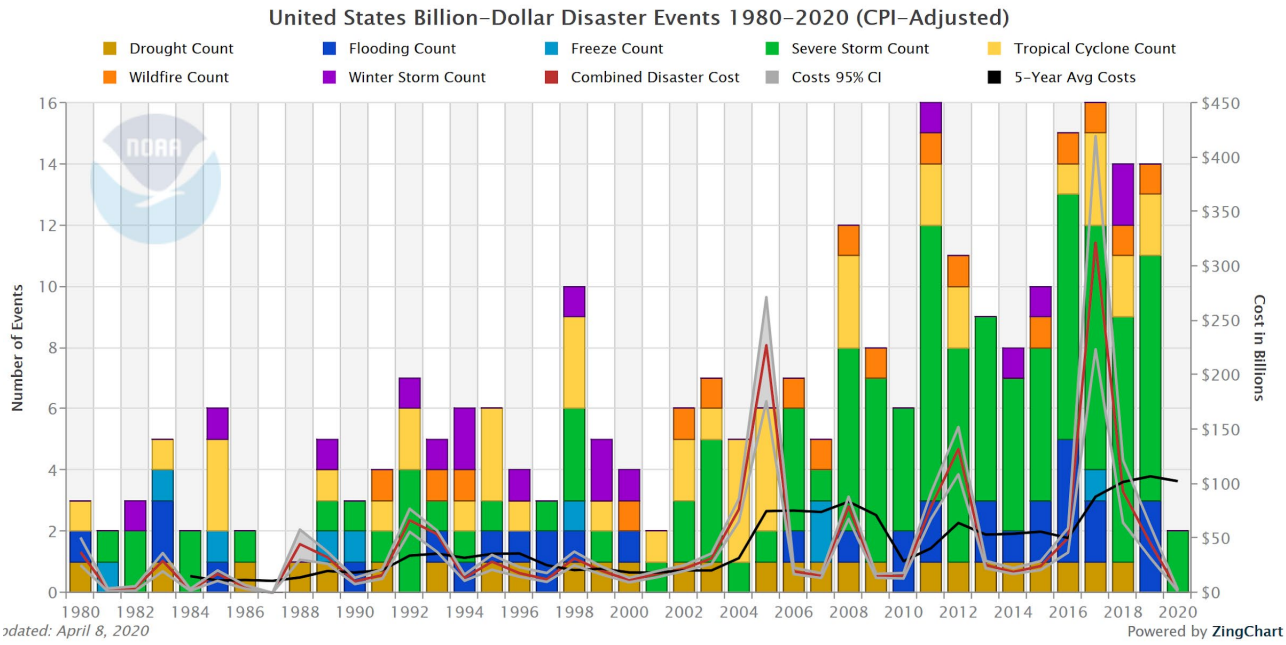

Figure 1. Billion Dollar Weather/Climate Disasters, 1980-2020. Weather and climate-related disasters have been increasing in recent years. This upward trend is expected to continue due to climate change. *NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2020). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73.*

By 2025, worldwide demand for waterborne commerce is predicted to more than double[4]. As the infrastructure, technology, and management systems that support the MTS evolve to support this demand, the best practices for the preservation of these functions throughout disruptions must be kept current and collaborative. The MTS is a critical node within a larger national transportation network that facilitates the flow of goods to every consumer in the United States. As such, disruptions affecting a single part or several parts of the MTS system, including ports, waterways, vessels, and supporting roadways, railways, and bridges, could potentially have national impacts. Furthermore, ports and the MTS play a key role in the recovery of the surrounding region after disruption, facilitating the mobilization of response and recovery assets and the delivery of life-sustaining commodities for impacted communities. A resilient MTS is critical to the national economy and to the communities in the region.

[4] United States Coast Guard (USCG). 2018. Maritime Commerce Strategic Outlook.

Methodology

Resilience is defined as the ability to prepare, absorb, recover, and adapt to and from disruptions (Presidential Policy Directive 21, 2013). This work employs a four-phase resilience cycle to conceptualize resilience, gather information, and analyze impacts and changes through time (Figure 2, The Resilience Cycle). By utilizing these four phases, it is possible to identify improvements in response and recovery efforts and make recommendations to advance the resiliency of the MTS to future events.

Figure 2. The cycle of the fundamental actions found in nearly all resilience definitions: prepare, absorb, recover, and adapt[5].

Critical to resilience is the ability to adapt between events to be better prepared so that future events will result in lower impacts and faster recoveries. One key part of adaptation is learning from the past, and the CMTS Resilience Integrated Action Team (RIAT) has intervened as a platform to convene Federal agencies to share and discuss their experiences and potential improvements with their partners. The RIAT is a consortium of Federal agencies that manage, operate, or are stakeholders in the MTS and have interests in increasing the resilience of the MTS to prepare, respond, recover, and adapt to disruption. The CMTS RIAT has served as a platform to gather federal agencies to foster collaborations, improve understanding of emerging challenges, and to determine impacts, best practices, and lessons learned after disruptive events. In 2017, the Coordinating Board of the CMTS tasked the RIAT with identifying the best practices and lessons learned from the 2017 hurricane season. The ensuing report, "The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System", outlines challenges, successes, and recommendations for increasing resilience based upon reported experiences of responding and recovering to

[5] Rosati, J.D., K.F. Touzinsky, and W.J. Lillycrop, 2015. "Quantifying coastal system resilience for the U.S. Army Corps of Engineers." Environment Systems and Decisions, 35(2):196-208

hurricanes Harvey, Irma, and Maria[6]. Following recommendations that post-storm interagency collaboration should continue, the RIAT committed to develop a companion report that would examine the federal agency response during the 2018 and 2019 hurricane seasons including hurricanes Florence, Michael, and Dorian. The RIAT held several virtual workshops and outreach events in 2019 to capture federal agency input on the impacts, challenges, and best practices of the 2018 and 2019 hurricane seasons and specify what adaptations had occurred between seasons. Input was provided by Federal agency personnel located in field offices and directly responsible for response and recovery actions.

The purpose of this report is to describe the impacts, challenges, and successes from the 2018, and 2019 hurricane seasons and to compare them with findings from the 2017 hurricane season. The report reviews changes in response practices between storm seasons and makes overall recommendations to enhance the future resilience of the MTS. The audience for these recommendations is federal agencies with a major role in MTS recovery planning and efforts. However, it is important to note the critical role that non-federal stakeholders play in ensuring the continued operation of the MTS from response and recovery efforts. A large portion of disaster recovery is the responsibility of state and local governments, nonprofits, and private industry. It is anticipated that the report will assist the coordination between federal and non-federal partners' efforts to support the U.S. MTS return to normal operations.

2017 Hurricane Season in Review

The extremely active 2017 hurricane season produced 17 named storms, 10 of which became hurricanes, and 6 became major hurricanes. During the 2017 season, three devastating major hurricanes made landfall in the U.S. and its territories including Hurricane Harvey in Texas, Hurricane Irma in the Caribbean and southeastern U.S., and Hurricane Maria in the U.S. Virgin Islands and Puerto Rico. Over the course of the 2017 hurricane season, Hurricanes Harvey, Irma, and Maria occurred in succession and affected the operating status of at least 45 ports across a vast geographic region. These ports provide critical services to regional economies in the Gulf, Southeastern coast of the U.S., and the Caribbean. The scale and intensity of these storms strained the U.S. emergency response community and tested the ability of MTS agencies to preposition and prioritize recovery efforts. There was also a stark contrast between a port's reopening and the ability to move goods and services where they needed to be – in some cases, almost every supporting and intermodal infrastructure system required major rehabilitation.

[6] U.S. Committee on the Marine Transportation System (CMTS). 2018." The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System", U.S. Department of Transportation, Washington, D.C. https://www.cmts.gov/downloads/CMTS_RIAT_2017Hurricanes.pdf

Despite these challenges, the MTS community successfully adjusted in order to communicate and engage across sectors to quickly and efficiently reopen these ports.

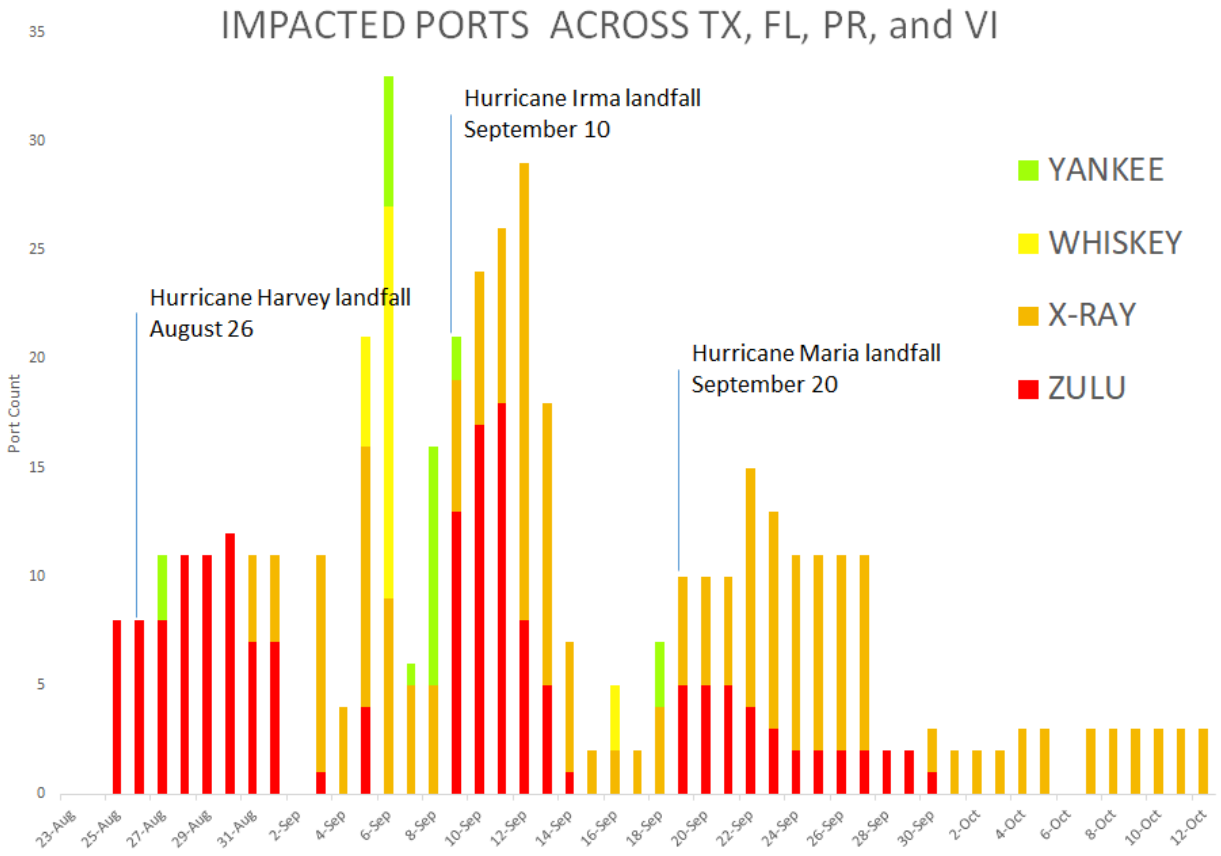

Figure 3. The 2017 hurricane season affected the operating status of at least 45 ports throughout the lower continental United States and U.S. Caribbean territories. When sustained gale force winds (39-54 mph/34/47 knots) from a tropical storm or hurricane are predicted to make landfall at the port within 72 hours, USCG will issue a Port Condition "WHISKEY"; when landfall at the port is within 48 hours, Port Condition "X-RAY" is issued; and when sustain gale force winds are predicted within 24 hours of landfall, Port Condition "Yankee" is issued. At Port Condition ZULU, USCG has declared the port closed.

A review of federal agency activities to restore MTS operations in response to all three storms revealed several emergent actions[7]. For pre-storm preparedness, these common actions included hosting early planning meetings, communicating between agencies, centralizing information distribution, and maintaining or updating existing response plans. Issues related to telecommunication and the prioritization of assistance to ports or other critical infrastructure were experienced by most MTS agencies. Lastly, the successes shared between agencies included engaging with the private sector to fill gaps in federal response operations,

[7] U.S. Committee on the Marine Transportation System (CMTS). 2018." The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System", U.S. Department of Transportation, Washington, D.C.

implementing local coordination efforts, and adapting and improving throughout the hurricane season as each storm presented new obstacles to overcome.

2018 and 2019 Hurricane Seasons

Following the historic hurricane season of 2017, the 2018 hurricane season offered little respite for the Nation's battered coastlines as 15 named storms formed in the Atlantic basin and two major hurricanes, Florence and Michael, made landfall in the U.S. A similarly active 2019 followed, which included Category 5 Hurricane Dorian in September 2019. These hurricanes exhibited distinct characteristics that posed unique challenges for the MTS, particularly with port response and recovery.

Hurricanes Florence, Michael, and Dorian challenged the MTS with entirely different characteristics — Florence was destructive because of its slow movement, rainfall, and flooding. Michael was devastating because of its fast speed, winds, and storm surge. Dorian had a massive area of impact and was highly variable in terms of speed and intensity. The storm spent almost three days in the vicinity of the Bahamas and southern Florida before rapidly weakening as it moved north towards Georgia and the Carolinas. In contrast, both Florence and Michael made direct hits on localized areas and impacted fewer ports than those impacted during the 2017 season and during Dorian in 2019. For the ports that were impacted, a highly coordinated effort was necessary to get commerce moving again.

Hurricane Florence: September 12–15, 2018

Hurricane Florence made landfall on 14 September 2018 near Wrightsville Beach, NC, as a Category 1 storm. While its maximum wind speed was not as strong as previous hurricanes upon landfall, Florence's slow-moving track caused major flood damage. According to the National Oceanic and Atmospheric Administration (NOAA), it was the wettest tropical cyclone on record in the Carolinas[8], causing approximately $24 billion in wind and water damage ($22 billion in North Carolina; $2 billion in South Carolina)[9] and resulting in 22 direct and 24 indirect fatalities.[10] A maximum storm surge of 8–10 feet (ft.) above ground level occurred along the shores of the Neuse River. Hurricane Florence produced rainfall totals of over 30 inches (in.) in southeastern NC between Wilmington and Elizabethtown, with maximum measured rainfall occurring in Elizabethtown, NC (35.93 in.). The combined surge and rainfall made large

[8] Stewart, S., and R. Berg. National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) (2018): "National Hurricane Center Tropical Cyclone Report: Hurricane Florence, September 12-15, 2018", available at https://www.weather.gov/mhx/Florence2018 as of November 2019.

[9] National Oceanic and Atmospheric Administration, National Centers for Environmental Information (2019): "U.S. Billion-Dollar Weather & Climate Disasters 1980-2019", available at https://ncdc.noaa.gov/billions/events.pdf as of November 2019.

[10] National Weather Service (2018): "Historical Hurricane Florence, September 12-15, 2018", available at https://www.weather.gov/mhx/Florence2018 as of November 2019.

stretches of main highways (Interstates 40 and 95, US-70) impassable, effectively closing all access routes to Wilmington and limiting access to the city for several days after Florence dissipated.

Hurricane Impacts, Challenges, and Successes

The increased availability of Automatic Identification System (AIS) data and new analytical techniques has made it possible to visualize and quantify the impacts of storms on port performance and across the region. A timeline of the most significant closures as well as accompanying vessel densities derived from AIS data is found in Figure 4. On 10 September 2018, as Florence approached the coastline, the USCG issued port condition warnings for several ports from Georgia to Maryland. On 12 September, the Port of Charleston entered condition YANKEE,[11] and the Ports of Wilmington (42 ft. depth) and Morehead City (45 ft. depth), both in North Carolina, entered Port Condition ZULU, suspending all maritime traffic in and out of these ports. That same day the Port of Virginia entered a modified Port Condition ZULU, closing navigation routes at the mouth of the Chesapeake Bay and in southern coastal Virginia. The Port of Georgetown (27 ft. depth), in South Carolina, entered Port Condition ZULU on 14 September.

The Port of Charleston and the Port of Virginia returned to Port Condition NORMAL on 15 September 2018. The Port of Georgetown reopened without restrictions on 16 September. The Ports of Wilmington and Morehead City were closest to Florence's landfall and reopened with restrictions on 18 September. The Port of Wilmington issued the following restrictions: 37 ft. draft restriction, daylight only transit (due to power outages), and no traffic permitted north of the Cape Fear Memorial Bridge; the Port of Morehead City restricted all self-propelled, oceangoing vessels over 500 gross tons, ocean going barges and their supporting tugs, and tank barges over 200 gross tons to daylight transit only. Restrictions were lifted at the Port of Morehead City on 19 September. The draft restriction at the Port of Wilmington was updated to 35 ft. on 20 September after identifying features/objects of interest on multibeam surveys that might impact navigation. All restrictions were lifted at the Port of Wilmington on 30 September.

These port conditions and subsequent restrictions have impacts on port performance that can be quantified with indicators derived from AIS data. Net vessel counts are a useful proxy for port performance because they measure ship traffic in and out of a major port area and can provide insights to the magnitude of the impacts of the storm.[12] Figure 5 provides a net vessel count for several of the largest ports in the Carolinas and Virginia— Charleston, Morehead City and Wilmington, and the Port of Virginia. Net vessel counts are derived from the Automatic

[11] Port Conditions are set by the U.S. Coast Guard and describe when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the Port: WHISKEY = 72 hours; X-RAY = 48 hours, YANKEE = 24 hours, ZULU = 12 hours.

[12] For more information on net vessel count, see Touzinsky, K., Scully, B.S., Kress, M.K., and K.M. Mitchell. 2018. "Using Empirical Data to Quantify Port Resilience: Hurricane Matthew and the Southeastern Seaboard."

Identification System Analysis Package developed by the U.S. Army Corps Engineer Research and Development Center with data furnished by the U.S. Coast Guard (USCG)

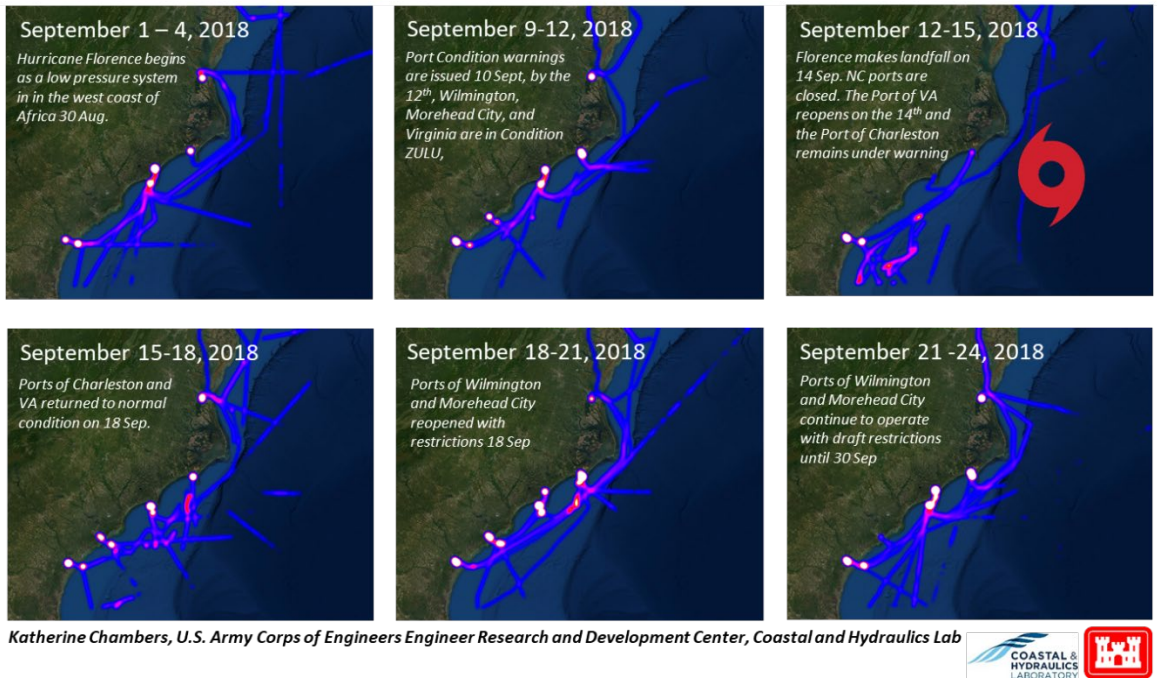

Figure 4. Hurricane Florence Cargo and Tanker Vessel Signal Density Plots: Select Times from September 1-24

NOTES: The largest finding from these vessel densities is that while Florence was devastating to the Ports of Wilmington and Morehead City, the effects across the region were short-lived. Vessels were quickly able to regain access to their necessary ports of call.

SOURCE: Cargo and Tanker Vessel Density maps derived from Automatic Identification System Analysis Package (AISAP), developed by the U.S. Army Corps of Engineers Research and Development Center with data furnished by the U.S. Coast Guard.

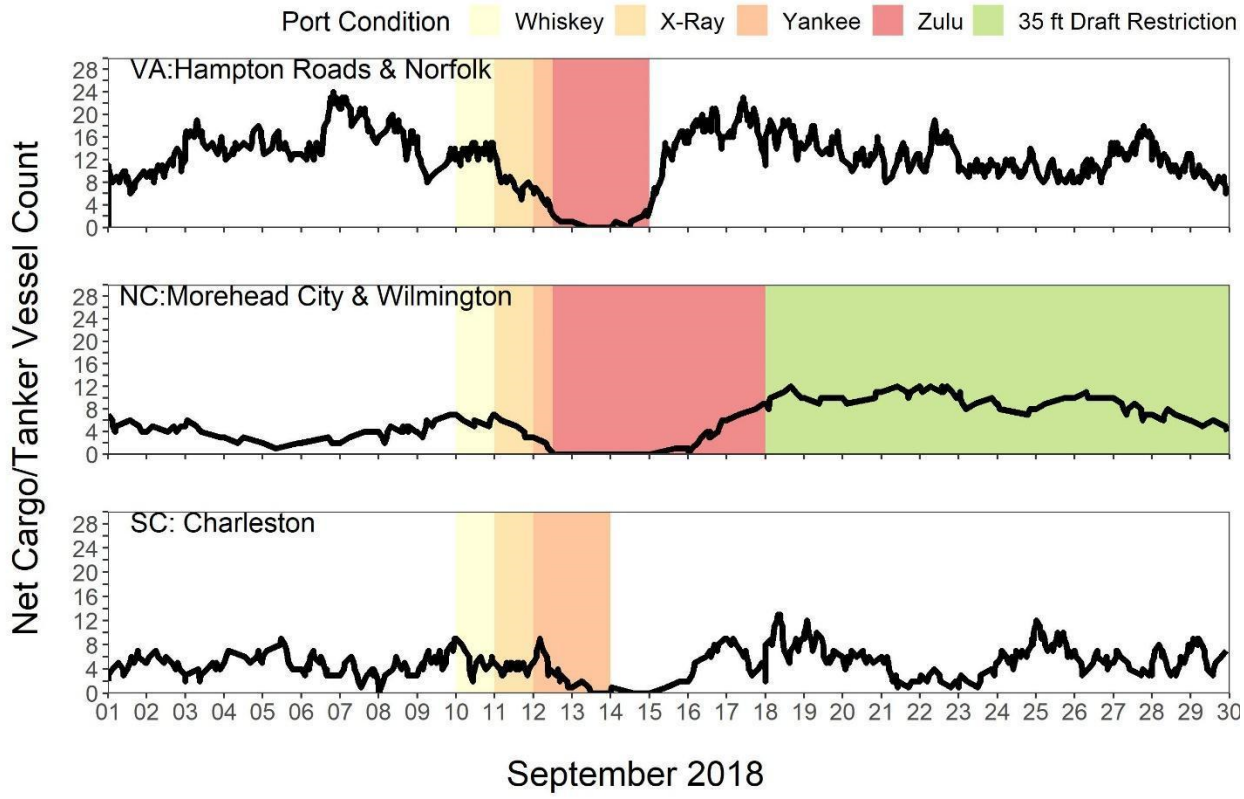

Figure 5. Net Cargo and Tanker Vessel Counts at the Ports of Virginia, Morehead City and Wilmington, and Charleston before, during, and after Hurricane Florence: September 1-30, 2018

NOTES: Port Condition describes when sustained wind gusts from a tropical storm or hurricane are expected to arrive at the port: WHISKEY=72 hours, X-RAY=48 hours, YANKEE=24 hours, ZULU=12 hours. These conditions are visible.

SOURCE: U.S. Army Corps of Engineers Research and Development Center, Automatic Identification System Analysis Package (AISAP), using AIS data provided by the U.S. Coast Guard.

Challenges: Hurricane Florence

The challenges during Hurricane Florence response and recovery efforts centered on the following: an evolving track of the storm making it difficult to develop pre-storm plans, communication issues due to cell service, and a lack of understanding of local needs.

- At one time, the forecast had the hurricane moving more towards Hampton Roads, and the Navy was evacuating Norfolk Naval Station since the storm was a Category 3 SE of Cape Lookout. **With changes in track, it was challenging to communicate forecast confidence among stakeholders**, and the strength of the storm contributed to this.

- It was **challenging to pre-position assets and people due to a rapidly changing storm track**. Once landfall occurred, there was a narrow window of time for teams to deploy from the locations where they rode out the storms to get teams into the impacted areas before flood waters from the prolonged post-landfall rain event cut off access to Wilmington, NC and Morehead City, NC. Had the team responding to Wilmington been delayed (for any reason) by approximately 2 hours, it likely would have been 2 days before flood waters receded enough for them to gain access to Wilmington to begin survey operations on the Cape Fear River.
- Restoring the Port of Wilmington to full navigational depth of operation after Florence was a large effort. Several bridges were damaged, prohibiting the passage of vessel traffic. There was also significant inland flooding, causing peak river flows and strong currents. Dive teams had to wait about four days after these peak flows until the river channels were safe to survey and remove obstructions.
- In Wilmington, the Navigation Response Team (NRT) was **cut off from the supply chain and utilities were unreliable for several days**. The NRT ran a portable gasoline generator at night to augment the power availability at the hotel in order to process the survey data acquired each day. Personnel resources had to divide time between executing the mission and finding food and fuel once the provisions they brought with them were depleted.
- There was a need for more radios for communications with the Port Recovery Teams, especially with the cell system potentially going down.
- The need to co-locate a USCG MTS professional assigned to ESF-1 in the FEMA (Federal Emergency Management Agency) regional response coordination center was highlighted. This professional would provide perspective on maritime issues and **align MTS operations with other transportation response and recovery efforts and priorities.**
- The USCG Common Assessment and Reporting Tool (CART) is a helpful resource to provide information on disruption events such as port closures. However, CART is only as good as the information that is feeding it and **information must be validated.**

Successes: Hurricane Florence

Many of the successes identified came from putting into practice lessons learned from past hurricane seasons. These successes included the efficient coordination between federal agencies and transportation modes as well an organized approach to distribute assets.

- There was **excellent coordination between different transportation modes (road, rail, marine)** to identify the best routes and mechanisms to get resources into the area, especially with the intense flooding.
- **Established coordination between federal agencies was leveraged and improved before and during Florence providing frequent updates on navigation conditions.** The USCG relied on NOAA to help with deep-draft surveys. NOAA identified multiple obstructions within the channel, resulting in salvage operations. USACE utilized lessons

learned from the Jacksonville district, and brought in the Navy to start salvage operations more efficiently.

- To hasten the recovery of ATONS and completion of channel surveys, the USACE South Atlantic Division and Wilmington District coordinated to **have vessels on standby and ready to perform post-storm channel surveys** to restore waterway and port navigation operations.[13]
- There was a **more centralized approach to distributing recovery assets** using an **on-going database to identify and flag for potential obstructions pre-storm** and share that information with other agencies. The USACE Charleston District was able to effectively assist the Port of Wilmington with the distribution of recovery assets and personnel.
- Based on lessons learned from Hurricanes Irma and Maria in 2017, the USACE South Atlantic Division (SAD) was well prepared to respond to and restore navigation with **numerous dredges under contract and available for support**.

Hurricane Michael: October 7 – 11, 2018

Hurricane Michael was a fast moving and powerful storm that caused approximately $25 billion in wind and water damage ($18.4 billion in Florida, $4.7 billion in Georgia, $1.1 billion in Alabama, and ~$1 billion in South Carolina, North Carolina, and Virginia).[14] Hurricane Michael made landfall on 10 October 2018 as a Category 5 storm near Mexico Beach, FL, with estimated wind speeds of 161 miles per hour (mph).[15] Hurricane Michael was initially described as a strong Category 4 storm at landfall; however, the storm was upgraded to Category 5 after detailed post-storm analysis of aircraft wind, surface wind, surface pressure, satellite intensity, and Doppler radar velocity data. This upgrade ties the storm as the 4th strongest hurricane making landfall in the United States and the strongest hurricane landfall along the Florida Panhandle. Maximum measured wind speeds of 139 mph were measured at Tyndall Air Force Base, and storm surge estimates ranged from 9–14 ft. above ground level between Tyndall Air Force Base and Port St. Joe. Strong winds and large storm surges that were exacerbated by wave activity resulted in catastrophic damage in Bay County, FL, with the worst damage occurring in Mexico Beach, where about 95 percent of buildings were reported damaged, and at Tyndall Air Force Base, where *all* buildings were reported damaged. Less severe, but extensive damage was also reported along the eastern portion of the Panama City metropolitan area.

[13] USACE Operations Update Brief, Hurricane Florence Response 2018.

[14] National Oceanic and Atmospheric Administration, National Centers for Environmental Information (2019): "U.S. Billion-Dollar Weather & Climate Disasters 1980-2019", available at https://www.ncdc.noaa.gov/billions/events.pdf as of November 2019.

[15] Beven, J., R. Berg, and A. Hagen. National Oceanic and Atmospheric Administration, National Weather Service (2018). "National Hurricane Center Tropical Cyclone Report: Hurricane Michael." available at https://www.nhc.noaa.gov/data/tcr/AL142018_Michael.pdf as of November 2019.

Hurricane Impacts, Challenges, and Successes

USCG port sectors along the Gulf Coast, from Gulfport, MS, to Panama City, FL, began issuing Port Condition Warnings as Hurricane Michael approached the Florida Panhandle. On 9 October, the Port of Mobile went into Condition YANKEE and the Ports of Panama City (36 ft. draft) and Pensacola (33 ft. draft), both in Florida, entered Port Condition ZULU. The Gulf Intracoastal Waterway (12 ft. draft) was closed east of mile marker 166, between 9 October and 11 October, and east of mile marker 221, between 12 October and 18 October. The Ports of Wilmington and Morehead City North Carolina entered Port Condition Zulu on 11 October. After landfall on the 10th, the Port of Pensacola returned to pre-storm operations on 11 October. The North Carolina Ports at Wilmington and Morehead City returned to pre-storm operations on 12 October. The Port of Panama City reopened with daylight transit only restrictions on 12 October. Figure 6 measures the impacts of the storm for several nearby ports (Mobile, Panama City, and Tampa Bay) with a net vessel count analysis derived from AIS data. It is clear from these net vessel counts that Michael was devastating to areas where it made a direct hit, but all nearby ports were able to quickly recover and begin to move cargo. Notably, Tampa Bay had almost no noticeable change in traffic during or after the storm. The ports throughout the Florida Panhandle are generally low tonnage; this minimized the number of affected vessels.

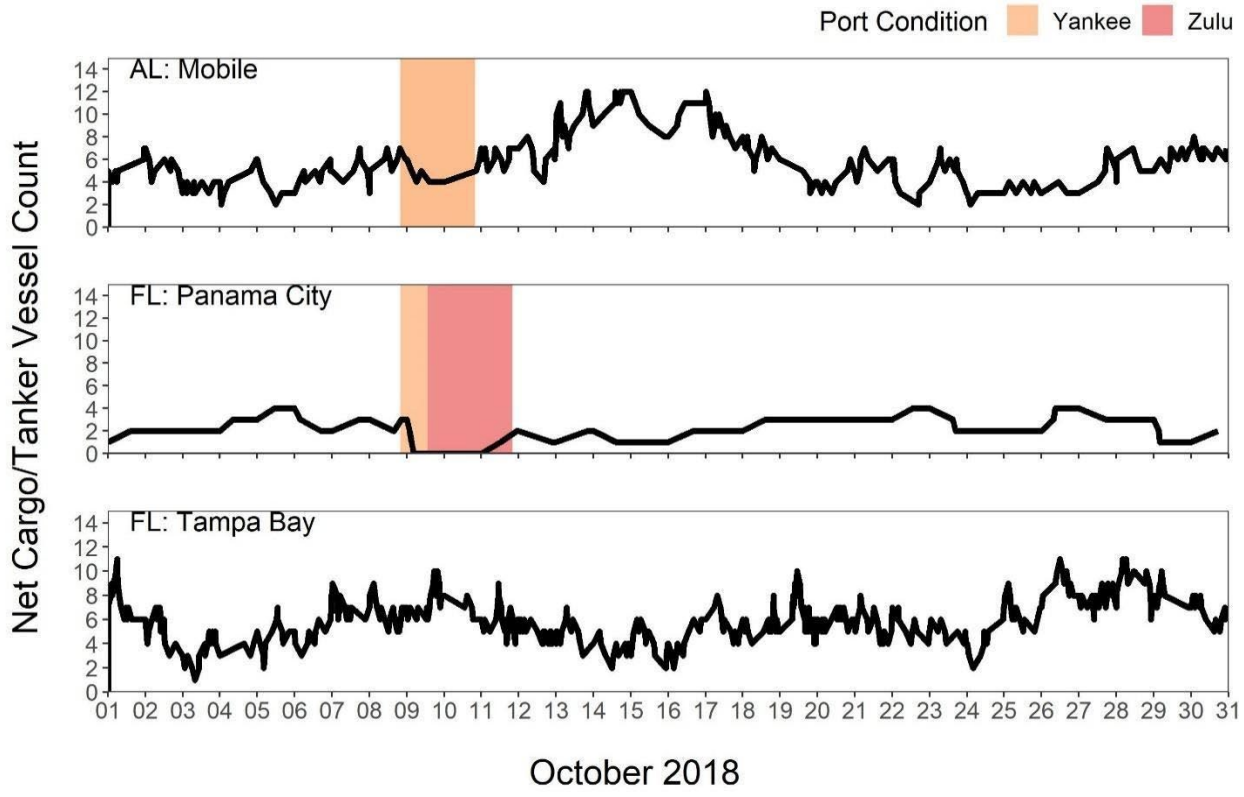

Figure 6. Net Vessel Counts before, during, and after Hurricane Michael for the Ports of Mobile, Panama City, and Tampa Bay: October 1-31, 2018. Tampa Bay is included because as a "neighboring" port it was unaffected by the storm and assisted in the recovery of Panama City.

NOTES: Port Condition describes when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the Port: YANKEE = 24 hours, ZULU = 12 hours.

SOURCE: U.S. Army Corps Engineers Research and Development Center, Automatic Identification System Analysis Package (AISAP), using AIS data provided by the U.S. Coast Guard.

Challenges: Hurricane Michael

Hurricane Michael posed challenges due to its' rapid intensification prior to landfall, and issues with loss of cell phone service - stressing the importance of clear and consistent communication.

- Rapid intensification of hurricanes, such as Hurricane Michael, is not atypical and can provide **both forecast and risk communication challenges**. It is important to be mindful of compressed preparation timelines.
- As it moved inland after landfall, Michael **quickly became a hybrid storm that impacted a large inland region many hundreds of miles from landfall**. The NWS office in

Wakefield, VA, was providing information on storm projections for the USCG and the Navy in Chesapeake Bay and Hampton Roads. These projections were challenging because of uncertainties and the distance overland.

- **Challenges arose with federal cell phones** and lack of service because the Verizon fiber cables in the Panama City area were destroyed in the storm. These issues were able to be overcome with use of personal cell phones on different carriers.
- There were many **challenges with getting survey assets from USACE and NOAA** in the far eastern areas of the Gulf Intracoastal Waterway (GIW) to support waterway and ATON constellation restoration. The GIW is a crucial waterway that connects petrochemical centers in East Texas/West Louisiana and consumers in population centers in Florida and Alabama. Terrestrial damages impeded access to the waterway and programmatic prioritization challenges delayed resource allocation to the area.

Successes: Hurricane Michael

Successes with Hurricane Michael relied on having relationships and coordination channels within and between agencies already established before the hurricane.

- **Information from the NWS Mobile was provided with enough lead time** to give the Port of Mobile time to focus their efforts further east.
- **The isolated impacts of Michael allowed neighbors to quickly convene on the area and complete recovery efforts**. Michael made landfall between NRT homeports in Fernandina Beach, Florida and Stennis Space Center, Mississippi. This allowed NOAA to quickly respond with two NRTs. Additionally, because nearby airports in Jacksonville, Florida and Mobile, Alabama were unaffected, additional personnel resources were easily flown into rendezvous with the teams en-route to Panama City and augment the personnel on the two NRTs. Because it was a single port impacted, multiple teams could respond to the same location and complete the survey efforts more quickly than is possible for storms that require each team to survey one or more waterways individually.
- Coordination between neighboring USACE Districts included expediting funds transfer to allow for faster assistance**.**
- Michael quickly became a hybrid storm that impacted a large area causing NWS Wakefield to inform the USCG and Navy in Chesapeake Bay and Hampton Roads, which was challenging due to the distance from landfall. However, **having the coordination channels and relationships already in place certainly helped with coordination**.
- The **Coast Guard had increasingly outstanding support from the NWS**, including expanding efforts to co-locate response and recovery personnel including an effort to get USACE staff in their incident command centers.
- The **cell phone outages were somewhat mitigated** by Iridium satellite phones.

Hurricane Dorian: August 24 – September 9, 2019

Hurricane Dorian was the fourth named Atlantic storm of the 2019 season and the second storm that made landfall in the U.S. (after Hurricane Barry, which made landfall in Louisiana as a Category 1 hurricane on 13 July). Dorian's speed and intensity varied over the course of its life cycle, visible in Figure 7. It formed on 24 August and initially made landfall in the northern Bahamas as a Category 5 storm on 1 September. After stalling for several days over the Bahamas, Dorian weakened to a Category 2 storm as it traveled offshore the coast of Florida. Around 70 miles southeast of Charleston, it again intensified to a Category 3 storm and subsequently weakened to a Category 1 storm before making landfall near Cape Hatteras North Carolina on 6 September. From North Carolina, the system transitioned into an extratropical storm as it rapidly tracked northeast to Canada, again making landfall in Nova Scotia on 7 September 2019.

Total losses caused by Dorian in the Bahamas was estimated at $3.4 billion dollars[16], which is over a quarter of the country's GDP. Most of the heavy rainfall occurred offshore, however, notable rainfall totals were recorded in Wilmington (8.32 in), Charleston (6.59 in), and on Ocracoke Island (13.74 in). Dorian caused significant sound-side storm-surge flooding in North Carolina, with the most severe storm surge of 4-7 ft. occurring on Ocracoke Island. Two 500-foot sections of NC Highway 12 on Ocracoke sustained severe damage, which were repaired by NC Department of Transportation.

[16]http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=EZSHARE-1256154360-486 (https://www.iadb.org/en/damages-and-other-impacts-bahamas-hurricane-dorian-estimated-34-billion-report)

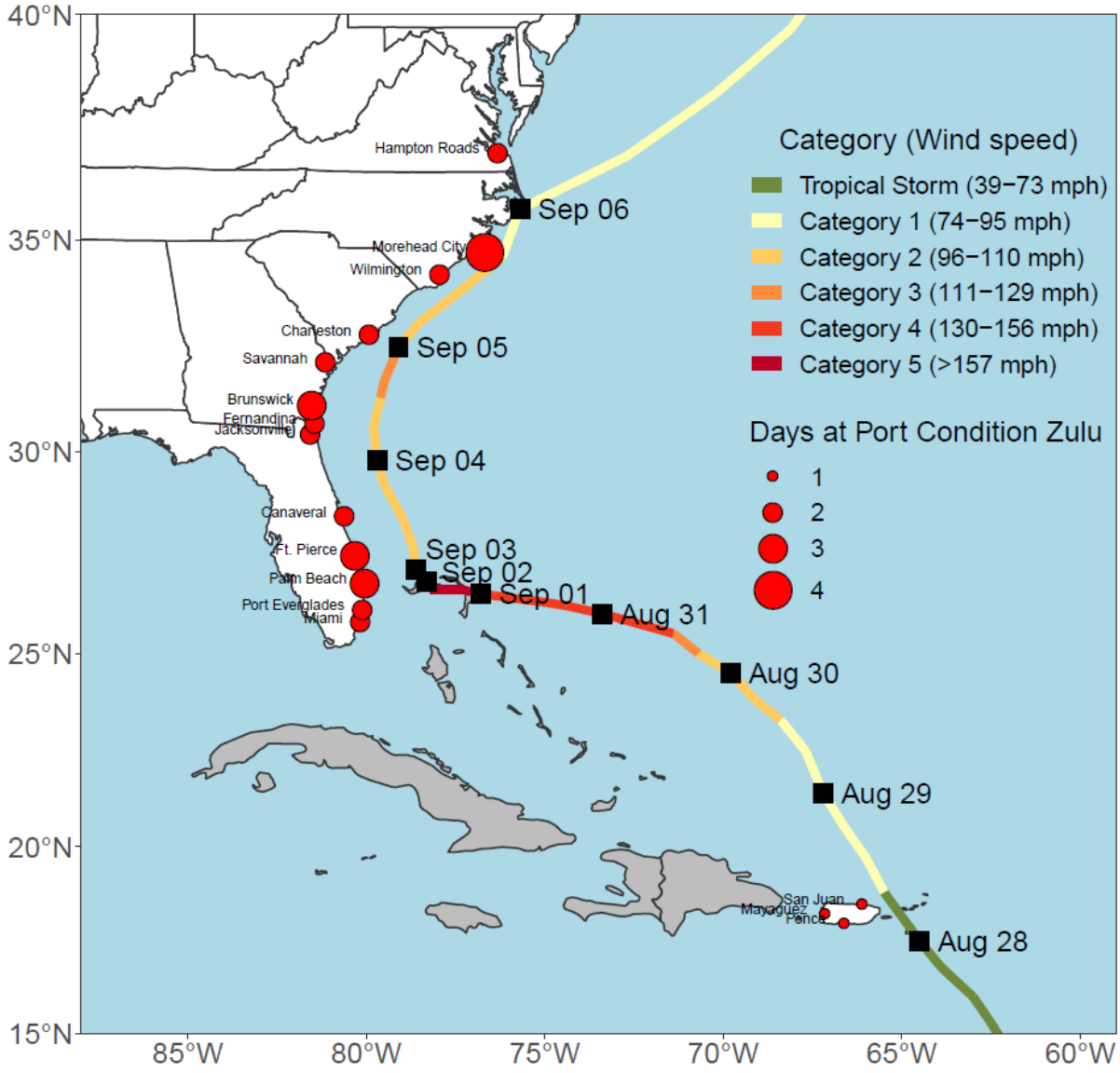

Figure 7. Hurricane Dorian storm track and the duration of closure (Port Condition ZULU) for 15 ports on the east coast and Caribbean.

NOTES: This figure displays how slow and intensely the storm moved over the Bahamas and the variation and speed of the storm as it moved up the East Coast before making landfall in North Carolina and moving offshore. Port Condition describes when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the Port: ZULU = 12 hours.

SOURCE: U.S. Army Corps Engineers Research and Development Center, Automatic Identification System Analysis Package (AISAP), using AIS data provided by the U.S. Coast Guard.

Hurricane Impacts, Challenges, and Successes

As Dorian tracked northward, 15 ports from Puerto Rico to Virginia were closed (Figure 8). Seven of the 15 ports that were impacted are considered in the top 25 in the U.S. for tonnage movements. All 15 ports were closed for a minimum of one day (Port of San Juan) to a maximum of two and a half days (Wilmington, Charleston, and Jacksonville). At the Port of Wilmington, reopening required daylight-only transits and a 30 ft. draft restriction.

The quantitative impact of these closures can be measured again with net vessel count, and Figure 9 attempts to align each of the net vessel count impacts with a comparison of USCG warnings, closures, and re-openings as the storm moved north up the coast. While the storm did not close any of the ports in question for a long duration, like Florence and Michael in 2018, Dorian offered its own unique challenges. Uncertainty around its future projections put the entire southeast coastline on high alert for the storm's potential arrival as it devastated the Bahamas. As Dorian moved north up the Atlantic Coast, the cumulative preparation across all 15 ports and harbors that were closed in anticipation of its arrival resulted in large disruptions to normal traffic flow and density (Figure 8).

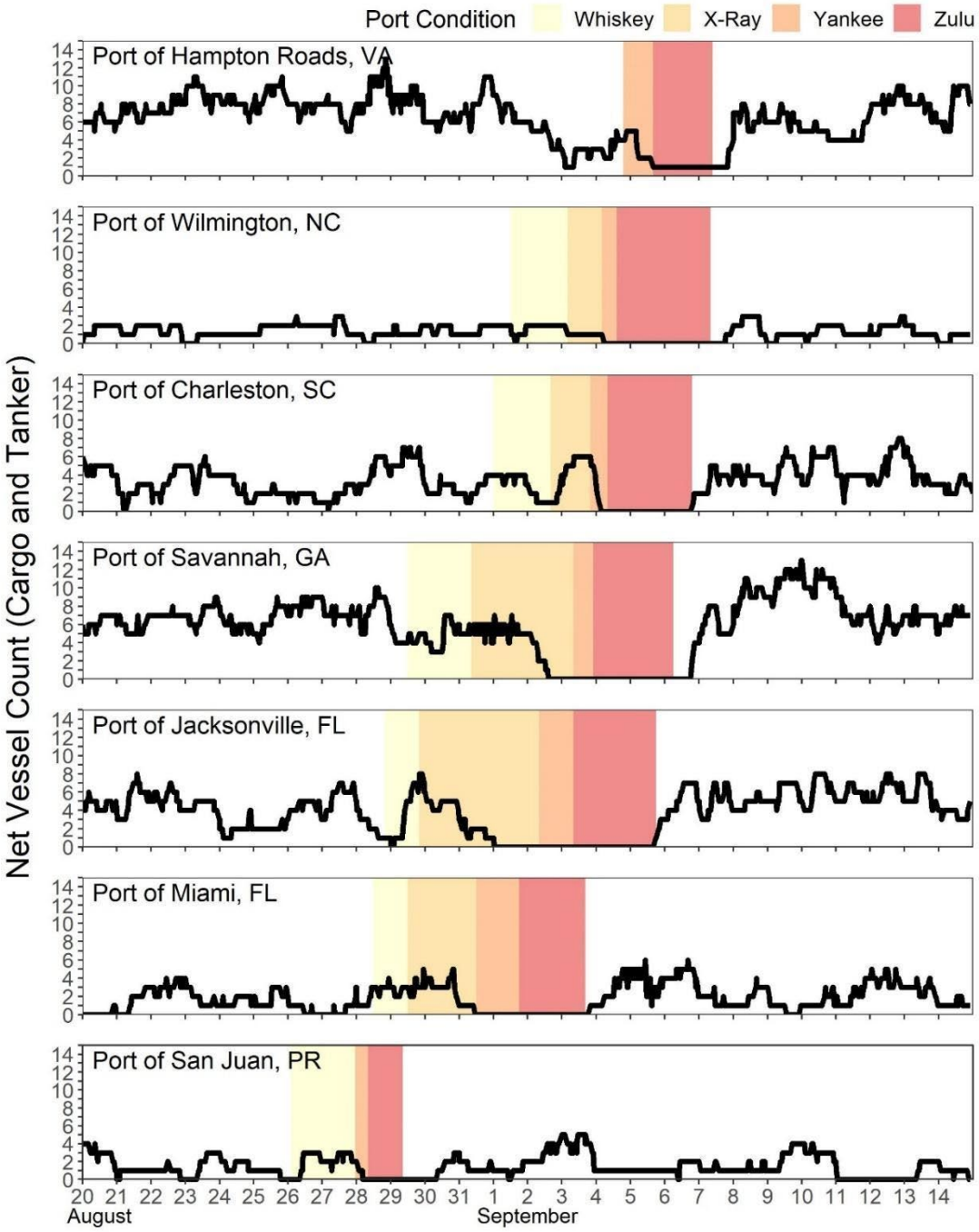

Figure 8. Net vessel counts of Cargo and Tanker Vessels for each of the Top 25 Ports (by Tonnage) impacted by Hurricane Dorian.

NOTES: Port Condition describes when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the port: WHISKEY = 72 hours (hrs.), X-RAY = 48 hrs., YANKEE = 24 hrs., ZULU = 12 hrs.
SOURCE: U.S. Army Corps Engineers Research and Development Center, Identification System Analysis Package (AISAP), using AIS data provided by the USCG.

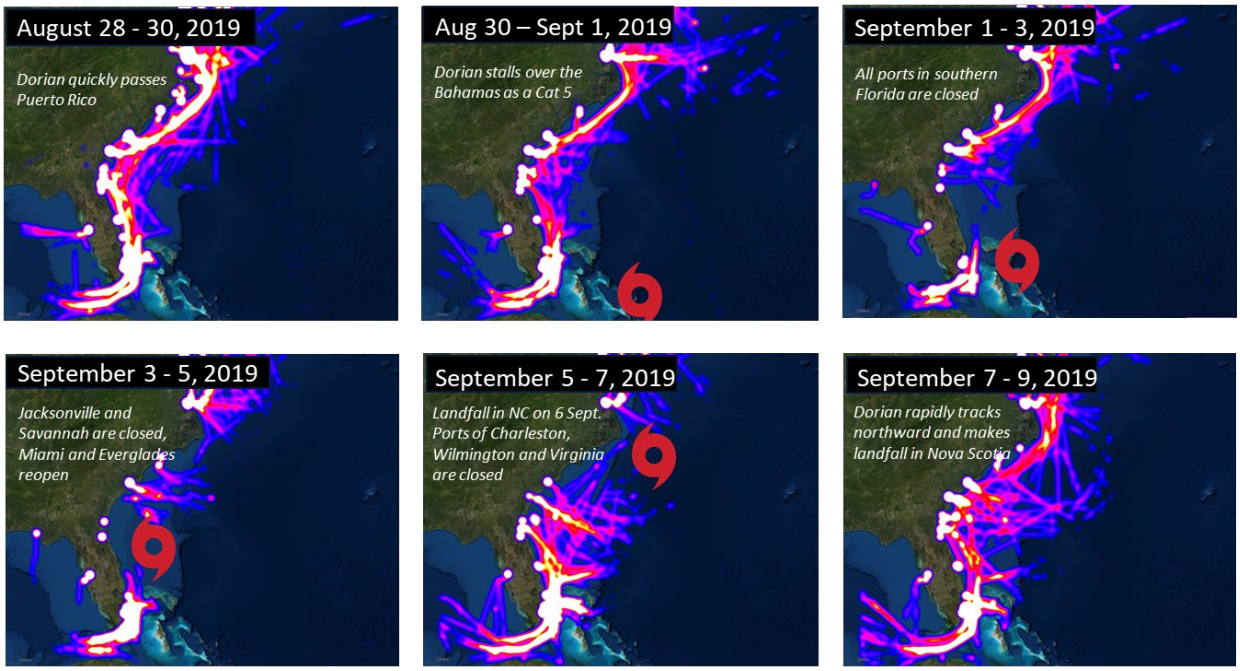

Figure 9. Cargo and Tanker Vessel Density Plots on the East Coast of the United States during Hurricane Dorian.

NOTES: The largest finding from these vessel counts is the breadth of impact of Hurricane Dorian among ports on the Atlantic Coast from Puerto Rico to Virginia. Shippers had to carefully track hurricane projections to avoid the storm's effects.

SOURCE: Cargo and Tanker Vessel Density maps derived from Automatic Identification System Analysis Package (AISAP), developed by the U.S. Army Corps of Engineers Research and Development Center with data furnished by the USCG.

Challenges: Hurricane Dorian

Hurricane Dorian was the strongest hurricane on record to impact the Bahamas with sustained winds of 185 mph. Dorian resulted in the potential need for international aid to the Bahamas. At the same time, the U.S. was preparing for widespread response along ports in the southeastern U.S., prohibiting larger response to the Bahamas.

- This storm posed a need for **potential international aid which was challenging to plan for** (and ultimately not needed).
    - NOAA had the Mobile Integrated Survey Team (portable survey equipment and personnel) standing by to board a USCG Cutter to respond as necessary to ports

in the Bahamas. The mission was ultimately scrubbed and the USCG Cutter was tasked to a continental U.S. mission.

- Hurricane Dorian **required planning for widespread potential response** to any of the ports from Miami, Florida to Morehead City, North Carolina.
- Charleston, South Carolina has experienced relatively few direct hits from major storms and generally been the recipient of fast post-storm response and recovery operations. As a result, some navigation managers at the USACE worry that stakeholder expectations of channel survey speeds have become unrealistic, and that they will be disappointed and/or surprised with the delay when a larger storm does greater damage.
- Dorian impacted Department of Defense (DOD) strategic ports and the military operations that had been scheduled through them. MARAD tracks the readiness of Commercial Strategic Ports daily to ensure their ability to meet DOD national defense purposes, including downgrades even when no military action is scheduled.

Successes: Hurricane Dorian

The track of Hurricane Dorian was originally a worst-case scenario, with response teams on alert from Miami, Florida to Hampton Roads, Virginia. The storm did not bring significant impacts; instead providing a real-world training opportunity to test coordination and communication efforts. The response to Dorian benefited from 3 years of previous hurricane responses; many of the successes identified came from putting into practice lessons learned from the 2017 and 2018 hurricane seasons.

- **FEMA was able to enact Mission Assignments very quickly;** a significant improvement from Hurricane Michael. Dorian efforts began five days prior to forecasted landfall in Puerto Rico, rather than after landfall, which has been the past precedent.
- NOAA was able to exercise a memorandum of understanding (MOU) with USCG to **pre-position its vessels in a hardened USCG facility** outside of Miami which allowed the team to follow behind the storm as it moved northward along the coast. **Other teams were positioned to "leap-frog" from port to port as waterways were surveyed** by the various federal agencies involved.
    - NOAA was able to pre-stage survey equipment on MARAD vessels in Charleston
- In Wilmington NC, **USACE, USCG, and NOAA were all co-located with USCG**.
    - NOAA provided contract support to procure ocean bar surveys to supplement USACE which helped tremendously as USACE was preoccupied with survey efforts for the ferry channels to Ocracoke Island.
    - The USACE was also able to co-locate physical assets with USCG as well as personnel.
- **Coordination with multiple federal agencies** allowed the Commercial Sea Lift program to provide support to the Bahamas.
- NRT / MTS Response Units (MTSRU) / USACE coordination in Miami, Florida was successful due to co-location. **Face-to-face coordination meetings were important and**

took minutes to hours, as compared to email communication which prolonged coordination. For example, coordination between NOAA and USACE to coordinate post-storm surveys only took a few hours.

- **USACE had pre-storm coordination with the Navy** to have assets in place at Navy facilities and prepare to assist as needed.
- In Charleston, South Carolina, USACE was able to **utilize the private sector dredging resources to help survey and clear the channel**.
- The MTS also relies on the ability of employees within ports, related service organizations, and federal agencies to protect their families and access their workplaces. Following the 2018 hurricanes, restricted access to port facilities and personal property and housing loss for community members and port employees was a challenge. In Wilmington, NC, port facilities sustained minimal damage; however, power outages and restricted access to the Wilmington area for returning employees prolonged port reopening. In 2019, the Port of Wilmington altered its hurricane plan to give more time for employees and tenants to prepare both the port and their own personal affairs. The new hurricane plan results in the port being ready 12 hours ahead of the planned USCG port conditions.[17]

Summary of Findings from 2018 and 2019 Hurricane Seasons

Federal Best Practices to Restore & Recover MTS Operations

The actions summarized below show common best practices that were employed during and between all three storms (Florence, Michael, and Dorian) and can be utilized to better respond to future storms. RIAT member agencies emphasized proactive preparation and establishing relationships and plans before events as vital in successful post-storm response and recovery efforts.

- *Advanced Tabletop Exercises Combined with Local Knowledge*
  A successful response is often rehearsed. The implementation of tabletop exercises between local USCG, USACE, NOAA, and other state and local partners to identify possible survey problem areas in each navigable channel and to develop scenario-based plans were very useful. However, detailed tabletop surveys for the massive waterways within USACE and NOAA surveyor's area of responsibility is not feasible, so it is critical that they rely on local subject matter experts when identifying which areas are of highest priority for surveying. When a MTSRU is stood up for an event, the plans can be reviewed and adapted to address actual storm response.
    - USACE and NOAA have different missions with respect to surveys so coordinating beforehand helps ensure that end-users get accurate and complete information and avoid duplication of efforts.

[17] Personal Communication, 2019. Port of Wilmington.

- *Co-locating during a storm*
  Co-locating assets and personnel was extremely helpful during Dorian. This co-location allowed for more effective pre-positioning of vessels as well as enhanced coordination of channel surveys.

- *Prioritizing Assets*
  It is vital to know what assets should be prioritized (ATONs, infrastructure systems, channels, terminals, etc.) to get the system back up and running expeditiously. This knowledge comes from tabletop exercises and preparation combined with reliance on local expertise during the response and recovery effort. This information is used to increase the efficiency of recovery.

- *Establishing Relationships Early and Coordinating Lines of Communication*
  In order to more effectively prepare for and respond to storm events, relationships within and between federal agencies and local officials need to be established prior to events. This includes establishing and coordinating lines of communication, which can assist in identifying the best routes and mechanisms to get resources into areas following storms. Face-to-face coordination meetings were more effective and took less time than coordination through email.

- *Sharing Useful Tools*
  Common Assessment and Reporting Tool (CART) is managed and operated by the USCG and is updated several times daily throughout the response and recovery phases of the storm to make information available on the status of all Essential Elements of Information (EEIs) and ultimately the port status as-a-whole. NOAA was able to take a CART training before Dorian to become familiar with the system, and it paid dividends for them. CART has been designed to allow access to non-USCG partners.

Future Recommendations

To ensure that critical functions of the MTS return to acceptable operating levels as soon as possible through response and recovery actions, gathering and communicating best practices between storms and hurricane seasons ensures that there is improvement in the recovery of the MTS following disruption. The resilience framework provides a concept to facilitate changes between storms to be better prepared for future storms and adapt through time to lessen impacts of future events. Adapting preparation and recovery actions from lessons learned will result in a more resilient MTS that is better prepared for future disruptions. It is important to note that after the 2018 hurricane season, agencies were already making changes to be more efficient during the 2019 season.

The RIAT has adopted the Presidential Policy Directive 21[18] definition of resilience as the ability to prepare for and resist/withstand, recover from, and adapt between disruptions as a part of a four-step cycle initiated by a disruptive event. Each step needs to have equal attention successfully increase resilience. Emergency response and recovery efforts naturally focus on preparation, absorption, and recovery. Addressing adaptation can be difficult without effective and consistent coordination and communication; a reason why the RIAT is explicitly addressing improvements across hurricane seasons, not just within them. The following recommendations were compiled by RIAT agency representatives and workshop attendees to increase preparation, response, recovery, and adaptation.

- Establish a common operating picture of survey data from all agencies involved. A GIS platform available to all agencies is recommended for this purpose. At present, many of these viewers have been developed for coordinating internal agency response. For example, the USCG's CG1View or USACE's Common Operating Picture (uCOP). The uCOP is a highly customizable application that provides the USACE with detailed and up-to-date visualization of its mission areas for analysis and decision making. Recently, the uCOP team created a similar platform that integrated various transmission models for COVID19. This platform was utilized to identify candidate counties for alternate care facilities and was made available to the public.[20]

One major hurdle for creating a data sharing platform is ensuring interoperability given the wide variety of requirements and restrictions across MTS agencies. The CMTS hosted the "Navigation Data Interoperability Roundtable: Commitment to Providing a Safer and More Secure MTS," to begin the discussion on how to overcome these hurdles. A path-forward was developed that identifies these challenges and provides guidelines to continue agency-to-agency data sharing, and the CMTS and its Federal partners will begin to work to address these items over this upcoming year.

- Participate in a hurricane response training that's geographically based and focused on the nuances of the local conditions (uniqueness of place).
    - Recommend referencing MTS Recovery Plans which exist in each COTP area and specifically highlight "uniqueness" of port areas.

- Establish relationships before an event including knowing who to contact, and where to go for information so that communications amongst teams is smoother during the recovery phase. An appropriate place for this information would be in the required MTS Recovery Plans for each COTP zone. It is recommended to update these plans with the lessons learned captured from these incidents.

[18] The White House (2013): "Presidential Policy Directive 21 – Critical Infrastructure Security and Resilience".
[19] Rosati, J.D. et al (2015): "Quantifying coastal system resilience for the US Army Corps of Engineers", Environment Systems and Decisions 35:196-208.
[20] https://swd-em.maps.arcgis.com/apps/opsdashboard/index.html#/1cc5cbde3c27434892022c6b934fff47

- Have response-related contracts in place to save valuable time and resources.

- Hold advanced tabletop exercises to understand the waterways and have a sense of what needs to be done and where to initially focus efforts, and then start to look at other areas of the waterway.

- Prioritize quickly and seamlessly the sharing of viewable data between agencies to get ports back online.

- Identify recurring hurricane response training and ways to capture information from each season and disseminate information.

- Facilitate greater coordination between USCG and MTS and port partners to streamline information reporting to MTSRUs in order to keep information in CART updated in a timely manner and relevant to recovery coordination amongst MTSRU partners. The MTSRU/CART training should be expanded to include federal partners and consider other port partners.

Federal Agency Connections

Effective coordination and communication among and between MTS federal agencies and stakeholders are frequently identified as a best practice resilience. Within the federal government, relationships among agencies and offices under a "business as usual" state are dictated by a myriad of formal policies, agreements and informal working groups. These connections change when the federal government is in a response or recovery posture, as the national frameworks for emergency support are implemented. Knowing how agencies are connected to each other and to their partners throughout the MTS can play a critical role in helping to promote better coordination and communication - before, during, and after disruption. Table 1 documents several interagency coordinating bodies that are initiated or utilized under disaster conditions to facilitate increased communication among MTS stakeholders internal and external to the Federal government.

Table 1. Federal stakeholder committees and groups initiated or utilized during and after disasters.

	CMTS	MTSRU	HSC	AMSC	ESF1	ESF3	ESF9	ESF10	ESF14
NOAA	x	xx	x	x	xx	xx	xx	xx	
USACE	x	xx	x	x	xx	Primary	xx	xx	xx
BTS	x								
USCG	x	xx	x	x	xx	xx	xx	xx	xx
MARAD	x	xx	x	x	xx				
EPA	x	xx				xx		Primary	xx
FMC	x								
CISA	x		x	x	xx	xx		xx	Primary
FEMA	x	xx			xx		Primary	xx	xx
DOT	x	xx			Primary	xx		xx	xx
NGA	x						xx		
Public		xx	x	x	xx	xx	xx	xx	xx
Industry		xx	x	x	xx	xx	xx	xx	xx
SLTT Govern-ments		xx	x	x	xx	xx	xx	xx	xx

x: normal conditions
xx: disaster response conditions

CMTS – *US Committee on the Marine Transportation System*
MTSRU – *Marine Transportation System Recovery Unit*
HSC *– Harbor Safety Committee*
AMSC *– Area Maritime Security Committee*
ESF 1 *– Emergency Support Function 1; jurisdiction – Transportation*
ESF 3 *– Emergency Support Function 3; jurisdiction – Public Works and Engineering*
ESF 9 *– Emergency Support Function 9; jurisdiction – Search and Rescue Annex*
ESF 10 *– Emergency Support Function 10; Oil and Hazardous Materials Response Annex*
ESF 14 *– Emergency Support Function 14; Cross-Sector Business and Infrastructure Annex*

An Examination of MTS Resilience Across Hurricane Seasons

The final step in this analysis is to compare the ability of the MTS to adapt between hurricane seasons. The RIAT report from the 2017 hurricane seasons identified best practices and recommendations to be carried forward in during future hurricane seasons. Table 2 compares a sampling of those recommendations to findings from hurricanes Florence, Michael, and Dorian during 2018 and 2019.

The table is split into two general themes that are important for ensuring that MTS critical functions are returned as quickly and efficiently as possible: 1) pre-event preparations, or actions in anticipation of a potential event and 2) response and recovery actions that occur during an event (and often depend on preparation). Throughout the table, there are several key themes that continuously surface within the findings: enhanced cross-agency coordination, improvements in data and information exchange, and capitalizing on lessons learned from previous storms to pre-establish local knowledge and mechanisms for quick response.

Table 2. A comparison of recommendations from 2017 with findings from the 2018 and 2019 hurricane seasons.

2017 Hurricane Season Report Recommendation	**2018-2019 Hurricane Season Findings**
Pre-event Preparations	
Participate in yearly trainings and drills to ensure that response and recovery teams and stakeholders are educated with the correct skill sets and credentials	Having local knowledge of an area was critical for establishing partnerships and familiarity with missions and protocols. **Tabletop exercises between USCG, USACE, NOAA, and others** were key in identifying known problem areas in each waterway to develop scenario-based plans.
Maintain pre-established contracting mechanisms for emergency response operations	NOAA was able to exercise a MOU with USCG to **pre-position their vessels in a hardened facility** outside of Miami which allowed the team to follow

	behind the storm as it moved northward along the coast. (Dorian) NOAA **provided contract support** to procure ocean bar surveys that greatly aided the USACE and expedited the channel survey process. (Florence). The USACE was able to quickly initiate navigation channel dredging and restoration by ensuring **dredges were under contract** and ready for support. (Florence)
Pre-identify staging areas and storage areas for response and recovery equipment, fuel, and supplies	There was a **more centralized approach to distributing recovery assets**. The USACE Charleston district was called upon to assist the Port of Wilmington and was able to do so more effectively. (Florence)
Prioritize key infrastructure systems and deliveries for directing response and recovery actions	There was successful **coordination between representatives from different transportation modes (road, rail, marine)** to identify the best routes and mechanisms to get resources into the area, especially under intense flooding (Florence)
Response and Recovery Efforts	
Share data across Federal agencies for recovery projects through interagency teams and data sharing platforms	USACE relied on an on-going database to **identify and flag for potential obstructions pre-storm** and share that information with other agencies (Florence)

Embed MTS experts where necessary – USCG, FEMA field offices, local offices	NRT / MTSRU / USACE coordination in Miami Florida was great due to co-location. **Face-to-face coordination meetings were important and took minutes to hours, not days to weeks as can happen with only email communications**. There was coordination with NOAA and USACE to coordinate post-storm surveys within hours. In the Wilmington District, **USACE, USCG, and NOAA were all co-located with USCG** which also leveraged expertise and accelerated collaboration.

Clearly, MTS stakeholders are well-versed in storm response; but there are also specific actions identified by this review that can be undertaken to improve the ability of the system to respond, recover, and better prepare for events beyond hurricanes. Increased resilience within the MTS will result in a system that is better prepared for future hurricanes and other disruptions (e.g. oil spills, technological failures, shipwrecks, tsunamis, etc.). The concept of resilience offers a useful framework to address these recommendations and Table 3 provides a summary of actions that were gathered from 2017-2019 hurricane seasons but can be adapted to address other disruptions to the MTS, such as the COVID-19 pandemic.

Table 3. Recommendations for the MTS to prepare, absorb and recover, and adapt to future disruptions

	Recommendation
Preparation Actions	Budget for and hold regular trainings and drills to educate response and recovery teams how to operate in different scenarios such as a virtual environment
	Establish important relationships and connections early and often and document the chain of command for emergency situations
	Hold yearly exercises to understand the needs of the local area and pre-identify storage areas and key infrastructure
Absorb and Recover Actions	Share data seamlessly across Federal agencies through interagency teams and existing easily accessible data sharing platforms
	Regularly update accurate data as information continues to evolve during disaster events and keep it relevant to recovery coordination
	Utilize a flexible workforce that can continue operations during an emergency
Adaptation Actions	Hold proactive after-action reviews focusing on what worked well, what challenges were faced, and to commit to implementing lessons learned and recommendations
	Develop an accessible common operating picture of vital information (survey data, port system requirements, dependent businesses)
	Document and communicate within and across agencies on the successes, challenges, and lessons learned following events

Conclusion

The MTS faces a future full of increased demand, more frequent coastal storms, and changing economic and community drivers. Ensuring that those who manage, prepare, and adapt the MTS to be more resilient have access to necessary information is extremely important, and the RIAT has attempted to foster a creative and collaborative approach to identify needs that are emerging out of hurricane response and recovery.

In reviewing the outcomes of this report, not only are federal MTS agencies successfully responding to the challenges of coastal storms, but they are adapting by utilizing lessons learned from the past to address vulnerabilities and improve their response to future storms. In the future, the RIAT team will continue to serve as a coordinating body for federal agencies,

but more work is warranted in reaching out beyond the federal family to the key partners within state, local, and tribal government agencies, and leaders in industry to weigh in on the practices that will make the system more agile, flexible, reliable, and resilient.

APPENDIX A: Agencies and Offices of February 2019 Workshop Attendees

Department of Defense

U.S. Army Corps of Engineers

Engineer Research and Development Center

Engineering and Construction Division

Directorate of Emergency Response & Contingency Operations

Operations & Regulatory Division

U.S. Committee on the Marine Transportation

U.S. Department of Homeland Security

Cybersecurity and Infrastructure Security Agency

U.S. Coast Guard

District Eight New Orleans: Enforcement Branch

Headquarters: Port Resiliency/Recovery

Headquarters: Office of Port & Facility Compliance

USCG FEMA Liaison

U.S. Department of Transportation

Bureau of Transportation Statistics

U.S. Maritime Administration

Office of Ports and Waterways Planning

Emergency Sealift Ops and Emergency Response

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

Office of Coast Survey

Office for Coastal Management

National Weather Service