UNITED STATES COAST GUARD

U.S. Department of Homeland Security

MARINE SAFETY ALERT

Inspections and Compliance Directorate

October 6, 2017 Safety Alert 11-17

Washington, DC

Remain Upright by Fully Understanding Vessel Stability

This Safety Alert addresses concerns related to vessel stability and watertight integrity. Recently, a marine casualty involving a fishing vessel in the Bering Sea resulted in multiple fatalities and complete loss of the vessel. A Marine Board of Investigation is currently analyzing the various circumstances surrounding the casualty. Although the investigation is not complete, testimony and fact finding indicate that vessel owners, operators, and crews should give special consideration to vessel stability concerns.

The need for operators to understand their vessel's Stability Instructions (SI) cannot be overstated. It is important to understand the document. Operators and crew should seek out opportunities to further their knowledge of stability via courses, training, workshops, and visits from Naval Architects. They should also take advantage of other various initiatives, both mandatory and voluntary, to discuss and compare a vessel's current SI to the actual loaded condition prior to departing port. An independent review of a vessel's loaded condition, equipment, and operations can often provide important insights.

Operators can significantly reduce the risk of capsizing by performing the following actions:

- Routinely review and update vessel SI,
- Stay below the limits for vessel and cargo detailed in SI,
- Ensure SI reflect the vessel's current arrangement, equipment, and operations (lightship and loaded cargo/fishing gear conditions), and
- Follow good marine practice by re-assessing the SI every five years.

Operators should confirm the accuracy of their SI whenever a vessel undergoes any of the following actions:

- Major conversions or substantial alterations (See 46 CFR 28.50 and 28.501, respectively),
- Changes to a vessel's rigging, deck, or fishing equipment (including pots),
- Changes in principal dimensions, cargo hold, or tank capacities,
- Circumstances of weight creep (i.e., the accumulation of extra gear, equipment, and parts carried aboard the vessel), and
- Any other weight change variations which may occur.

Carry pots?

- Pay special attention to pot weights,
- Annually weigh a percentage of them to verify if the actual weight (including shots of line and buoys) matches that recorded in the SI,
- Weigh them wet - soaked lines can add as much as 15 pounds per shot, and
- Consult a Naval Architect for loading recommendations and amendments if pots are heavier than what is listed in the SI.

Icing makes a vessel dangerously unstable:

- Regulations for SI assume only 1.3 inches of accumulation on horizontal surfaces;
- Real life conditions easily and often exceed 1.3 inches of icing;
- Unless tested for a value over 1.3 inches a vessel's capsizing and sinking risk increases when that value is exceeded on horizontal surfaces;

- A vessel's center of gravity can rapidly rise when freezing spray accumulates high above the main deck;
- Operators should use all available resources to determine if icing and freezing spray is forecasted in their operational location for the next 48-72 hour time window;
- If icing conditions are forecasted or present – operators should seek shelter, reduce speed, change course, and manually remove ice;
- If forecasted prior departure, operators should consider reducing the amount of bait, gear, and pots.

Operators should perform the following actions to maintain watertight integrity:

- Follow SI associated with watertight doors (WTDs) and hatches,
- Frequently train and inform crew to habitually close watertight doors and hatches at sea,
- Label WTDs to be closed,
- Keep hatches closed to the greatest extent possible, and
- Practice closing WTDs that are routinely permitted to be open during emergency drills.

Important vessel stability training hyperlinks:

Fishsafewest.info:	Online Stability Training
CG-CVC-3:	Stability Guide
	Stability Card
	Sample Stability Guide
	Stability Modification Sample

This safety alert is provided for informational purposes only and does not relieve any domestic or international safety, operational, or material requirements. Developed by a Coast Guard Marine Board of Investigation in conjunction with Coast Guard District 13 and 17 Prevention Divisions. Questions may be sent to HQS-PF-fldr-CG-INV@uscg.mil.

Marine Safety Information Bulletin

Commandant (CG-5PC)
Attn: Inspections and Compliance Directorate
U.S. Coast Guard
2703 Martin Luther King Jr Ave SE, Stop 7501
Washington, DC 20020

MSIB Number: 01-21
Date: January 19, 2021

E-Mail: HQS-DG-1st-CG-INV1@uscg.mil

Improving Fishing Vessel Stability

It has been three years since the release of USCG Marine Safety Alert (MSA) 11-17. Since then, additional commercial crab fishing vessels have sunk, resulting in losses of life due to stability related conditions. In addition to the information communicated in MSA 11-17, this bulletin is intended to be informational to assist mariners in identifying ways to improve their stability awareness. Please note that it is the vessel master's responsibility to maintain satisfactory stability at all times.

Stability is the tendency of a vessel to rotate one way or the other when forcibly inclined. Operators can significantly reduce the risk of capsizing by performing the following actions:

1) Review the vessel's Stability Instructions (SI) periodically to ensure it accurately reflects the vessel's design and actual conditions (pot weights, fuel loads, icing conditions, as may be applicable).
2) Be aware of the assumptions or conditions outlined in the vessel's SI.
3) At the end of any vessel modifications, ensure all alterations made to the vessel are accurately accounted for in the ship's SI. (Special attention should be given to modifications that include changes to fuel tanks, freeing ports areas or areas of the hull near or below the waterline).
4) While at sea, be cognizant of watertight integrity.
5) During icy conditions, be proactive in removing ice build-up.
6) Do not make the mistake of overestimating a vessel's ability to handle heavy loads and heavy seas!

<u>Periodically review the vessel's SI</u>:

- Identify load conditions outlined in the SI.
- Identify the assumed weight of gear loaded on deck.
- Weigh the actual gear used and resolve any differences within the SI.
- Understand how the gear is arranged in the SI, especially for pots. Confirm the height of the stacked gear and its orientation.
- Understand the geographic restrictions and types of waters reflected in the SI.

<u>Be aware of the assumptions and conditions outlined in the SI</u>:

- Identify the max environmental conditions used in the calculations such as wind on the vessel's sail area. Confirm that the sail area includes pots, deck loads, rigging, running gear, tarps, icing, etc.
- Be conservative when considering the environmental effects on gear. Wet lines can add as much as 15-pounds per shot. (Example: 100 pots with 2 shots per pot could add 1.5-tons of water weight).
- If the vessel carries pots, identify the weight used for each pot. Weigh a representative sample of each different type of pot including lines and buoys. Rectify any differences in the SI or consult a naval architect to assist.

<u>Review/Evaluate changes to the SI following any maintenance period</u>:

- Pay attention to changes or blockages to freeing ports. If a freeing port location has changed, ensure a naval architect has evaluated the new conditions for compliance with 46 Code of Federal Regulations (CFR) 28.555.

- Verify changes to a vessel's rigging, deck, fishing equipment, principal dimensions, cargo holds, tank capacities, or machinery. Any major conversion or substantial alteration needs to be addressed in the vessel's SI. When in doubt consult 46 CFR 28.501.
- Follow SI guidelines with respect to watertight doors and hatches. Monitor the condition of these boundaries periodically when underway, as is safe to do so. The safest practice is to ensure all watertight and weathertight closures are secured while at sea unless in immediate use.
- Set the operational expectation to ensure your crew practices good watertight integrity procedures by putting it in your safety procedures.
- Test bilge alarms periodically. Monitor spaces underway for water intrusion where alarms are not installed.

Ice:

- Vessel operations: Be aware of horizontal/vertical icing condition parameters as outlined in 46 CFR 28.550.
- Know the icing standard used in the vessel's SI.
- Identify if pots are included in the SI icing condition calculations. Be aware that icing calculations may be based on an assumption that ice only accumulates on the pot's external surfaces, which would not account for aggregation of ice on the pot's internal netting and gear.
- Be proactive with removing build-up of ice. When removing ice build-up, break ice from the top down. Removing lower ice first may have detrimental effects on the vessel's overall stability by raising the center of mass of the remaining ice.
- Use available meteorological resources to anticipate potential freezing spray forecasts. One possible source is https://ocean.weather.gov/icing_rates/compare.php?area=ak&fhour=012.

Important vessel stability training on-line resources:

- Vessel Stability Guidance:
  - FishSafe Stabiltiy Resources: http://www.dco.uscg.mil/fishsafe
  - Stability Reference Guide: https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/CVC3/references/Stability_Reference_Guide.pdf
  - USCG MSA 11-17 (Stability): https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/INV/Alerts/1117.pdf
  - Stability Training: http://www.fishsafewest.info/Training.asp

- Centers for Disease Control and Prevention (CDC):
  - http://www.cdc.gov/niosh/topics/fishing/default.html

- Food and Agriculture Organization (FAO) :
  - http://www.fao.org/fishery/safety-for-fishermen/50787/en/
  - http://www.fao.org/3/a-i0625e.pdf

Questions or comments may be sent to HQS-PF-fldr-CGINV@uscg.mil or to CGCVC3@uscg.mil.

U.S. Department of Homeland Security
United States Coast Guard

Commanding Officer
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Serial: A0-2100543
22 Feb 2021

MEMORANDUM

From: A. R. Lawrence
CG MSC - SERT

Reply to
Attn of:

To: G. A. Callaghan, CAPT
CGD ELEVEN (dp)

Subj: MSC ANALYSIS OF ASYMMETRIC ICING ON SCANDIES ROSE

Ref: (a) Phone conference between CDR Denny, LCDR Comerford, Mr. Barnum, and Mr. Lawrence on 01 Feb 2021
(b) MSC Technical Report: SCANDIES ROSE Sinking, dated 08 Feb 2021

1. The Marine Safety Center (MSC) completed an additional stability analysis considering asymmetric crab pot icing aboard SCANDIES ROSE, as requested by reference (a).

2. Documentation of our analysis is provided as an addendum to our technical report, reference (b), and is included as enclosure (1) to this memorandum.

3. If you have any questions or require additional information, please contact me at (202) 327-3986.

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Encl: (1) MSC Technical Report: SCANDIES ROSE Stability Analysis with Asymmetric Crab Port Icing, dated 22 Feb 2021

U.S. Coast Guard
Marine Safety Center

Technical Report Addendum

SCANDIES ROSE Stability Analysis with Asymmetric Crab Pot Icing

February 22, 2021

1. INTRODUCTION

The U.S. Coast Guard Marine Safety Center (MSC) was asked by the SCANDIES ROSE Marine Board of Investigation to analyze the effects of asymmetric icing on the estimated casualty voyage loading condition. This document is an Addendum to MSC's "Technical Report: SCANDIES ROSE Stability Analysis," dated February 8, 2021 (herein referred to as ref. (a)).

46 CFR 28.550 provides little guidance for the manner in which crab pots should be treated for icing. The text of the regulation requires ice to be applied to horizontal and vertical surfaces. This could mean just the outer round tube structure of the pot and not the mesh in between, however pictures of iced crab pots suggest that this is not a conservative assumption. In our Technical Report, we assumed that the top of the exposed tier, outboard sides, and fore and aft extents of the stack of crab pots are surfaces prone to icing, and treated them as continuous horizontal and vertical surfaces. This results in a symmetric ice loading that causes parallel sinkage of the vessel (it sits heavier in the water, at a deeper draft), but without an ice-induced heel angle.

Actual icing has been shown to affect vessels asymmetrically as a function of vessel heading, wind and wave encounter, and resulting sea spray. This analysis attempts to identify the effect of asymmetric icing on the crab pots loaded on SCANDIES ROSE during the casualty voyage. The actual nature of icing on SCANDIES ROSE was not fully known and many details about SCANDIES ROSE's condition at the time of casualty are unknown as documented in ref. (a). Because of these factors, this analysis should only be used with a full understanding of the extensive assumptions made to account for unknown loading conditions and environment information.

2. ANALYSIS ASSUMPTIONS

The exact loading condition of SCANDIES ROSE during the casualty voyage is not known. To generate a loading condition for analysis, MSC used information provided by the Marine Board of Investigation as well as engineering assumptions as described below.

2.1. Information Provided by Marine Board of Investigation

For this analysis, icing is applied to the loading condition estimated for the casualty voyage where all wing fuel tanks are full. This is "Investigating Officer's Condition 1" in ref. (a). In this condition, the following loads are assumed:

- 195 pots were loaded
- Holds #2 and #3 were full
- 20,000 lbs. (8.9 long tons) of bait loaded in the freezer in the port forecastle
- All wing and aft fuel tanks are assumed full.

The Marine Board of Investigation indicated that actual crab pot load distribution was as shown in Figure 1 for the casualty voyage. Because Figure 1 does not show the full extent of crab pot loading, Figure 2 was used to indicate the typical way that crab pots are loaded aboard SCANDIES ROSE. During the casualty voyage, asymmetric ice accumulation on crab pots was reported on the starboard bow, from amidships forward.

Figure 1: Pictures of Crab Pot Loading from Casualty Voyage (provided to MSC by Marine Board of Investigation)

Figure 2: SCANDIES ROSE Crab Pot Loading from Unidentified Voyage. Assumed to be Typical Crab Pot Loading (Provided to MSC by Marine Board of Investigation)

2.2. MSC Assumptions

In order to complete the loading condition, MSC made the following assumptions:

- Crab pots are "small pots" with dimensions of 7 x 6.5 x 3 feet and a total weight of 835 pounds each (as defined in ref. (a))
- Crab pots are loaded with four tiers on the main deck with the first tier on its side (7 x 3 feet surface down). The second and third tiers are loaded with the 7 x 6.5 feet surface down.
- 0 pots are loaded under the shelter deck forward.
- 11 pots are loaded on top of the shelter deck
- Total pot weight and center of gravity are as shown in Table 1. A representation of the crab pot loading is shown in Figure 3.
- Crab pot weight (without icing) is shifted transversely to attain zero initial heel angle so that heel angles during analysis are a result of asymmetric ice and liquid weight shifts only.
- 11.3 long tons of icing is present on the hull and superstructure surfaces of SCANDIES ROSE as assumed in Table 1 of ref. (a)
- Two values for lightship weight and centers of gravity were used as documented in ref. (a):

Lightship Characteristics Source	Lightship Weight (Long Tons)	LCG (ft aft of MS)	VCG (ft abv. baseline)
Culver 2019	548.32	3.30	14.69
MSC 2019	578.33	0.52	15.26

- Hydrostatic analysis is conducted without consideration of waves or motion induced by the environment. Wind forces are evaluated statically.
- Wind speed analysis considers wind pressure acting on the port side. This represents a relative wind heading of 270 degrees with the bow at 0 degrees and is assumed for worst-case for calculation and analysis purposes (wind pressure on the port side is normally inconsistent with ice accumulation from spray on the starboard bow).
- All other loading assumptions of ref. (a) remain valid

Position	Quantity	Weight (lbs.)	LCG (ft aft of MS)	VCG (ft abv. baseline)
Foc'sle Deck	11 Pots	9,185	-39.2	31.0
Tier 1	82 Pots	68,470	-4.1	20.1
Tier 2	36 Pots	30,060	-3.3	24.9
Tier 3	33 Pots	27,555	-2.1	27.8
Tier 4	33 Pots	27,555	-2.0	30.8
Total	*195 Pots*	*162,825*	*-5.2*	*24.7*

Table 1: Assumed Pot Stack Weights and Centers of Gravity

3. ANALYSIS APPROACH

To evaluate asymmetric icing of crab pots on the starboard bow, MSC applied ice only to the exposed crab pots on the starboard side, forward of amidships and exposed forward extent of the stack. This results in 24 crab pots experiencing icing as shown in Figure 3. The initial hydrostatic condition of the computer model with the assumed loading is shown in Figure 4 and Figure 5.

For the purpose of this analysis, icing is assumed to occur on all 24 affected pots equally. Using MSC's hydrostatics model, 100 lbs. of icing weight per pot is added incrementally to the 24 pots until the model indicates capsize. Icing weight is added at the center of gravity of the 24 affected pots (Table 2).

LCG (ft aft of MS)	**TCG (ft stbd of centerline)**	**VCG (ft abv. baseline)**
-25.39	5.19	28.15

Table 2: Center of gravity of 24 ice affected crab pots

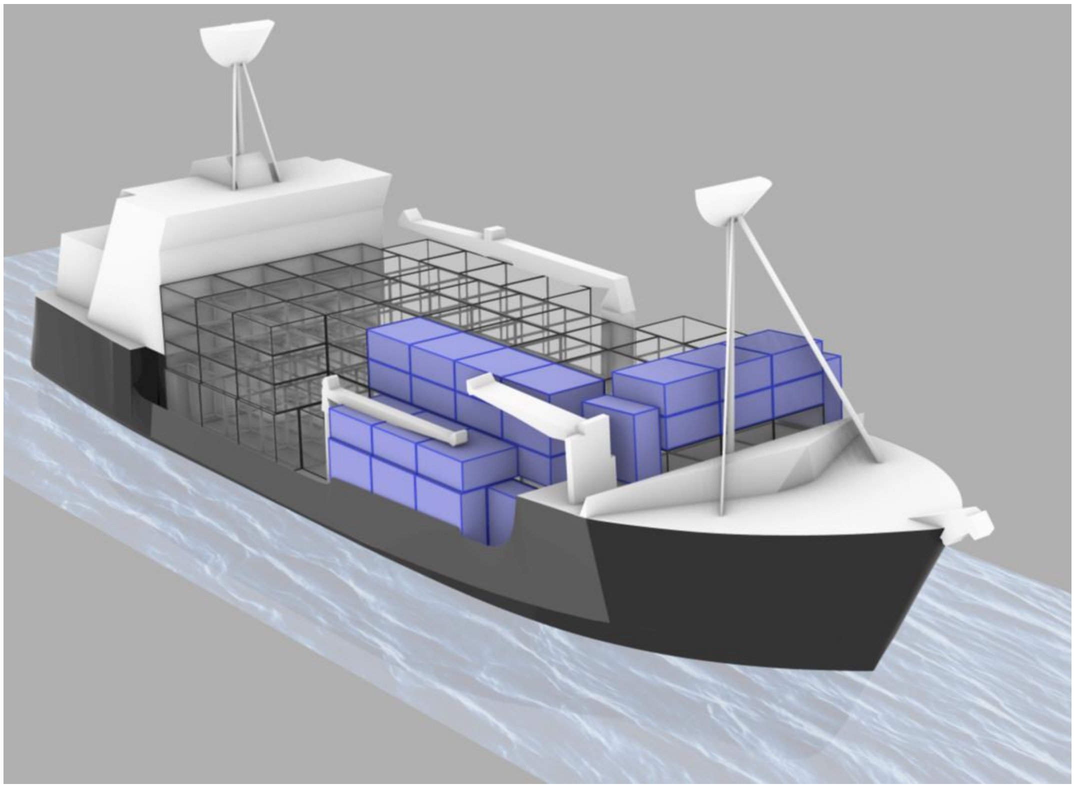

Figure 3: Graphic representation of MSC model with 195 crab pots loaded and 24 exposed crab pots on the starboard bow affected by ice (shown in blue)

195 Pots, Holds 2 and 3 Full. Fuel and Water Full, 20kip bait

Light Ship Source: Culver2019

WEIGHT and DISPLACEMENT and LATERAL PLANE and FREEBOARD STATUS

Baseline draft: 12.779 @ 60.63f, 13.597 @ 0.00, 14.415 @ 60.63a

Trim: Aft 1.64/121.25, Heel: zero

Part	Weight(LT)	LCG	TCG	VCG
LIGHT SHIP Culver2019	548.32	3.30a	0.00	14.69
Crew and Stores	2.50	8.60a	0.00	16.80
Bait	8.93	50.00f	8.00p	22.00
POTS-Focsle: 11	4.10	39.17f	1.61s	30.96
POTS-TIER1: 82	30.57	4.08f	1.61s	20.12
POTS-TIER2: 36	13.42	3.34f	1.61s	24.86
POTS-TIER3: 33	12.30	2.09f	1.61s	27.83
POTS-TIER4: 33	12.30	2.02f	1.61s	30.83
Ice	11.31	9.95a	0.44p	26.17
Total Fixed	**643.75**	**1.73a**	**0.06s**	**16.13**

	Load	SpGr	Weight(LT)	LCG	TCG	VCG	RefHt
HOLD2.C	1.000	1.025	140.87	12.72f	0.00	8.94	
HOLD3.C	1.000	1.025	122.17	6.26a	0.00	8.81	
FWDWING.S	0.929	0.870	9.01	29.17f	13.02s	6.44	-9.97
FWDWING.P	0.929	0.870	9.01	29.17f	13.02p	6.44	-9.97
MIDWING.S	1.000	0.870	19.29	12.41f	13.56s	6.05	
MIDWING.P	1.000	0.870	19.29	12.41f	13.56p	6.05	
AFTWING.S	1.000	0.870	17.82	6.26a	13.60s	5.95	
AFTWING.P	1.000	0.870	17.82	6.26a	13.60p	5.95	
AFTFUEL.S	1.000	0.870	23.41	44.73a	10.70s	10.05	
AFTFUEL.P	1.000	0.870	17.62	44.69a	11.87p	10.14	
DAYTANK.P	0.925	0.870	11.70	55.49a	10.11p	10.94	-13.24
WATER.S	0.913	1.000	24.87	28.80a	13.66s	8.13	-13.10
WATER.P	0.913	1.000	24.87	28.80a	13.66p	8.13	-13.10
LUBEOIL.P	0.823	0.870	4.76	44.80a	7.12p	8.95	-12.20
SEWAGE.S	0.472	1.025	7.03	55.20a	9.96s	9.39	-10.31
Total Tanks			**469.55**	**5.77a**	**0.09p**	**8.42**	
Total Weight			**1,113.30**	**3.44a**	**0.00**	**12.88**	
			Displ(LT)	**LCB**	**TCB**	**VCB**	
HULL		1.025	1,113.30	3.50a	0.00	8.00	-13.60
		Righting Arms:		0.00	0.00		

Part	LPA	LCP	HCP	LPA	LCP	HCP
Displacers	1448.9	0.77f	-6.13	714.1	10.84f	5.69
Sails	98.8	30.43a	-13.66	2179.2	0.98f	12.21
Total Lateral Plane->	**1547.7**	**1.22a**	**-6.61**	**2893.3**	**3.41f**	**10.60**

Distances in FEET.

Least freeboard is 0.47 Ft located at 27.15a

ER Vent (Downflood) Height: 9.05ft PATRICIA LEE Load Line Height: -0.64ft

Note: Heel Corrected by Shifting Pots 1.61 feet

Figure 4: Initial hydrostatic condition without crab pot icing, using provided lightship characteristics

195 Pots, Holds 2 and 3 Full. Fuel and Water Full, 20kip bait
Light Ship Source: MSC2019

WEIGHT and DISPLACEMENT and LATERAL PLANE and FREEBOARD STATUS
Baseline draft: 14.041 @ 60.63f, 13.937 @ 0.00, 13.832 @ 60.63a
Trim: Fwd 0.21/121.25, Heel: zero

Part	Weight(LT)	LCG	TCG	VCG
LIGHT SHIP MSC2019	578.33	0.52a	0.00	15.26
Crew and Stores	2.50	8.60a	0.00	16.80
Bait	8.93	50.00f	8.00p	22.00
POTS-Focsle: 11	4.10	39.17f	1.62s	30.96
POTS-TIER1: 82	30.57	4.08f	1.62s	20.12
POTS-TIER2: 36	13.42	3.34f	1.62s	24.86
POTS-TIER3: 33	12.30	2.09f	1.62s	27.83
POTS-TIER4: 33	12.30	2.02f	1.62s	30.83
Ice	11.31	9.95a	0.44p	26.17
Total Fixed	**673.76**	**0.58f**	**0.06s**	**16.56**

	Load	SpGr	Weight(LT)	LCG	TCG	VCG	RefHt
HOLD2.C	1.000	1.025	140.87	12.72f	0.00	8.94	
HOLD3.C	1.000	1.025	122.17	6.26a	0.00	8.81	
FWDWING.S	0.929	0.870	9.01	29.22f	13.02s	6.44	-9.52
FWDWING.P	0.929	0.870	9.01	29.22f	13.02p	6.44	-9.52
MIDWING.S	1.000	0.870	19.29	12.41f	13.56s	6.05	
MIDWING.P	1.000	0.870	19.29	12.41f	13.56p	6.05	
AFTWING.S	1.000	0.870	17.82	6.26a	13.60s	5.95	
AFTWING.P	1.000	0.870	17.82	6.26a	13.60p	5.95	
AFTFUEL.S	1.000	0.870	23.41	44.73a	10.70s	10.05	
AFTFUEL.P	1.000	0.870	17.62	44.69a	11.87p	10.14	
DAYTANK.P	0.925	0.870	11.70	55.47a	10.11p	10.94	-14.09
WATER.S	0.913	1.000	24.87	28.77a	13.66s	8.13	-13.54
WATER.P	0.913	1.000	24.87	28.77a	13.66p	8.13	-13.54
LUBEOIL.P	0.823	0.870	4.76	44.78a	7.12p	8.95	-12.89
SEWAGE.S	0.472	1.025	7.03	55.17a	9.96s	9.39	-11.16
Total Tanks			**469.55**	**5.76a**	**0.09p**	**8.42**	
Total Weight			**1,143.30**	**2.02a**	**0.00**	**13.22**	
			Displ(LT)	**LCB**	**TCB**	**VCB**	
HULL		1.025	1,143.31	2.01a	0.00	8.14	-13.94
		Righting Arms:		0.00	0.00		

Part	LPA	LCP	HCP	LPA	LCP	HCP
Displacers	1492.1	2.47f	-6.31	670.9	8.26f	5.56
Sails	98.8	30.42a	-13.54	2179.2	1.37f	11.85
Total Lateral Plane->	**1590.9**	**0.43f**	**-6.76**	**2850.1**	**2.99f**	**10.37**

Distances in FEET.
Least freeboard is 0.42 Ft located at 0.60f

ER Vent (Downflood) Height: 9.21ft PATRICIA LEE Load Line Height: -0.98ft

Note: Heel Corrected by Shifting Pots 1.62 feet

Figure 5: Initial hydrostatic condition without crab pot icing, using MSC's lightship characteristics

4. ANALYSIS RESULTS

Depending on the lightship characteristics used, MSC's hydrostatics model with the assumed casualty loading condition indicated capsize with 1,800 to 2,900 lbs. of ice on each of the 24 exposed starboard bow crab pots as shown in Figure 6 and Figure 8.

Because ice formation is coupled with wind speed, MSC also evaluated the wind speeds at which capsize or downflooding would occur with asymmetric icing as shown in Figure 7 and Figure 9. It is important to note that the model indicates SCANDIES ROSE has low righting energy in the loaded condition (as shown in ref. (a), page 88) and capsize is indicated with wind speeds as low as 39 knots with no pot icing.

As noted on page 87 of ref. (a), metacentric height (GM) is closely related to the time it takes for the vessel to roll back and forth at small angles (roll period); this is why rolling is frequently used to subjectively assess ship stability. GM is represented graphically as the initial slope of the righting arm curve. As shown in Figure 6 and Figure 8, GM remains relatively unchanged with increasing levels of asymmetric icing. With increasing levels of icing, heel angle increases slightly (remaining below 5 degrees) but the roll period of the vessel would remain similar at small angles up to 5 degrees, after which rolling would start to feel sluggish, especially with higher icing weights.

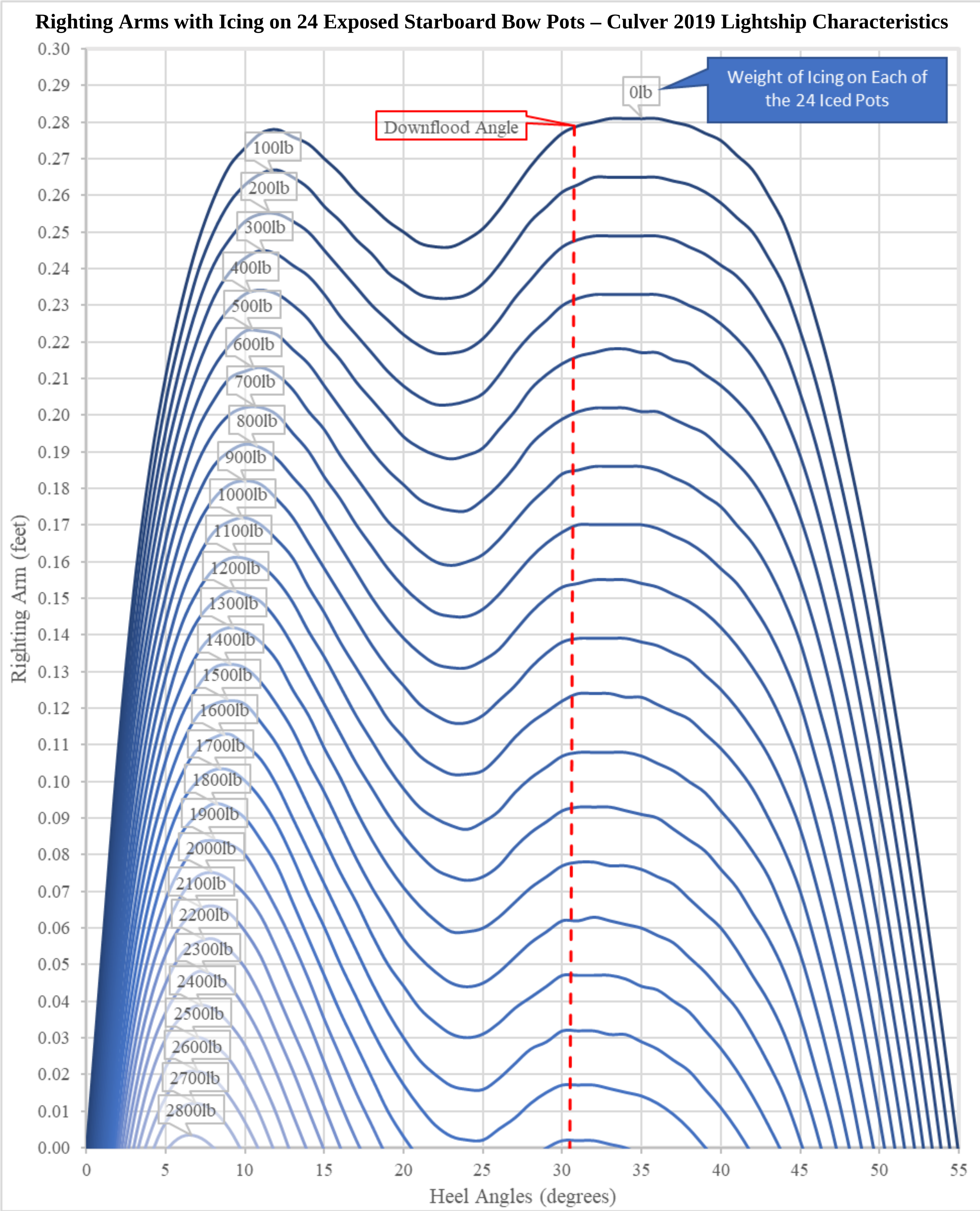

Figure 6: Righting arm plots with increasing ice weights for the 24 exposed crab pots on the starboard bow using Mr. Culver's provided lightship characteristics from 2019

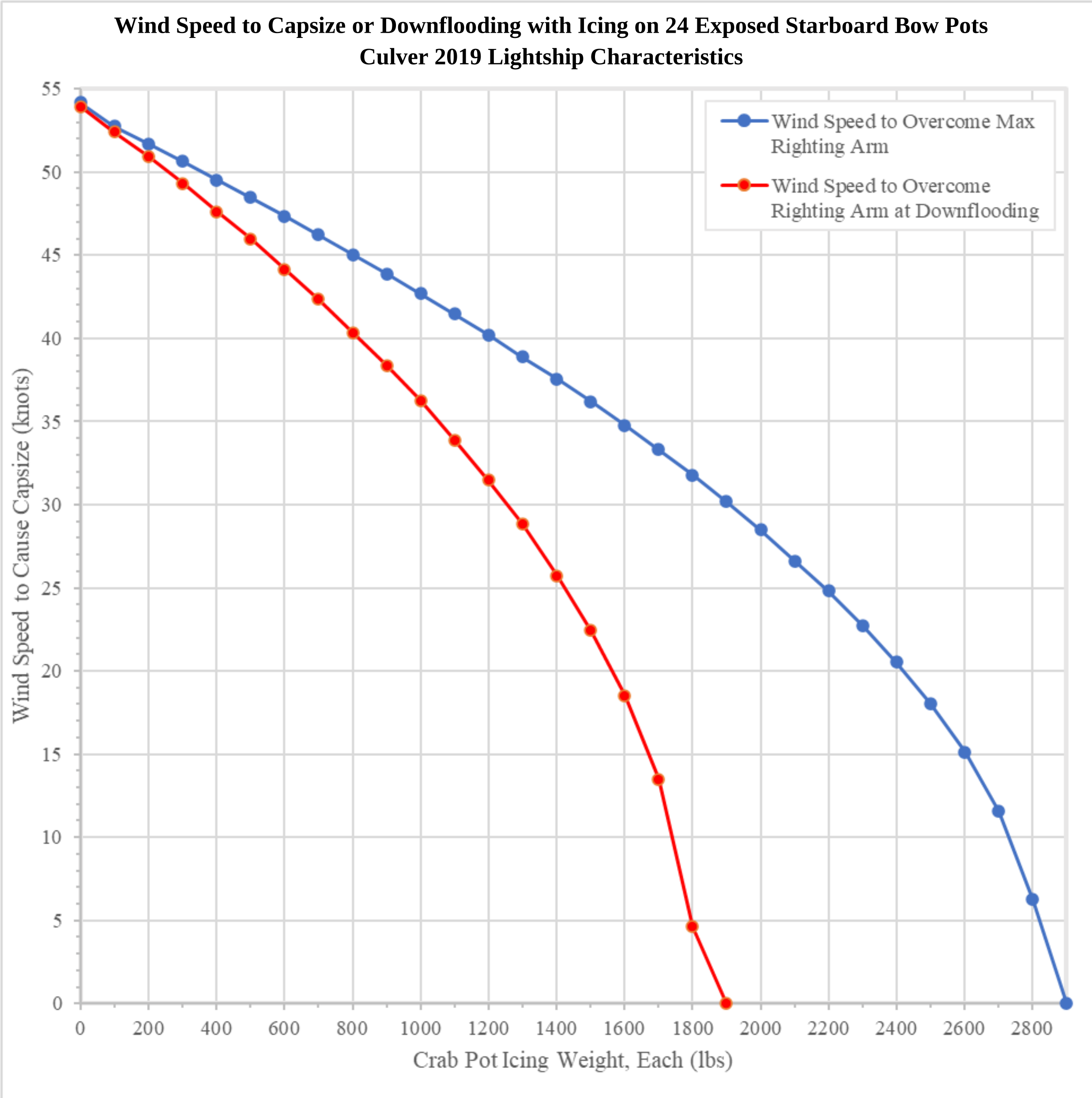

Figure 7: Wind speed to cause capsize or downflooding vs. crab pot icing weight on 24 exposed starboard bow pots using Mr. Culver's provided lightship characteristics from 2019

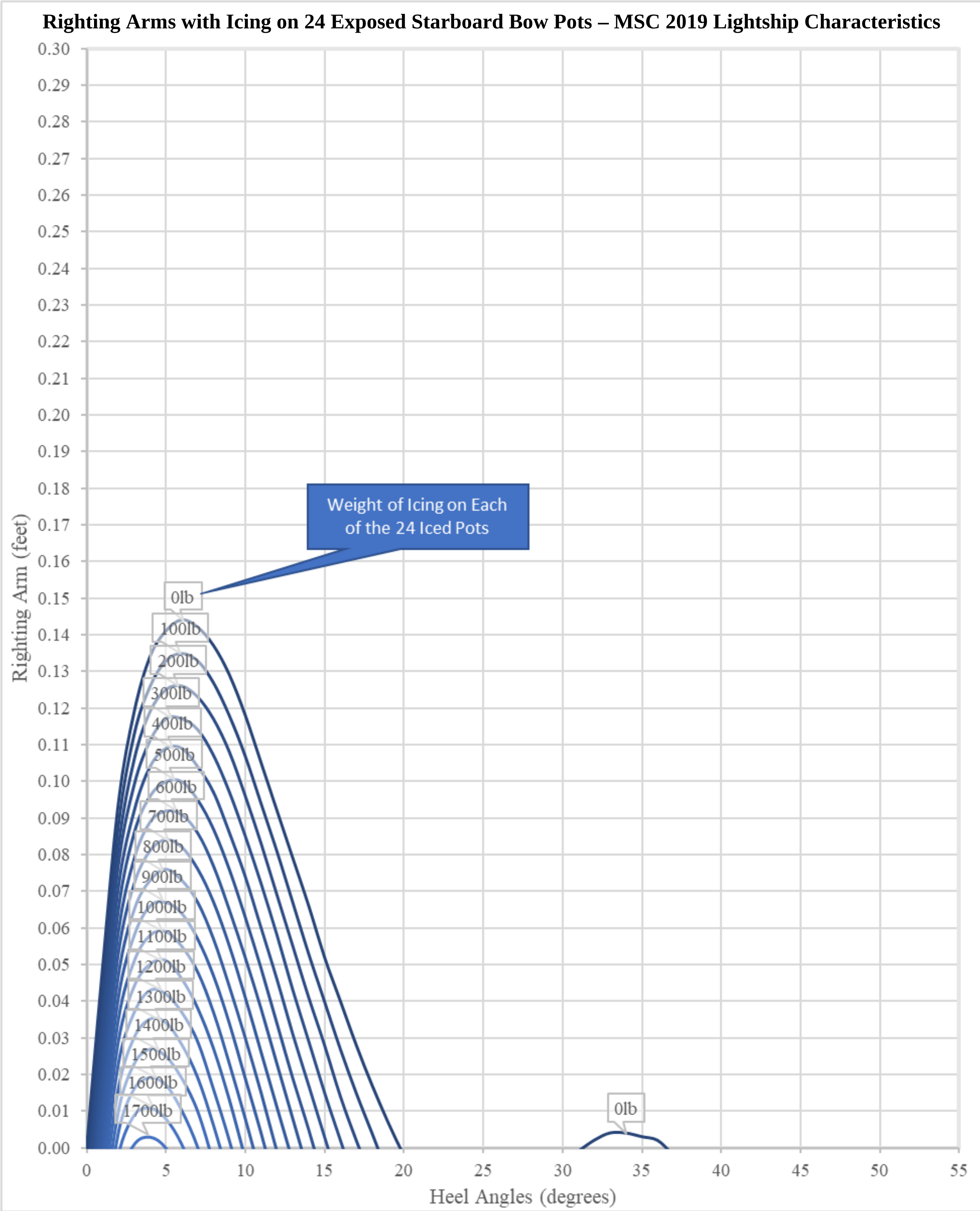

Figure 8: Righting arm plots with increasing ice weights for the 24 exposed crab pots on the starboard bow using MSC's calculated lightship characteristics from Mr. Culver's 2019 stability test notes

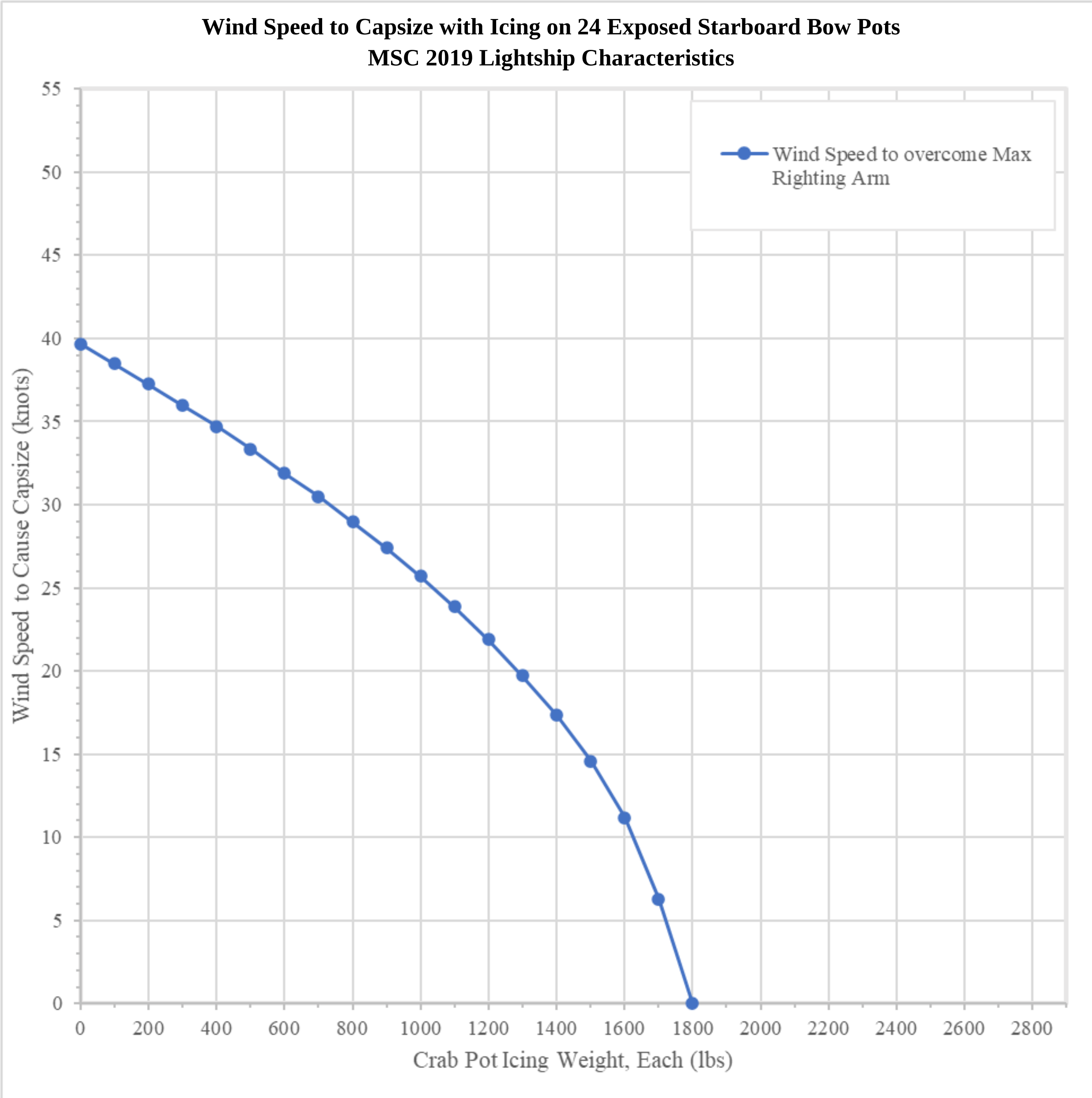

Figure 9: Wind speed to cause capsize vs. crab pot icing weight on 24 exposed starboard bow pots using MSC's calculated lightship characteristics from Mr. Culver's 2019 stability test notes

THE CLOCK IS TICKING... I HAVE A MARINE

EMERGEN

MISSING THAT CRITICAL OPPORTUNITY TO PREPARE FOR ABANDONING SHIP

The crab fishing vessel *Scandies Rose* sank near Sutwik Island, AL on December 31, 2019.

ICY"

BY KEITH FAWCETT

"THE CLOCK IS TICKING… I HAVE A MARINE EMERGENCY"

El Faro sank in the Atlantic on October 1, 2015, east of the southern Bahamas Island Chain.

The time on the morning of October 1, 2015 was 7:27AM. "Let everybody know I'm gunna ring the general alarm," the captain of the American ship SS *El Faro* was heard saying on the bridge as he told the bridge crew to prepare to abandon ship. Just after 7AM, he had called ashore to notify company personnel of the ship's perilous situation in the middle of a powerful hurricane. As the ship was sinking, the captain grew frustrated with the operator at the shoreside call center. He said to the operator, "The clock is ticking.... I have a marine emergency."

Faith in their vessel, pride, loss of situational awareness, and commercial pressures are factors that can contribute to a situation where the master or crew of a vessel misses a critical opportunity to identify and report when their vessel is in serious danger. In the case of *El Faro,* the benefit of hindsight makes it obvious that there was a failure to declare a true emergency until long after that situation occurred.

Our purpose here is to examine the sinkings of the steam ship *El Faro*, the commercial fishing vessel *Scandies Rose,* and finally the tall ship *Bounty*. Each of these vessels was lost amid scenes of horrific and harrowing weather. In the cases of *El Faro* and *Scandies Rose*, the captain declared the actual distress at the last minute, despite there having been ample time and indicators of the danger of the situation leading up to the sinkings. There had been time to notify the entire crew, alert the United States Coast Guard (USCG), and prepare for the worst moment of a mariner's life. That is the moment you tell the crew to prepare for potentially abandoning ship into the peril of the stormed-tossed sea.

In the case of *Bounty*, struggling in 20-to-30-ft. seas under sail and power in Hurricane Sandy, the timely decision to notify the USCG and prepare the crew for abandoning the vessel most likely improved the final outcome, which was survival. Even in this case, in which 14 of the crew survived, there could have possibly been a better outcome when you examine the dramatic final moments in the life of the vessel.

SS *El Faro*

October 1, 2015
Atlantic Ocean, east of the southern Bahamas island chain

At 07:39AM (Atlantic time) the voyage data recorder (VDR) records its last bridge communication and shortly thereafter the ship plunges to the bottom of the Atlantic Ocean, coming to rest more than 15,000 ft. below the surface. In this tragedy, 33 sailors lost their lives in one of America's worst marine accidents on record. The captain, on the bridge, decides to sound the general alarm and wake the crew up 12 minutes before the 790-ft. ship sinks. Based on all of the available evidence, the ship was in trouble hours before the decision to declare the emergency to the crew. For unknown hours, the ship was taking on water as it steamed toward its destination of San Juan, Puerto Rico at full speed into a rapidly intensifying hurricane.

The mates on watch twice recommend to the captain via the ship's phone that they dodge the erratic hurricane, and twice they are rebuffed. The chief mate comes on the bridge at approximately 3:45AM to take his watch, and notices the severe heeling of the ship in the worsening weather and the automatic steering alarm, which is sounding occasionally. The captain can be heard entering the bridge, in the recording at 4:09AM and is greeted by the chief mate. At 4:40AM, the chief mate is on the ship's phone with the engine room and the VDR, the silent marine investigators' sentinel, records the chief mate saying "Captain—chief mate. The chief engineer just called and (then/they) called back again (yeah) something about the list and oil levels * * *." The ship's heeling would affect the level of oil in the main engine sump, the oil critical to the lubrication of *El Faro*'s steam turbine engine.

One could argue as to the exact moment where the captain should have become very concerned for the situation on the ship. Ultimately, however, with a course change later in the morning to close an open deck scuttle allowing water to course into the ship's cargo hold, the ship would lose the steam turbine engine and be at the mercy of the hurricane. After the engine room call regarding the vessel's list and lube oil issues, there were more indicators of a developing emergency onboard. At 5:11AM, the superintendent of an onboard ship repair crew, himself an off duty *El Faro* chief engineer, is heard to remark, "I've never seen it list like this– you gotta be takin' more than a container stack * I've never seen it hang like this." Things were going horribly wrong as the helmsman struggled to keep the ship on course. Water had been coursing down into the hold from an open scuttle on deck and likely from other sources, including the hull ventilation ducts and a potentially damaged fire main.

At 5:43AM, the captain is notified of the open deck manhole in the watertight deck above three hold. The sequence of events that follows would include attempts to turn *El Faro* to position the hurricane force winds on the ship's starboard side so that the chief mate could secure the open scuttle located on the starboard side of a partially enclosed deck, pump the holds, and shift ballast. Still the crew was not called out or notified of the dire situation onboard and the general alarm was not rung. "I think we just lost the plant…" the captain is recorded as saying at 6:13AM, referring to the main engine on the VDR recording. Now, without propulsion, in close proximity to a category 3 storm, in the gathering dawn, *El Faro* was doomed. The investigations into the loss of the ship would reveal that the lube oil flow to the main steam turbine was lost, the engine was beyond any hope of shipboard repair, and the vessel was listing heavily with no means of control.

Based on all of the available evidence, the ship was in trouble hours before the decision to declare the emergency to the crew.

There were no survivors from the sinking of *El Faro* on that early October morning. One deceased victim was located and not identified in an immersion suit. Unfortunately, the search operations precluded the recovery and identification of that victim. Later searches would fail to re-locate the victim in that immersion suit as searchers combed the vast ocean in an attempt to locate survivors, debris, and other clues to what happened to *El Faro*. If one person managed to get off the ship, could others have been more fortunate and managed to survive the sinking? Despite the chaotic situation onboard the ship, the captain waited until 12 minutes before the sinking to sound the general alarm and call out the entire crew to prepare for their worst nightmare, abandoning ship in a powerful hurricane.

On the bridge, there was no discussion on the VDR recording about planning and preparing for abandoning ship, and no mention of using the two 44-person open lifeboats. In this hurricane, that was out of the question. The VDR did record a brief mention o*f* "Yeah– yeah– yeah– get into your get into your rafts * * throw all your rafts (in/to) the water. [yelled throughout]" at 7:32AM, shortly before the final moment on the recording when the ship sunk. At that moment, there was little time remaining to confront the reality of notifying USCG, mustering the crew, and planning for abandoning ship, which should have been reinforced by countless drills and training.

“THE CLOCK IS TICKING… I HAVE A MARINE EMERGENCY”

This *Scandies Rose* computer model depicts the vessel with a 10 degree list to starboard, listing into a 60–70 knot wind on the starboard bow, from sometime after 8PM on the night of the accident. The orange rectangles are crab pots on the starboard side that had begun to accumulate ice as the voyage continued. Source: USCG Marine Safety Center.

Alaskan crab vessel
Scandies Rose

December 31, 2019
south of the Aleutian island chain

At the Coast Guard Air Station in Kodiak, Alaska, the USCG helicopter pilot begins preparing for the worst flight of his life, the flight to the reported position of the distressed fishing vessel, *Scandies Rose*. The flight planning is difficult and takes longer than normal with ferocious winter weather conditions and limited nighttime visibility. Time is of the essence in this harsh environment, where every minute matters to any potential survivors.

Flying through blinding and driving snow, the helicopter arrives in a miraculous circle of clear visibility. The flight crew strains to identify a search target in the 20-ft. seas with no helpful electronic position rescue beacon (EPIRB) transmissions or homing signal from the *Scandies Rose* rescue beacon. The survivors are not equipped with personal locator beacons to assist rescuers such as the aircrew of the rescue helicopter. Suddenly, the aircrew spots a light, and the helicopter maneuvers to lower the rescue swimmer to a bobbing raft in the crashing sea. Keeping the swimmer hooked on the hoist cable due to the danger below, the raft is searched and found to be empty. Glancing ahead, with the two pilots struggling to control the aircraft, the co-pilot sees a light waving side-to-side. Quickly repositioning the helicopter to the second raft, the hoist goes down twice with the swimmer, and two of the seven-person crew of *Scandies Rose* are rescued.

Time is always a critical factor for search and rescue operations, especially in cold water environments. Aboard *Scandies Rose*, before it capsized and sank, the captain bravely stayed at the control station in the wheelhouse and broadcasted a voice mayday call twice, which was received and acknowledged by the USCG in Kodiak. Could the outcome have been different, if additional crewmembers had been able to get off the vessel into one of the vessel’s two rafts? Could all of the crew have been saved and be alive today?

Before the sinking, *Scandies Rose*, with a deck load of large crab pots and gear, raced to get to the commercial fishing grounds as she transited westward, south of the Aleutian island chain of islands. As the clock ticked on New Year’s Eve, a steady and uneven layer of ice began to coat the starboard, forward side of the vessel. The captain took the watch from a deckhand in the early evening, and there were “a few” degrees of list to starboard. In hindsight, there was something terribly wrong. A few degrees to starboard might seem insignificant, but the ship was listing into more than 40 knots of wind on that same side and the wind was propping up the vessel. Without the winds, the list would have likely been far worse at a time when there was increasing icing conditions and a heavy icing forecast in effect for the voyage.

The captain and deckhand discussed potentially breaking off the ice, but there was no way to safely go forward, except sending the crew forward over the top of the iced crab pot stacks. From the wheelhouse, at night, there was no way on *Scandies Rose* to determine just how much ice was building. The captain settled into the watch at the helm and on course for Unalaska Pass, and he made several phone calls to tell his friends and associates. In those calls, he talked about the worsening situation onboard *Scandies Rose*. In one of those calls, the captain said that he intended to head to Sutwik Island to seek shelter from the weather. In a subsequent conversation, he told an associate at 8:37PM that his vessel was icing "really bad" and had developed a 20° starboard list. This 20° list was still a list into gale force winds on the starboard bow and forward beam. The captain reported the weather to be winds at 60-70 knots from the west and air temperature of 12° F. If the "few" degrees noted at the previous watch change wasn't a point of serious concern, the time leading up to this moment when the list began increasing was a serious and dangerous situation.

As the captain completed this final satellite phone call to an associate, the deckhand who was relieved by the captain earlier and the other deckhand in the cabin were alarmed by the sudden heavy list to starboard. In subsequent investigation interviews, one of the deckhands stated, "I jumped out of my bunk in a panic and ran upstairs. I knew something was wrong right away." The clock was ticking off the moments before the sinking and the loss of five of the crew. Heading to the wheelhouse, the scene was chaotic with crew struggling to access and don survival suits. At 9:55PM, the captain issued a mayday call to USCG, giving the position and the fact that the vessel was rolling over. Minutes later, the vessel sank on its starboard side and the two survivors jumped into the frigid water in their immersion suits and luckily made it to one of the two liferafts. There they would struggle to survive in the water-filled raft until they heard the rotor blades of the helicopter maneuvering in the storm overhead, four hours later.

It is important to ponder if there were missed opportunities that would have prevented or mitigated this tragic incident. That may be the case, especially if the captain had announced an emergency onboard the vessel after making his 8PM New Years Eve call, when he told a friend that his vessel had icing and a list. The vessel was far from potential rescuers and shelter and in dangerous environmental conditions at that time. At that moment, notifying USCG and the crew to prepare them for the possibility of the situation worsening may have saved lives. Later, when the captain made the last phone call to the captain of another fishing vessel, his tone had changed to one of alarm. However, it was too late to properly prepare the crew at that point and, moments later, he would call the mayday as the vessel was sinking.

Identifying the moment when the situation began to seriously deteriorate would have allowed the crew to avoid the "pure mania" in the wheelhouse as people struggled to prepare to abandon ship. It would have allowed USCG to track the situation on the vessel and begin communication checks and as the situation worsened it might have allowed USCG aircraft crews more time to plan for this harrowing rescue and minimize the time to arrive on-scene. Onboard *Scandies Rose*, the crew could have been mustered in an orderly way, with survival gear checked and immersion suits donned, and it would have allowed the captain to ensure that USCG understood his situation and was tracking him using the vessel's automatic identification system. That early tracking would have eliminated the need for the captain to remain at the helm for the transmission of the final distress message as the fishing vessel capsized to starboard.

As the situation worsened, according to protocol, USCG would have told him to activate the EPIRB, to aid in locating and homing on the vessel. The EPIRB, which had been recently inspected and serviced ahead of the fateful voyage, was never located and its signal was never received by satellites equipped to receive the distress signal and transmit that vital information to search and rescue authorities such as USCG.

Scandies Rose is shown moored in Seattle, WA in June 2019. Photo courtesy Erling Jacobsen.

"THE CLOCK IS TICKING... I HAVE A MARINE EMERGENCY"

Tall ship
Bounty

October 29, 2012
Atlantic Ocean, 123 miles east of the North Carolina coast

Hurricane Sandy, in late 2012, was a devastating storm. The USCG Report of Investigation Executive Summary begins, "On Thursday October 25, 2012, the Tall Ship BOUNTY sailed from New London, CT, bound for St. Petersburg, FL with 16 crew aboard." The exhaustive report would detail the events and circumstances that would result in the presumed death of the captain and the death of one of the crew and the replica ship's sinking in Hurricane Sandy, off the coast of North Carolina. The rescue would strain the USCG flight crews due to the distance offshore and the impact of the hurricane weather as the ship declared distress.

By Sunday, October 28th, *Bounty* and her crew were struggling in attempting to cope with the dangerous hurricane. Multiple crew members were seasick due to seas of 20 to 30 ft. and sustained winds more than 90 knots as the vessel progressed at 4 knots on a southeasterly course with a combination of sails and engine powering the ship. Water was in the bilges with dewatering pumps straining to keep up as the day progressed and the situation continued to worsen. The ship's engineering systems were not able to cope with the seas and wind and its generators, which were vital to pumping the bilges, began to fluctuate.

At 4:26AM on October 29, Bounty rolled on her starboard side, buried her bow, and capsized violently onto her beam ends.

The crew notified the vessel owner who advised them to notify USCG. At 8:45PM, the shoreside support for *Bounty* notified USCG of the dire situation onboard the ship. Upon this notification, USCG also received a rescue beacon signal from *Bounty*'s EPIRB, prompting USCG to launch a fixed-wing aircraft to *Bounty's* position to keep an eye on the ship because the weather was too extreme to send a rescue helicopter to the scene. The USCG C-130 established communications with *Bounty's* crew, who reported that there was six feet of water in the ship's hold at this point. The aircraft estimated the weather onscene as 40 knot winds and 18-ft. seas. As Monday morning dawned, the situation continued to worsen. At approximately 3AM, the captain told the crew to prepare to abandon ship. Their plan was to abandon ship at first light in order to provide daylight conditions for the rescue and to allow the hurricane to move away from the ship, giving USCG better conditions to affect what would still be considered a hazardous rescue operation.

At 3:30AM, the water in the bilge had risen to the tween deck spaces, which effectively forced the crew to retreat to the open weather deck where they prepared ditch kits, donned immersion suits, and prepared to abandon ship. Via email, at 3:41AM, the captain told USCG, "We have lost all dewatering abilities. Estimate 6 – 10 hours left. When lose all power we will lose email. There should be an EPRB going off. Water is taking on fast. We are in distress. Ship is fine we can't dewater. Need pumps."

Ashore at the USCG Air Station, another C-130 fixed wing aircraft and two H-60 helicopters were being readied for the rescue. *Bounty's* crew were in their immersion suits, prepared and ready to abandon ship. The ship was still struggling in the sea and still afloat when, at approximately 4:20AM, the chief mate recommended that they abandon ship in perhaps the best conditions they would encounter. Twice the chief mate reported that the captain told him, "not yet." At 4:26AM on October 29, *Bounty* rolled on her starboard side, buried her bow, and capsized violently onto her beam ends. Survivors recounted the movement of the vessel now as chaotic. The mast and rigging slammed down onto the surface of the sea in the dark with 40-50 knot winds and 18–20-ft. seas. With no time for the crew to grab the ditch kits, several crew were temporarily trapped by the rigging, spars, and their safety harnesses. From the USCG investigator's report, "At 0434 a.m., the order was given for all planned Coast Guard air assets to launch. The onscene weather was still outside the operating capabilities of the H-60s."

The plan had been to do an orderly, under the conditions, abandon ship with a line used to enable movement of the

Aerial photo taken by a USCG rescue aircraft of the replica tall ship *Bounty*, just before it sank in the Atlantic Ocean during Hurricane Sandy on October 29, 2012. Photo courtesy USCG.

crew to liferafts tethered to the ship until they were loaded with the crew. The two 25-person liferafts would be thrown into the water, inflated, and tethered to the ship for boarding as they abandoned ship. Under these conditions, the crew reported that, in the chaos, it took almost an hour (with injuries to some crew) to board the water-filled rafts. One of the crew was found unresponsive and later died, as life support was attempted in the helicopter enroute to shore and waiting medical facilities.

In marine and aviation terminology, “mayday,” indicating distress, means a grave or imminent situation requiring immediate assistance. In the *Bounty* tragedy, the captain and crew wisely identified the perilous situation and notified USCG of their situation and prepared to abandon ship. As time went on and the situation became a distress situation with 6 to 10 ft. of water in the bilges in hurricane conditions, the ship’s motions in the seaway were still manageable and the crew missed the opportunity to abandon ship under the best possible conditions. Prepared and ready, the crew could have potentially had the rafts in the water, with ditch kits containing survival supplies and have been over the side waiting for the dawn rescue, clear of the sinking ship, spars, and rigging. Although those conditions are less than ideal, the crew would have likely been waiting for rescue in the rafts equipped with canopies and water ballast to improve stability, and it’s possible that everyone could have survived the sinking.

In each of these tragic and preventable cases, lives and vessels were lost. In the case of *El Faro* and *Scandies Rose*, the key decision makers did not identify the true nature of the situation in time and waited to ready the crew to prepare for abandoning the vessels in the center of intense storms. Notifications to rescue authorities, in this case USCG, were also delayed, preventing authorities from conducting early monitoring and using their well-honed tactics and procedures to prepare for and affect a potential rescue of the mariners at risk.

In the case of *Bounty*, the captain notified USCG prudently and had the crew prepared to abandon ship. However, the captain waited until the last minute to give the dreaded, but vital, command to abandon ship. Precious time was lost that could have enabled the crew to safely disembark the ship into the rafts and await the rescue forces that were enroute to the scene. With daylight overhead, at 6:41AM, the first of two USCG helicopters arrived and began hoisting 14 survivors into the aircraft. At 4:38PM, one victim was sighted and recovered unresponsive. The captain was never located.

Tragedy provides lessons that need to be taken to heart. If a situation begins to deteriorate on your vessel, be aware and continually assess the risks and consequences, if you have time. Erring on the side of caution to prepare the crew, notify rescue authorities, don lifesaving equipment, and ready the EPIRB for potential deployment often means the difference between life and death for mariners in extremis. In addition to making all possible preparations ahead of abandonment, a timely decision on when to actually abandon your vessel is paramount to increasing the potential for survival for the crew. **MT**

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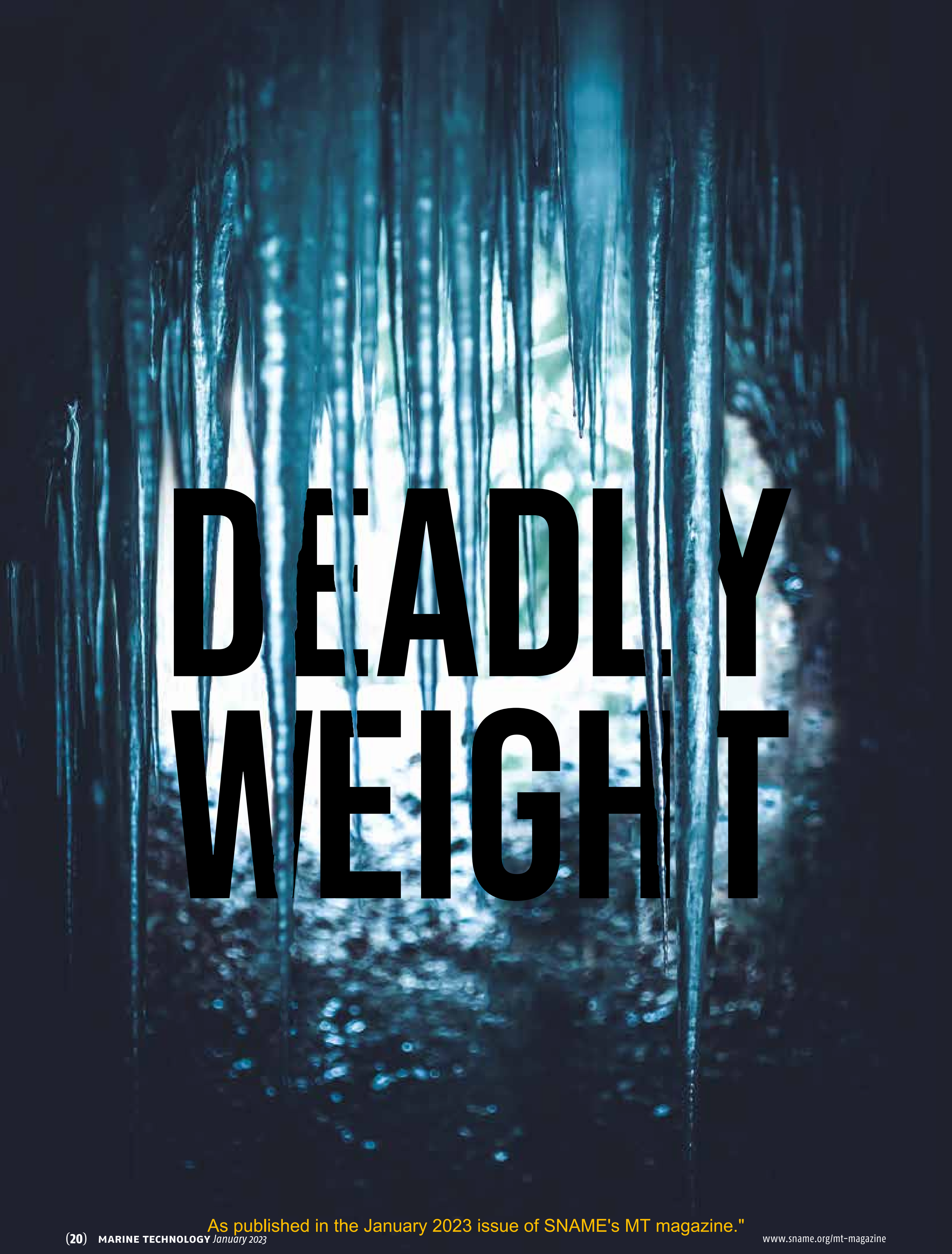
DEADLY WEIGHT



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The danger of ice accretion on large crab pots

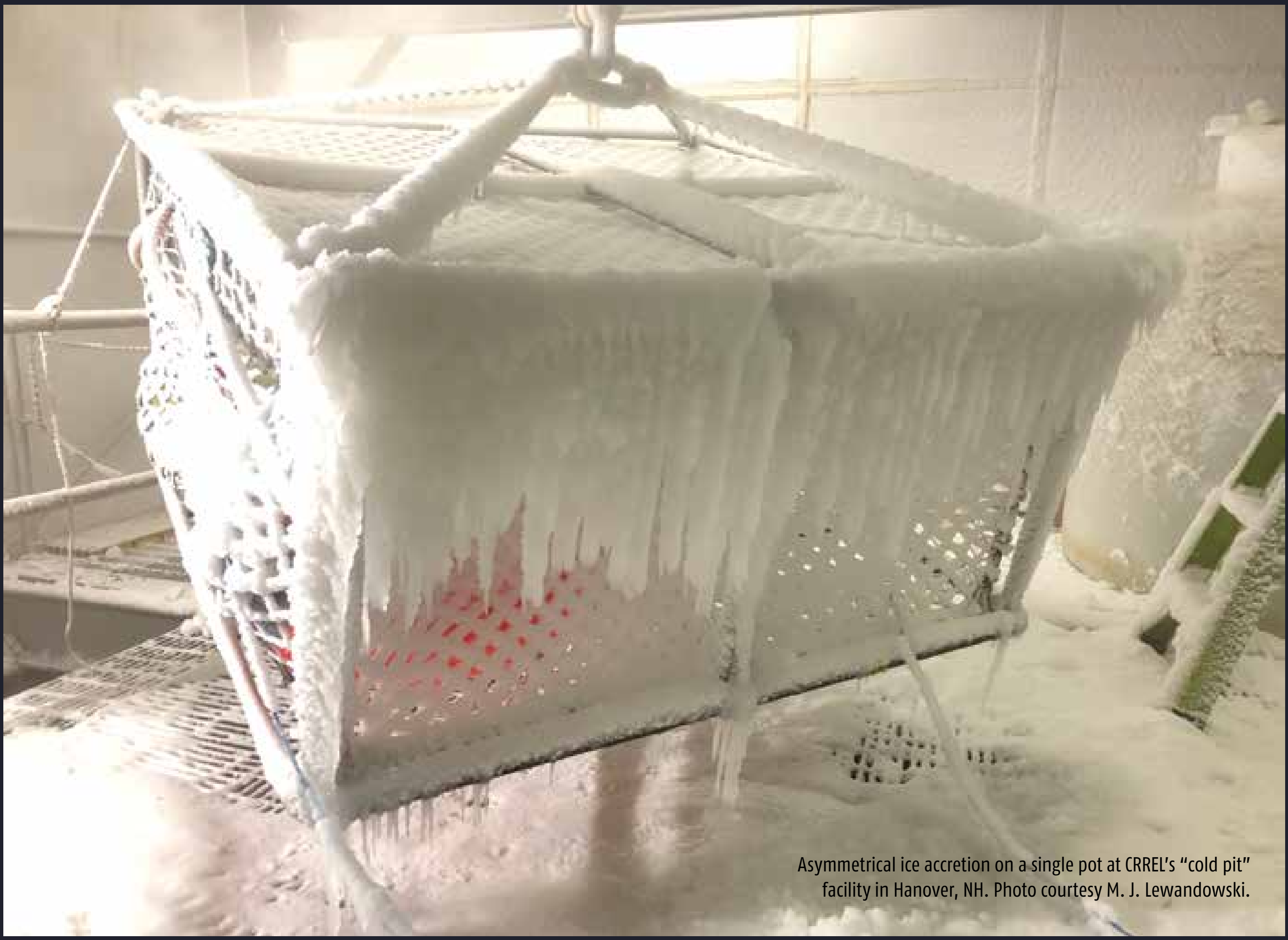
BY KEITH FAWCETT , M.J. LEWANDOWSKI, AND SHALANE REGAN

In the past few years, twelve fishers have perished as a result of the apparent and sudden loss of stability aboard two Alaskan crabbing boats. In 2017 and on New Year's Eve 2019, fishing vessels *Destination* and *Scandies Rose*, respectively, were lost in Alaskan waters. According to the United States Coast Guard (USCG) and the National Transportation Safety Board, the most likely cause for both cases was ice accretion on the upper tiers of large, stacked crab traps caused by sea spray and freezing temperatures common to the Alaskan marine environment.

A typical Alaska crabber can be 75 to 120 ft. long, with a crew of 7 to 10, and might carry more than 200 large crab traps (pots), with some as large as 9 x 9 x 3 ft. and weighing up to 900 lbs. when dry. Vessels can—and will—stack these pots up to nine high. For transits to the fishing grounds, these pots will hold buoy lines and marker floats, and they are typically covered by synthetic mesh webbing to ultimately contain the catch.

During transit, freezing sea spray and howling winds create conditions that dangerously impact a crabber's intact stability. In many cases, the vessel captains do not have formal stability training; they know that icing is inherently dangerous and recognize changes to the vessel's roll and pitch, but they may be unaware of the dangers posed by the uneven layers of pot ice and the potential for catastrophic loss of vessel stability.

Scandies Rose sank in dangerous weather as the vessel attempted to reach shelter at Sutwik Island, which was only a few miles beyond the accident site. To examine all facts related to the loss, the USCG convened the highest-level investigative body, known as a Marine Board of Investigation (MBI). The two surviving crewmembers both reported ice accretion on the starboard-side crab pots. Eventually, because of the heavy ice build-up, *Scandies Rose* was listing **into** the 60 to 70 knot wind and the list exceeded 20 degrees to starboard. After effecting a turn into the wind and



Asymmetrical ice accretion on a single pot at CRREL's "cold pit" facility in Hanover, NH. Photo courtesy M. J. Lewandowski.

Alaska crabber with pots stacked. Photo courtesy Coast Guard Marine Board of Investigation.

heading to the shelter of Sutwik Island, the vessel suddenly capsized. Could this list to starboard and the ice accretion on the pots on that side have been the culprits?

The MBI reached out to the USCG's Research and Development Center (RDC) for answers. Could the RDC determine a scientific answer for the weight increase of large crab pots keyed to the thickness of ice that would be typically encountered in these dangerous and frigid waters? The end goal was to better prepare fishing vessels that may typically encounter these dangerous, frigid conditions to understand the dangers of vessel and gear icing.

Formulating a Plan

Gathering information from the MBI, the RDC began to formulate a plan. Initially, they thought to capitalize on using an icebreaker, the Coast Guard cutter *Polar Star*, already in Alaskan waters, with an RDC staff engineer embarked. The plan: get a large commercial crab trap onboard the ship and develop a test procedure to have ice accumulate on the pot, and then determine the accumulated weight.

The RDC, MBI, and Seventeenth Coast Guard District (CGD17) worked to locate a pot with all of the associated internal gear that researchers could observe for an informal ice accretion test onboard *Polar Star* during its Arctic West winter patrol. After locating a representative pot, *Polar Star* loaded the 1,000-pound, 8 x 8 x 3-ft. pot in Dutch Harbor, AK, strapped it to the deck, and rigged a spray system with a garden hose and mist gun to simulate sea spray. After approximately 60 hours, the spray created noticeable accretion, particularly on the pot mesh webbing.

When *Polar Star* tried to weigh the pot, the total weight exceeded the scale capacity, indicating a total weight of more than 3,000 lbs.—an additional 2,000 lbs. of ice. This preliminary test showed that severe icing could **triple** the weight of a pot.

Simultaneously, the RDC aimed to develop a more representative methodology to replicate sea-spray icing conditions. Unable to procure pots or establish a testing site outdoors before spring weather reached their coastal Connecticut facility, the RDC called on the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. CRREL had done extensive work on vessel ice accretion in the past and had access to controlled-environment facilities, enabling tests to occur without regard for outside air temperature.

For the CRREL tests, the RDC procured three slightly smaller pots, each complete with external webbing, lines, and marker buoys. RDC collaborated with CRREL personnel and MBI investigators to design an experiment that would best replicate real-world conditions, operate within facility constraints, and best meet the needs of the MBI. For example, when unable to recreate gale-force winds and heavy sea spray, the teams compensated by using an oscillating nozzle to direct pressurized saltwater spray at either the top, side, or corner of a pot or stack of pots with direction

Hoisting the crab pot onto the scale for weight after accretion onboard *Polar Star*. Photo courtesy Shalane Regan.

DEADLY WEIGHT

During transit, freezing sea spray and howling winds create conditions that dangerously impact a crabber's intact stability.

determined by the test plan target. The test plans also dictated whether pots were tested in individually or in stacks (up to three high), and the frequency with which pot weight, ice thickness, and distribution of ice formation were measured.

Test Chambers

The experiments used two spaces in CRREL's "cold pit" (the smaller of the two chambers), and the "materiel evaluation facility," where the pots could be stacked three high. Both test chambers were capable of -15°F air temperatures and allowed an oscillating spray of 36°F saltwater to replicate conditions that *Scandies Rose* faced in Alaskan waters.

Researchers monitored the test conditions and ice accretion through a constant-readout load cell and 30-minute measurements of ice thickness at designated test points on the pot frame(s). The procedure aimed to determine a correlation between accreted thickness and accumulated weight, as in much of the MBI testimony crews talked about ice thickness and did not describe the weight changes in an individual pot and gear. To compare ice accretion between uncovered and covered pots, researchers also conducted two experiments with pots under weatherproof tarps.

Currently, crabber stability calculations only consider ice accretion on the exterior of pots. By comparing ice accretion on uncovered and covered pots, the researchers investigated how much additional ice accretion (and therefore, additional weight) an untarped pot might allow, and the potential impact on the stability calculations.

Both the uncovered and covered pots recorded substantial ice accretion weight during their test periods with the greatest ice accretion exceeding 1,000 lbs. within 3 hours. Table 1 shows the maximum change in weight for one-, two-, and three-pot combinations. Although covered pots experienced less ice accretion than uncovered pots, these covered pots still increased in weight by more than 400 lbs. within 2-1/2 hours, a period of time much shorter than Alaskan crabbers and other fishing vessels experience taking spray.

Because of the laboratory facility limitations, the placement of the spray nozzles favored asymmetrical ice accretion, causing the pots to "lean in" toward the spray. This led to further discussion of whether non-uniform, heavier ice loading on an exterior row of pots could further compromise stability and complicate its calculation.

Difficult to Estimate

The MBI had concerns about how mariners commonly estimated ice accretion in terms of inches. To address this, after two of the last tests, the researchers placed the three-high stack 45 ft. from an elevated stand to simulate the vantage point that the two *Scandies Rose* survivors had from the wheelhouse, before the accident. Without a reference point, accurately estimating the ice thickness on any point of the distant pot(s) is very difficult. From the wheelhouse, the ice that appears to be only inches thick may actually be much thicker, and large areas of the pot stack are not visible, such as the area forward of the stack of pots.

TABLE 1: Characteristics of Small-Scale Tanks

STACK HEIGHT	COVERED?	WEIGHT INCREASE (POUNDS)	SPRAY DURATION
1	No	840	2 hr. 07 min.
2	No	1,080	3 hr. 00 min.
3	No	1,654	7 hr. 03 min.
1	Yes	520	2 hr. 20 min.
3	Yes	420	2 hr. 30 min.

The materiel evaluation facility test chamber at CRREL in Hanover, NH, showing a 3-pot stack and oscillating spray nozzle. Photo courtesy M. J. Lewandowski.

DEADLY WEIGHT

Crab pot under weatherproof tarp to demonstrate ice accretion on covered pots. Photo courtesy Michael Wurl.

Ice accretion as viewed from 45 ft., part of the tests carried out at CRREL's facilities. Photo courtesy M. J. Lewandowski

Ultimately, these experiments were limited by the inability to accurately replicate **wind-driven** spray and spume consistent with the sea spray that *Scandies Rose* likely encountered in 60 to 70 knot winds, for the duration beyond a few hours. The research team fully understood this limitation, and reported out only what they found. The degree of real-world ice accretion could be expected to exceed that encountered in the lab experiment.

Understanding that these results provide a minimum baseline, additional testing is necessary to further quantify ice accretion on the exterior and interior of pots in order to better quantify the associated accumulated weight, and inform stability calculations and subsequent policies governing commercial fishing vessels operating in cold weather environments. Maintaining safety for the vessel crews is a paramount concern, and additional testing may establish the grounds to enhance safety measures to better protect those operating in some of the harshest marine environments.

Ideally, an accurate metric to correlate observed accretion to an accurate accumulation of extra weight would be a good tool for the fishing industry. In this case, the study was not able to make a direct scientific correlation that would be helpful.

The RDC published formal results of the work as a Rapid Evaluation and Analysis of Critical Technologies (REACT) study "Ice Accretion on Crab Pots," available at: AD1157461.pdf (dtic.mil). **MT**

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