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Stress Tests on the Wolfson Stability Method for Small Fishing Vessels Small Grant Final Report Sg4\100045

1 INTRODUCTION

The Wolfson Stability Method adopted in the 2021 UK Code of Practice for Small Fishing Vessels (Merchant Shipping Notice 1871 Amendment 2) enables fishermen to assess the limits for operating their own boats safely. The Method relies on vessel capsize tests at model scale and selected UK casualty data up to 2012.

This report presents an expanded vessel casualty database obtained from a review of accident investigation reports worldwide, and its use for stress testing the Wolfson Stability Method. This work was commissioned on 9th December, 2021 by Dean Cassar representing Lloyd's Register Foundation (LRF), following Small Grant application ref. Sg4/100045 dated 1st November, 2021.

2 LIST OF ABBREVIATIONS AND ACRONYMS

Marine Accident Investigation Bodies

ATSB	Australian Transport Safety Bureau
DMAIB	Danish Maritime Accident Investigation Board
EMCIP	European Marine Casualty Information Platform
FEBIMA	Federal Bureau for the Investigation of Maritime Accidents, Belgium
GAMA	Gabinete de Investigação de Acidentes Marítimos
IoM SR	Isle of Man Shipping Registry
MAIB	Marine Accident Investigation Branch, UK
MCA	Maritime and Coastguard Agency, UK
MCIB	Marine Casualty Investigation Board, Ireland
SHK	Statens Haverikommission, Sweden
TAIC	Transport Accident Investigation Commission, New Zealand
TSB	Transportation Safety Board of Canada

Other Abbreviations

B	Beam Overall, metres
Δ	Displacement, tonnes
GZ_{max}	Residual Righting Lever, metres
Hs	Significant Wave Height, metres
H_{crit}	Critical Wave Height to Capsize
LR	Registered Length, metres
L	Length Overall, metres
Range	Range of Positive Residual Stability, degrees
RM_{max}	Maximum Residual Righting Moment, tonne.metres

3 BACKGROUND

On 6/9/2021 the new UK Code of Practice (CoP) for the Safety of Small Fishing Vessels came into force. The CoP regulates new and existing fishing vessels less than 15m length overall and introduces new requirements that are intended to reduce the high rate of fatalities in the fishing industry, approximately 100 times higher than that of the UK general workforce.

With regard to vessel stability and freeboard, the CoP implements key Marine Accident Investigation Branch recommendations such as 2016/30 (F/V JMT) '...all existing vessels of under 15m to be marked using the Wolfson Method or assessed by use of another acceptable method'. Crucially, the CoP states that 'all vessels not required to hold a Stability Information Book must have a Wolfson Stability Notice posted on board the vessel, which gives information on the loading of the vessel and its effect on stability'. This new requirement applies to nearly all fishing vessels under 12m RL and to pre-2017 fishing vessels between 12m Registered Length and 15m Overall Length.

A simple online tool available at **http://www.wolfsonunit.com/services/vessel-safety** enables fishermen to produce a Wolfson Stability Notice and associated Freeboard Mark at no cost, based solely on the length and beam of their own boat. The Notice contains vessel-specific lifting and loading limits in relation to the prevailing seastate and conveys them via a simple traffic lights system. The Freeboard Mark enables fishermen to assess the current level of safety of their own vessel whilst in operation.

4 SCOPE OF WORK

The Wolfson Stability Method, formulated in 2004-06, stems from model capsize tests on high-speed craft hull forms [1]. Subsequently, additional model test data and documented vessel capsizes confirmed the predicted area of safe operation, [2] and [3]. These data are shown in Figure 1 and are referred to as 'STAB 2012' casualties in this report.

The critical wave height to capsize proposed in [3] is:

$$Critical\ Wave\ Height = \frac{Range\sqrt{RMmax}}{10B} \quad (1)$$

Eqn. 1 represents the minimum wave height to capsize a vessel of beam B with known residual stability characteristics. Eqn. 1 normalised by overall length is referred to as 'Wolfson Formula' that is, the solid black line of Figures 1 and 2 which separates the safe zone of the plot (vessel expected to be safe from capsize) from the unsafe zone (vessel vulnerable to capsize). The STAB 2012 casualties fall either within the unsafe zone of the plot or on the critical line, which supports the Wolfson Method.

Fifteen years after its formulation, it was deemed appropriate to stress test the Method by adding further UK and international vessel casualties to the database, to confirm or adjust the extents of the safe zone of Fig. 1.

5 EXTENSION OF THE WOLFSON CASUALTY DATABASE

A capsize event is suitable for the Wolfson casualty database if its loss condition and probable wave height at the time of the accident can be estimated with reasonable accuracy. For documented vessel capsizes, this information was obtained from accident investigation reports and additional documents, including Fatal Accident Inquiry reports (Scottish Courts), Coroners' Inquest reports (England and Wales), vessel stability reports compiled by independent consultants, model test reports and computer stability models, where available.

2403 published marine accident investigation reports from 10 marine investigation bodies worldwide were considered for this study. Some national (ATSB, DMAIB) and international (EMCIP) databases enabled

filtering by event type, hence capsize/listing and flooding/sinking events were searched. Other accident databases enabled keyword searches, therefore a wider range of keywords was used, including 'loss', 'stability', 'foundering' and 'downflooding'.

268 vessel casualties were identified, whose reports were examined to assess the exact nature of the accident and the data provided. Vessel losses not related to stability (e.g. catastrophic hull failures, groundings and tug girthing events) were filtered out, as were those presenting minimal stability information, unreliable weather data and/or inconclusive findings. As a result, 25 new casualties were deemed suitable for the Wolfson stability database which are 16 fully documented casualties (all fishing vessels bar 1 passenger vessel) and 8 casualties with incomplete stability data. The missing data has been requested but had not been made available at the time of writing this report.

Initially, selected STAB 2012 casualties were re-analysed to ensure consistency between the 2006, the 2012 and the 2022 analysis. Minor inconsistencies were found in the derivation of the probable wave height at the time of the accident from the published sea state data, so the relevant STAB 2012 points were adjusted as appropriate. Subsequently, the new casualties were analysed and assessed against the Wolfson formula. Table 2 presents the new Wolfson casualty database and Figure 2 provides the result of the analysis.

6 CONCLUSIONS

6.1 The Wolfson casualty database was extended from 13 to 30 casualties, and now encompasses a wide range of hull forms, hull dimensions, methods of fishing and loading conditions. In addition, 8 partially documented casualties were identified and the missing data requested to the relevant accident investigation bodies.

6.2 All the new capsize events, designated in Figure 2 as 'LRF 2022' fall on the Wolfson line or to the unsafe side of it. This supports the current formulation of the Wolfson Method, as adopted in the new UK Code of Practice.

6.3 An efficient method for reviewing and analysing marine accident investigation reports has now been established. This will enable adding future casualties efficiently, as well as existing documented casualties from additional accident investigation bodies.

6.4 More than 200 fishing vessel accident investigation reports were reviewed. This exercise, as expected, highlighted common themes as to what causes capsizes and fatalities, namely:
- weight growth and centre of gravity upward shift over time, resulting in loss of residual stability;
- vessel overloading, resulting in loss of residual freeboard;
- gaps in the regulation or inspection regime, hence undetected deterioration of the vessel stability;
- installation of winches and lifting equipment powerful enough to capsize the vessel;
- financial pressure, resulting in risk-taking behaviour, crew fatigue and poor vessel maintenance;
- deficient water freeing arrangements, causing water trapped on deck in heavy seastates;
- lack of safety training/awareness resulting in poor safety standards onboard, eg. limited use and/or poor maintenance of Personal Flotation Devices (PFDs), Personal Locator Beacons (PLBs), Emergency Position Indicating Radio Beacons (EPIRBs), liferafts and bilge pumps.

7 REFERENCES

1. Deakin, B., 2006, "Loading Guidance for Fishing Vessels Less than 12m Registered Length", Maritime & Coastguard Agency Research Project 559 Phase II, Final Report No. 1903/2, Wolfson Unit MTIA. Available at http://www.wumtia.soton.ac.uk/about-us/published-papers/stability-and-loading-guidance-fishermen as of 31st March, 2022.

2. Deakin, B., 2010, "Collating Evidence for a Universal Method of Stability Assessment or Guidance", Trans RINA, Vol. 152, Part A2, International Journal of Maritime Engineering.

3. Deakin, B., 2012, "Spend Less, Save More (Lives)", Proc. of the 11th International Conference on the Stability of Ships and Ocean Vehicles (STAB 2012), Athens, Greece.

Figure 1 Correlation of Casualty and Model Data with the Wolfson Formula, STAB 2012 [3]

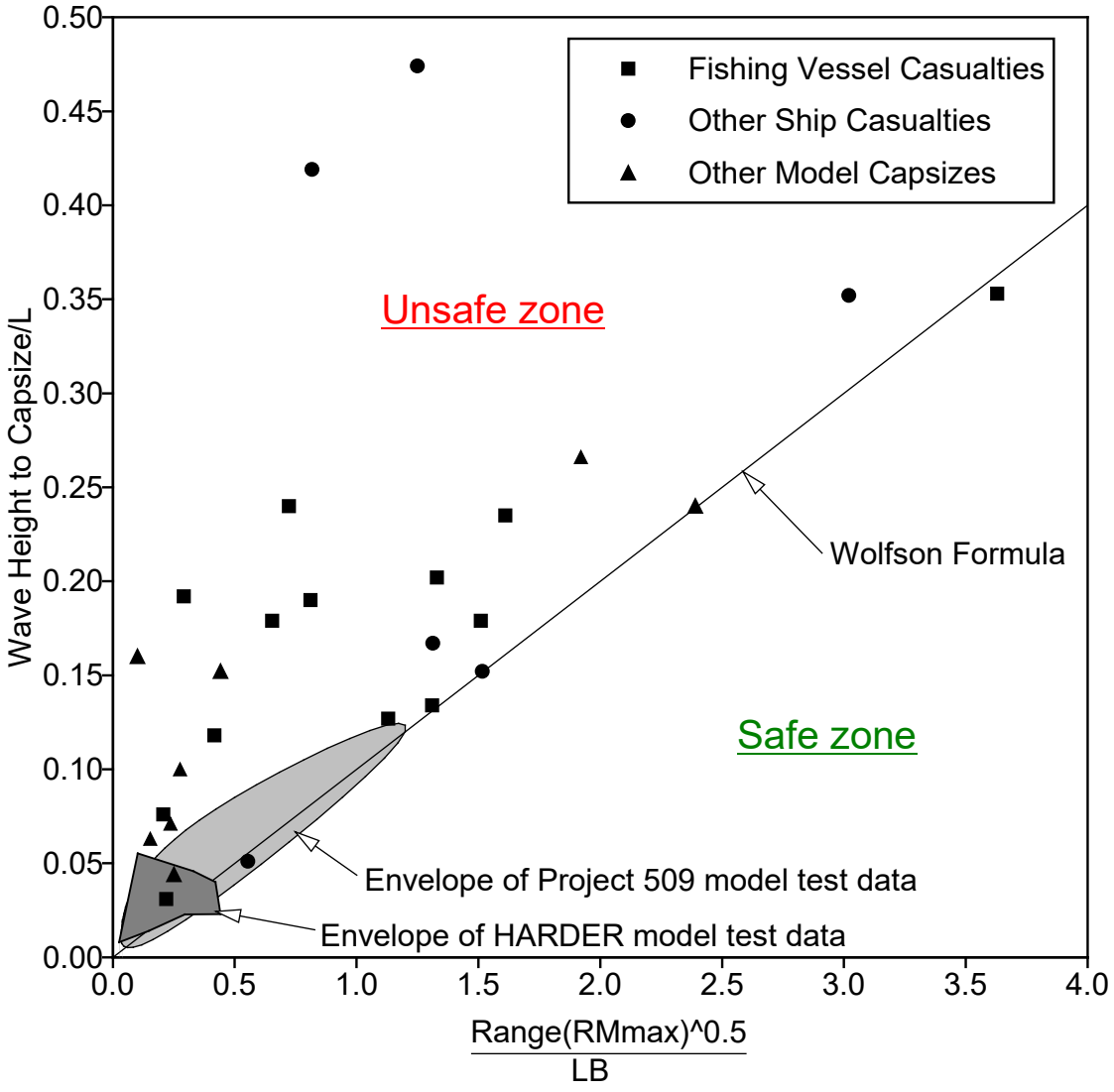

Figure 2 **Correlation of Casualty and Model Data with the Wolfson Formula, 2022 LRF Study**

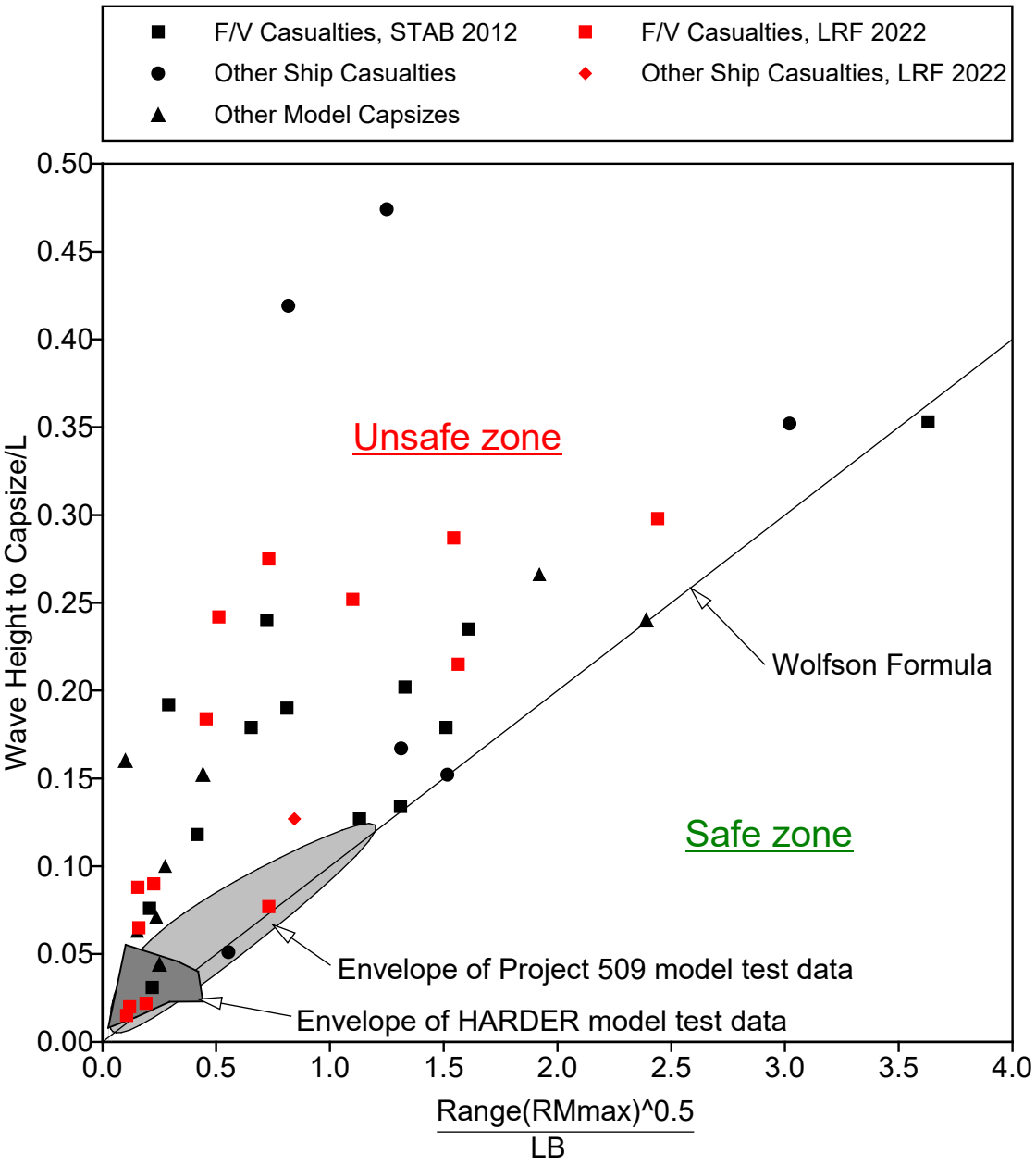

Table 1 Marine Accident Investigation Reports Available and Casualties Evaluated

			Vessel Casualties		
	Total Reports Available	Flooding/Stability Reports Evaluated	Published STAB 2012 [3]	New 2022 LRF Study	Additional Data Requested
Australia, ATSB	370	6		1	
Belgium, FEBIMA	22	4		2	
Canada, TSB	526	38	1		1
Denmark, DMAIB	124	25			
Ireland, MCIB	251	24	1	2	
Isle of Man, IoM SR	38	3	1		1
Portugal, GAMA	84	15			
New Zealand, TAIC	238	6		1	
Sweden, SHK	97	4	1		3
UK, MAIB	653	143	9	11	3
TOTAL	**2403**	**268**	**13**	**17**	**8**

Table 2 Wolfson Casualty Database

Boat	PLN	Gear	Source	LOA	BOA	Depth	Draught	Min F	Disp	KG	GM	List	Downflood	GZmax	GZarea30	GZareaf	GZarea	AVS	Range
				m	m	m	m	m	t	m	m	deg	deg	m	m.rad	m.rad	m.rad	deg	deg
Amber Rose + flooding		Pair trawler	MAIB report 24/2000	26.33	7.46	3.32	4.25	0.06	423.8	3.595	0.190	0.0		0.016	0.003		0.003	14.0	14.01
Angela no shelter		Twin rig trawler	MAIB report	16.99	6.10	2.97	2.88	0.37	116.2	3.701	0.416	8.7		0.039	0.006		0.006	29.0	20.27
Charisma		Trawler (mussel dredger)	MAIB report	10.66	4.00	2.12	2.11	0.35	34.7	2.334	0.328	0.0	20.1	0.048	0.012	0.012	0.012	23.0	23.00
Amber with rock		Trawler	MAIB report	9.98	3.40	1.74	1.47	0.14	19.0	1.845	0.150	4.0		0.005	0.003	0.003	0.003	10.0	6.00
Gorah Lass		Netter	MAIB report	8.23	2.90	1.28	1.05	0.23	9.1	1.286	0.551	0.0	20.8	0.106	0.039	0.027	0.045	41.0	41.00
Kirsteen Anne		Potter	MAIB report	6.50	2.20	1.15	1.04	0.11	4.5	1.260	0.335	0.0	13.0	0.032	0.007	0.005	0.007	21.7	21.73
Sapphire + flooding		Trawler	MAIB report	21.95	7.01	3.98	3.61	0.33	263.7	3.710	0.430	0.0	17.8	0.095	0.027	0.018	0.030	31.0	31.00
Tetsuko		Scallop dredger	IOM Casualty Report 8	8.98	3.05	1.04		0.10											
Donna M		Potter	MAIB report	8.80	2.86	1.41		0.03											
Sundance		Trawler	MAIB report	9.07	3.20			-0.10											
Margaretha Maria		Beam trawler	MAIB report	22.80	5.82	2.70	2.38	0.31			0.187	0.0	23.0	0.023	0.004	0.004	0.004	16.0	16.00
Harvest Hope		Twin rig trawler	MAIB	28.23	8.70	7.40													
Glittsjo		Trawler	Sweden	14.05	5.00	2.57	2.42	0.15	54.9	2.780	0.290	0.0	0.0	0.043	0.011		0.011		23.00
Orion		Mussel dredger	MAIB	26.89	4.53	2.45													
Meridian	KY147	Pair Trawler	MAIB 20/2007	22.66	6.79	3.47	2.63	1.07	139.6	3.005	1.255	0.0		0.422	0.141		0.141	72.5	72.53
Trident (MARIN model)	PD111m	Seine-net trawler	MARIN	25.91	6.86				170.0			0.0		0.250					52.00
Trident (2011 Rehearing)	PD111	Seine-net trawler	MAIB	25.91	6.86	3.35			170.0			0.0		0.210					48.00
Trident (1976 NMI report)	PD111	Seine-net trawler	NMI / MAIB	25.91	6.86	3.35	2.48		167.6	3.161	0.732	0.0	0.0	0.210	0.075		0.075	45.0	45.00
Alize	WD207	Scallop dredger	MCIB/297	11.61	5.22	3.02	2.78	0.60	59.0	3.273	0.265	0.0		0.095				40.0	40.00
Nancy Glen	TT100	Twin rigged prawn trawler	MAIB 6/2019	12.98	5.10	2.00			71.4		0.232	5.0		0.045				32.0	27.00
Ocean Way	FR349	Twin rigged stern trawler	MAIB 23/2015	17.07	5.67	1.98	2.57	-0.05	118.8	3.420	0.400	11.7	45.9	0.040				44.1	32.44
JMT	M99	Scallop dredger	MAIB 15/2016	11.42	4.38	2.89	1.15	0.22	44.0	1.478	0.041	2.9	45.8	0.008	0.001	0.001	0.001	16.0	13.14
Stella Maris	HL705	Stern Trawler	MAIB 29/2015	9.96	4.09	2.15	1.79	0.07	28.7	2.245	0.265	8.4	22.6	0.010				17.5	9.07
Aquila	BA379	Scallop dredger	MAIB 5/2010	13.41	5.16	2.56	2.20	0.41	75.7	2.278	0.653	-2.5	40.1	0.208	0.079	0.107	0.107	40.1	42.55
Heather Anne	FY126	Ring netter	MAIB 2/2013	11.05	4.21	2.02	1.82	0.13	38.5	2.050	0.192	1.8	34.7	0.016	0.002	0.002	0.002	15.1	13.31
Sally Jane (1998 capsize)	SM74	Twin beam & stern trawler	MAIB	13.60	4.86	2.10			63.2	2.254		12.3	90.0	0.008				22.2	9.89
Sally Jane (2013 capsize)	SM74	Twin beam & stern trawler	MAIB 21/2014	13.60	4.86	2.10			67.7	2.250		12.8	40.8	0.026				35.5	22.72
Catrina	NN194	Stern trawler/twin beam scall	MAIB	13.92	4.84	2.12	1.59		46.7	1.946	0.869	0.0	33.0	0.213	0.082	0.090	0.082	33.0	33.00
Pamela S	IH308	Whelk potter	MAIB	9.16	2.86	1.69	1.45	-0.03	9.6	1.758	0.297	0.0	1.8	0.019				11.7	11.74
Rising Sun	WD209	Potter & Stern Trawler	MCIB/118	8.29	3.41	1.37		0.18	15.1	1.820	0.455	0.0		0.057	0.014	0.014	0.014	22.0	22.00
Maggie B	WD113	Beam Trawler	MCIB/122	15.72	5.18	3.33			83.3	2.720	0.834	0.0		0.025	0.006		0.006	41.1	28.90
Easy Rider	2213	Potter	TAIC MO-2012-201	11.00	3.76		1.58	0.00	27.4	1.890	0.340		4.0	0.040	0.009		0.009	20.0	20.00
MV Rabaul Queen	121187	Pax Vessel	ATSB MT-2012-003	47.34	8.20		2.18		381.0					0.230					35.00
Sonja	Z19	Beam Trawler	FEBIMA 2018/001228	30.70	7.27	3.62	2.83		242.7	3.655	0.301	17.7	>70	0.046	0.005	0.005	0.005	28.4	10.74
Morgenster	Z85	Beam Trawler	FEBIMA 07/2015	23.82	6.00		2.13	-0.38	148.4	2.425	0.850	18.6	69.3	0.065	0.008		0.008	69.3	50.64
Ryan's Commander	826129	Crabber/Shrimper	TSB M04N0086	19.79	7.315	3.2	2.56		117.8	4.176	0.792	0.0	0.0	0.201	0.077	0.077	0.077	39.0	39.00