Development of Very Simple Stability and Loading Guidance

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ABSTRACT

Much research has been conducted worldwide on the subject of stability and safety in the fishing industry. Generally, the objectives are a better understanding of vessel behaviour, and improved regulation. This paper describes an alternative approach, concentrating on the provision of guidance to fishermen regarding their level of safety, rather than prescriptive regulation. It is hoped that, given improved information, the industry will be able to maintain use of the existing fleet while becoming more aware of its limitations, perhaps with some improvement in the safety culture.

1. INTRODUCTION

This paper presents a brief summary of two research projects conducted during 2005/6 for the Maritime and Coastguard Agency (MCA) in the UK. Both were aimed at the provision of simple guidance on the level of safety with regard to stability, taking account of the loading of the vessel, and the effects of lifting. Project 560 concerned vessels over 12 metres registered length, for which stability booklets are required. Project 559 concerned the smaller vessels for which no stability calculations currently are required.

The reports on all MCA Research Projects are available on their website: www.mcga.gov.uk.

2. THE UK FISHING FLEET

The UK fleet comprises around 6500 vessels, 80% of which are less than 12 metres registered length, and entirely unregulated in terms of their stability. It encompasses a wide diversity in terms of the range of vessel sizes and types, the fishing methods employed, and the environmental conditions encountered.

A number of regulatory boundaries have influenced the design of fishing vessels. The lack of stability requirements under 12 metres, and relaxation of fishing licensing restrictions under 10 metres, have given rise to a proliferation of "rule beating" designs that lie outside the normal design envelope and are evident in Figure 1. Many of the under 10m vessels are equipped with engines and fishing gear equivalent to much larger traditional designs. They have full shelter decks and are equipped for offshore trawling. One of the objectives of the work was to extend the regulatory boundary to include these vessels among those required to comply with stability criteria, but this was the only area where additional regulation was envisaged.

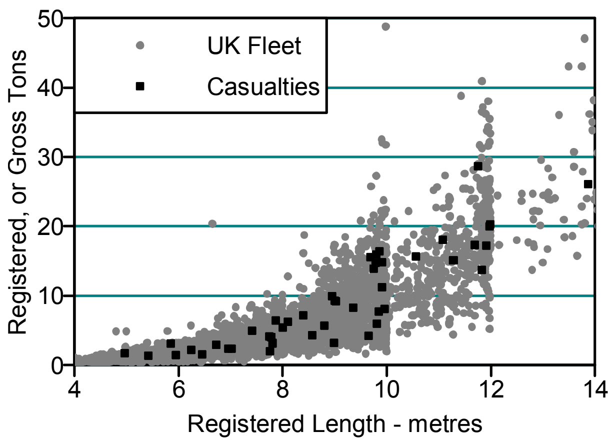


Figure 1 Tonnage of the UK small vessel fleet

3. PRINCIPLE OF SAFETY ASSESSMENT

Conventional stability assessments, relying on constant GZ criteria regardless of the size of vessel and the seastate, provide a pass/fail boundary but do not enable the level of safety to be assessed. The recommendations described here are based on the assumption that the level of safety is related to the size of the vessel, its residual stability when loaded and lifting, and the seastate.

4. RELATIONSHIP BETWEEN STABILITY AND SAFETY

The relationship between stability and safety is based on the findings of MCA Research Project 509 (Ref.1). This comprised model tests on a wide range of hull types and configurations including monohulls, catamarans and a trimaran, intact and damaged, upright and heeled. Tests were conducted at a range of wave heights, periods and headings to determine the minimum wave height to capsize for each configuration. The objective was to determine the level of safety provided by the IMO High Speed Craft Code minimum criteria, but the diverse range of hull forms were tested drifting freely and the results are believed to be applicable to all ship types. The range of positive stability was found to be the most important parameter in terms of vulnerability to capsize. Whilst requirements for minimum areas under the GZ curve ensure reasonable stability, these parameters did not correlate directly with vulnerability to capsize. It was concluded that the IMO criteria provide adequate stability in most cases, but they achieve it indirectly by assessing parameters that are usually related to the critical ones.

The combination of parameters that was found to relate most closely to the minimum wave height required to capsize, was that defined on the x-axis of Figure 2, where: Range is the residual range of positive stability, RMmax is the maximum residual righting moment, and L, B are the overall length and beam. Note that these are residual stability data, after the application of any heeling moments, and so do not necessarily refer to the upright case.

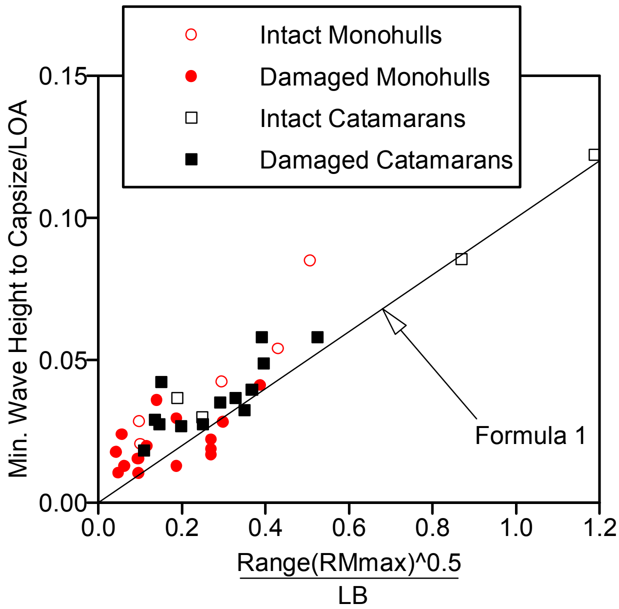


Figure 2 Model test capsize data

A formula, represented by the solid line on Figure 2, was proposed to enable estimation of the minimum wave height to capsize:

$$\text{Critical WaveHeight} = \frac{\text{Range}\sqrt{\text{RMmax}}}{10B} \qquad (1)$$

Since the proposal was developed, capsize casualties have been studied to estimate the residual stability and wave height at the time of the incident. These provide further support for the relationship derived from the idealised tests, and are shown in Figure 3.

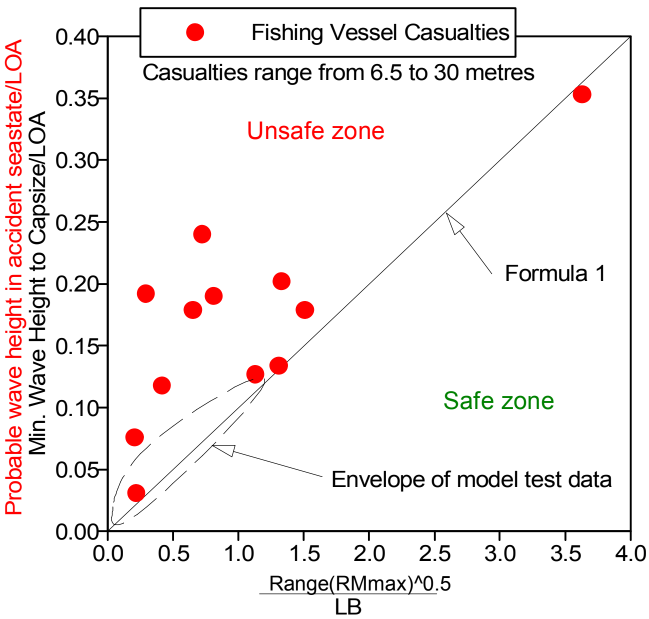


Figure 3 Casualties in relation to Formula 1

For the purpose of guidance to fishermen, it is more appropriate to refer to seastate or significant wave height. It has been assumed that waves of twice the significant height are likely to be encountered. The probability of this is once every few hours, depending on the wave period and the nature of the spectrum. The maximum recommended significant wave height, or critical significant wave height, Hs_{crit}, therefore is given by the formula:

$$Hs_{crit} = \frac{Range\sqrt{RMmax}}{20B} \quad (2)$$

5. THE STABILITY NOTICE

A number of options were considered for the format of the information. A method developed in Canada by Womack (Ref.2) is perhaps the best known. It comprises a relatively complex matrix of loading data, and a much simpler format was recommended to the MCA. A single page was proposed, that could be posted prominently in the wheelhouse, and would convey the message that the safety of the vessel is variable, may be inadequate, and is under the control of the fisherman.

This Stability Notice would be based on those used for some years in Norway and Iceland. They use a green/amber/red colour code indicating good safety, poor safety, and danger of capsize for different load cases, but do not consider lifting, and their safety zones are not prescribed or published. The emphasis is on simple guidance, rather than accurate prediction.

6. DEFINITION OF SAFETY ZONES

In order to comply with the IMO minimum criteria, a GZ curve will have a GZmax of at least 0.2 metres, and is likely to have a range of at least 45 degrees. The level of safety provided by the IMO criteria was estimated in terms of Hs_{crit}, using these notional minima, together with actual values of beam and displacement, for the database vessels. See Figure 4. The formula that defines the fit was used to develop the boundaries of the safety zones.

$$Hs_{IMO} = \sqrt{1 + 0.4LOA} - 1 \quad (3)$$

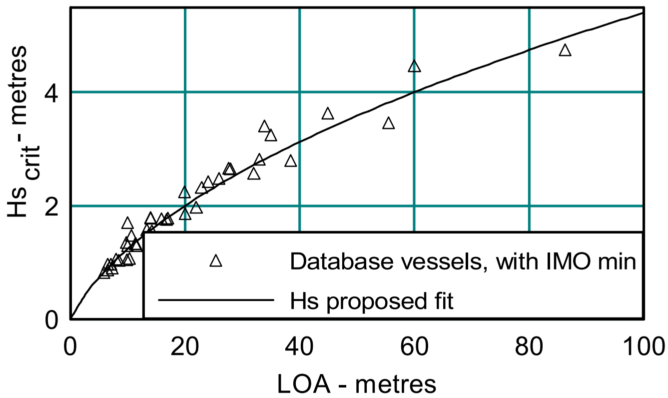


Figure 4 Level of safety implied by the IMO criteria

The stability characteristics of the recent UK casualties were used, in conjunction with other fishing vessel data, to select boundaries between the coloured safety zones, Figure 5.

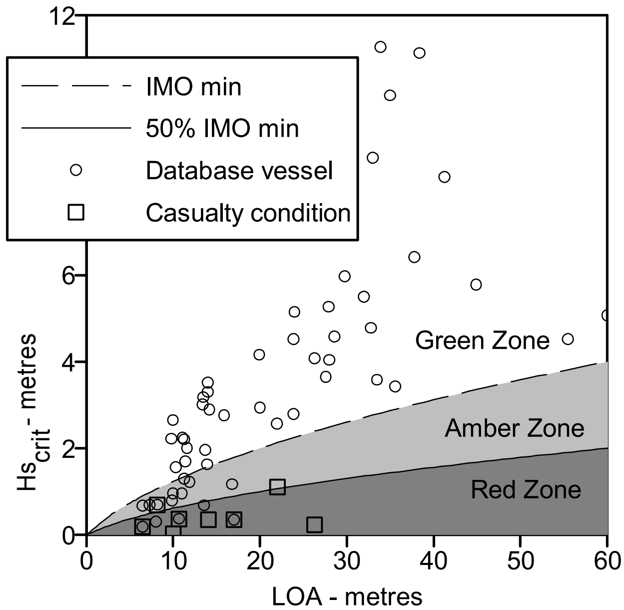


Figure 5 Defining the safety zones using Hs_{crit}

Because the use of Hs_{crit} relies on knowledge of residual stability, some casualties could not be used because the available data referred to the vessel in a normal operating condition, and the casualty occurred after application of an unknown heeling moment, or undefined flooding. The data plotted refer to residual stability in the casualty condition. Where that corresponds to an upright intact condition, a circle appears within the square symbol.

Values of 50% and 100% of Hs_{IMO}, derived using Formula 3, were selected to define the red/amber and amber/green boundaries respectively. These values are subjective, and others could be used to provide alternative levels of safety. On the basis of the proposed boundaries, some small vessels in the available database operate with relatively low levels of safety in their normal upright conditions. They need not be prevented from operating, but should be advised of the maximum recommended seastate appropriate to their size and stability.

7. RELATING SAFETY TO VESSEL OPERATION

When preparing the stability booklet, little additional effort is required to determine in what circumstances the residual stability will correspond to these boundaries.

For a vessel loading bulk fish it may be when the hold is filled to a certain depth, in which case this should be made clear on the Stability Notice. Critical cases may be due to filling of a hopper, or loading on deck. The relevant limits should be calculated and noted.

For most vessels heavy lifting will be the most hazardous operation, perhaps trying to raise gear that is overloaded or fastened on the seabed. The maximum lift can be defined for the values of Hs_{crit} corresponding to the safety zone boundaries, using the maximum height and outreach of the lifting gear, and stated on the Stability Notice. Where warp tension monitoring equipment or load cells are fitted, these will give a direct measure of the level of safety.

If lifting loads are not monitored, the guidance could be in the form of the maximum recommended heel angle, since this will also be defined by the calculation. Fitting an inclinometer with a time averaging facility will provide accurate safety monitoring information, but a simpler type of inclinometer will provide worthwhile guidance. It is well known that observers' estimates of heel angle are unreliable, so even a simple instrument enabling the fisherman to estimate, and familiarise himself with, heel angles will be valuable.

The residual freeboard in the critical cases should also be stated on the Stability Notice.

8. VESSELS WITHOUT STABILITY DATA

For the small vessels, for which no calculations are conducted, an approximate method was required to define the safety zone boundaries. Without calculations or accurately controlled measurements, it is not possible to incorporate important variables such as displacement or vertical centre of gravity into an approximate method. The intention was to use parameters that could be monitored easily by the crew, and which provide approximate guidance on the same basis as for the larger vessels.

9. RELATIONSHIP BETWEEN FREEBOARD AND SAFETY

It is well known that freeboard is an important factor in safety, but in the UK there are no requirements for minimum freeboard for fishing vessels under 12 metres, and no requirements for freeboard or load line marks on fishing vessels of any size. Many administrations apply minimum requirements, but they vary considerably and the level of safety that they provide was not known.

The relationships between size, various stability parameters and freeboard were studied for a range of vessels, for various loading and lifting conditions. A strong relationship exists between freeboard and stability, particularly the range of stability which is known to be a good measure of safety. This is illustrated for symmetric loading of a selection of vessels, Figure 6, and for lifting over the side on one of them, Figure 7. The effect on the range is similar in all cases in terms of its variation with the residual freeboard. The data form an envelope with an apparent lower boundary, suggesting that freeboard might be used to provide a conservative estimate of the range.

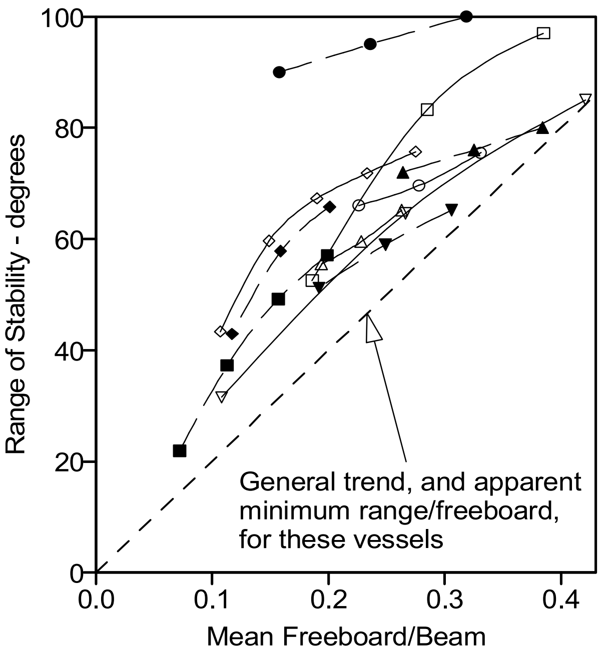


Figure 6 Reduction of range of stability with increased loading for 10 fishing vessels

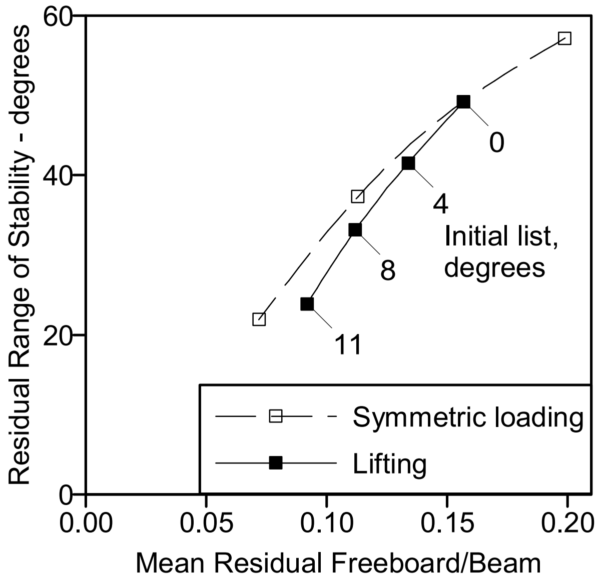


Figure 7 Reduction of range of stability with increased load lifted over the side

Several measures of freeboard were considered, including the minimum freeboard, and the mean freeboard taking account of any intact poop, focsle or shelter. One would expect the latter to be more closely related to stability at large angles, particularly where the upper decks extend over a large proportion of the vessel.

Figure 8 presents the range of stability for the database vessels, plotted against two of these measures of freeboard, normalised with respect to beam. Whilst mean freeboard gave the best collapse of the data, there are some casualties outside the main envelope, with relatively low range for their freeboard. This is a dangerous characteristic if freeboard is used to estimate safety.

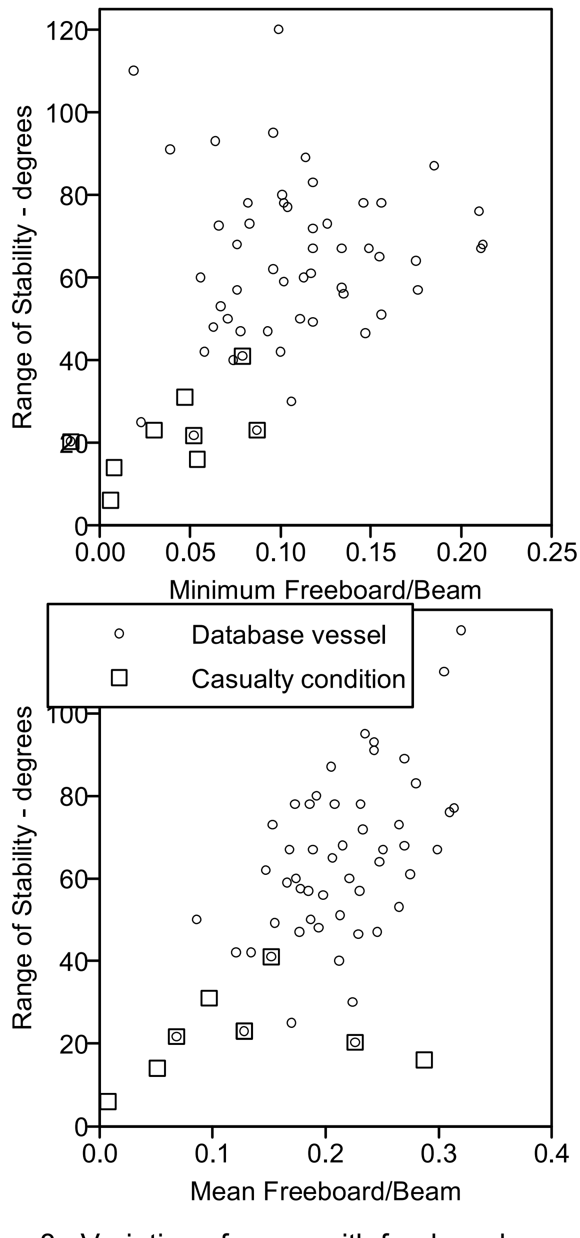


Figure 8 Variation of range with freeboard

It appears that the minimum freeboard, whilst not necessarily giving a very reliable prediction, is best suited to giving a conservative one. Other important considerations are that it is the simplest to define and measure, and for the fisherman to relate to.

Figure 9 presents the variation of Hs_{crit}/L with minimum freeboard/beam. The simplest relationship between the two ratios, $F/B = Hs_{crit}/L$, is indicated on the graph, and is proposed as a simple means of estimating the safety. If it is used to estimate Hs_{crit}/L, it will provide a conservative result in most cases. It is therefore proposed that, where no stability data exist, values F/B can be used to define the red/amber and amber/green boundaries respectively.

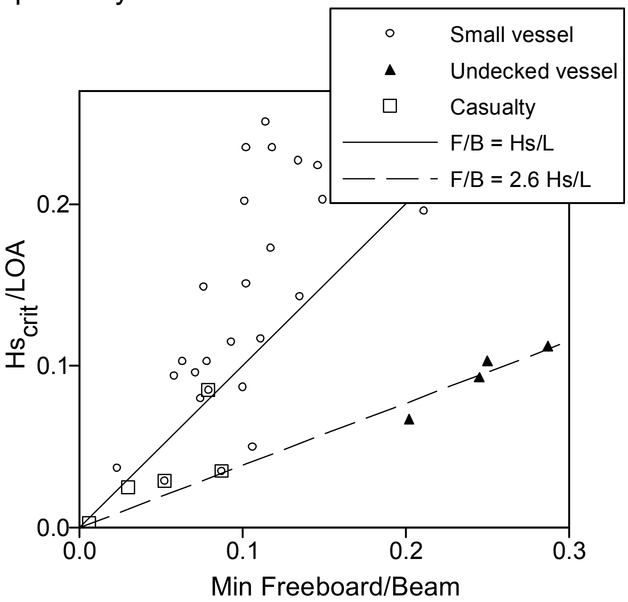


Figure 9 Variation of Hs_{crit} with freeboard

10. IMPLICATIONS FOR SMALL VESSELS

The implication of this in terms of the guidance given to the fleet is indicated by Figure 10. Most of the casualties lie inside the red zone, with two in the lower part of the amber zone. In their normal operating conditions, many vessels operate with freeboards in the proposed amber zone, and some in the red zone. This is appropriate if those vessels are relatively unsafe, and may be acceptable if they operate in the appropriate seastates. It might, however, indicate that the proposed zone boundaries should be relaxed. Further validation and impact assessment is in progress to finalise these boundary definitions such that they provide adequate safety advice that will be respected by the fishermen.

Two vessels of identical proportions will have the same freeboard guidance, but may have very different stability characteristics, because of different arrangements of outfit. This may appear to be a failing of the proposal but, because the guidance relates to residual freeboards, the more stable vessel will be able to lift a heavier weight before heeling to the minimum freeboard. On each vessel, the guidance will inform the fishermen of their levels of safety, and if they compare their experiences they will know that one vessel is safer than the other, in that it can sustain heavier lifts.

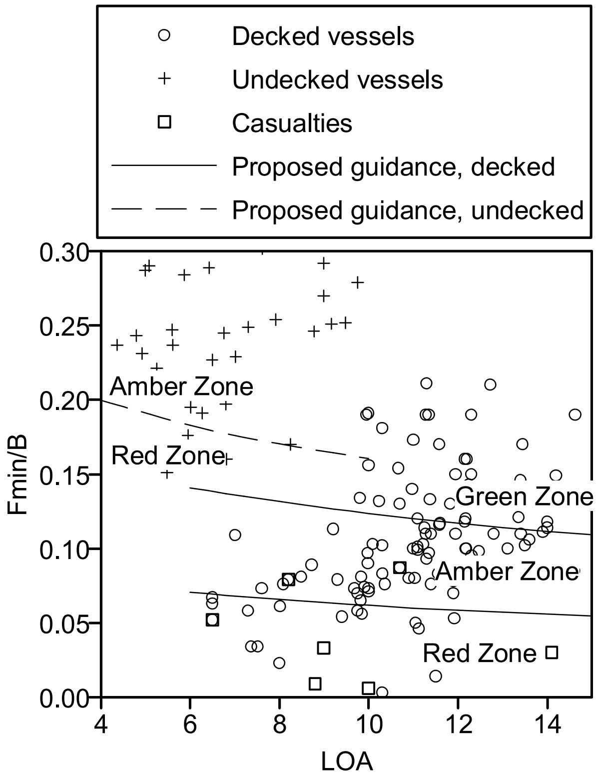


Figure 10 Proposals for freeboard guidance

11. UNDECKED VESSELS

The range of stability of open boats is limited to the angle of gunwale immersion.

If an undecked vessel is to have an equivalent level of safety to a decked vessel, it needs to have a similar value of Hs_{crit}/L. The same green, amber and red zones therefore can be used if stability calculations are available. It is unlikely that this will be the case, and so the level of safety should be based on freeboard in a similar way to decked vessels.

Undecked vessels are included on Figure 9, where the relationship $F/B = 2.6\ Hs_{crit}/L$ was derived. Only four such vessels were in the stability database so this proposal is a tentative one.

Undecked vessels can never be as safe as decked vessels, being vulnerable to swamping in breaking waves and having limited range of stability, and it is recommended that only the amber/red zone boundary be defined for them, as indicated on Figure 10.

12. FORMAT OF STABILITY NOTICES

Stability Notices are recommended for all registered fishing vessels, and examples are shown at the end of this paper.

Each will be specific to the vessel, with the name and other identifying details. It will present guidance on the transitions between the safety zones, in terms of the loading configuration, lifting load, heel angle or residual freeboard. Guidance on the maximum recommended seastate will be given in each case.

The notice will include general advice on maintaining stability such as, keeping doors and hatches closed in bad weather and when lifting, keeping bilges dry, securing fish and gear against movement, etc. This advice can be tailored to suit the particular vessel or fishing method. It will include a dated photograph of the vessel to enable substantial changes to the arrangement to be identified by any visiting surveyor. All the information will fit on one A4 sheet, laminated and prominently displayed.

It is also suggested that, if a vessel is equipped for lifting, a simple heel test is conducted using the fishing gear lifted from the highest, or furthest outboard block. The heel angle can be measured with a simple inclinometer and recorded with the date on the notice. Such a test can then be repeated at intervals, by a surveyor or responsible owner, and any significant change in the vessel stability, lifting point or gear weight should be apparent.

13. GUIDANCE FREEBOARD MARK

It is recommended that a mark be placed on each side of the vessel, not as a regulatory minimum, but to provide further safety guidance. It should be at the longitudinal location at which the minimum freeboard is likely to occur. This may be near midships or at the stern.

A line could be placed at one of the guidance freeboards, but it is proposed that a mark be used such that its top and bottom edges indicate freeboards corresponding to the safety zone boundaries. See Figure 11. On undecked vessels, where only the amber/red boundary is presented on the Stability Notice, only the upper half of the mark might be used, and this will distinguish them from decked vessels.

If the value of Hs_{IMO} is determined using Formula 3, the freeboard associated with the amber/green zone boundary is determined using the appropriate formula given on Figure 9. The red zone freeboard is half that value.

A simple spreadsheet to calculate the data and freeboard mark dimensions is available on the Wolfson Unit website at:
http://www.wumtia.soton.ac.uk/shipsafety.html

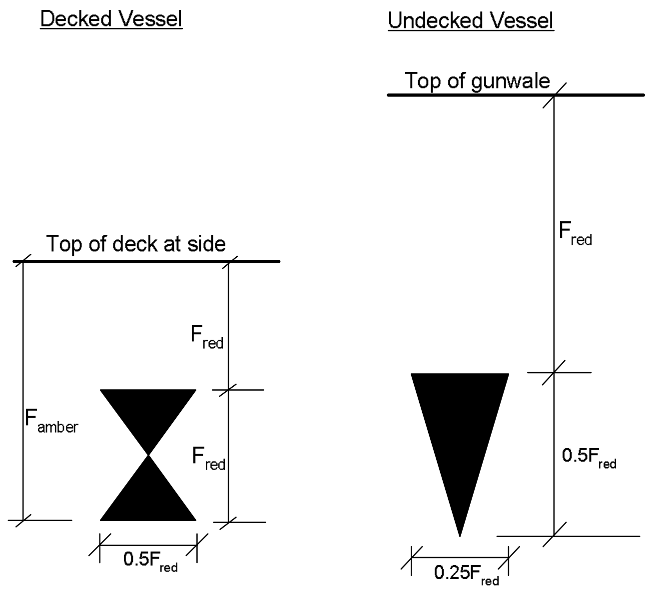


Figure 11 Proposed guidance freeboard marks

For a 10 metre long decked vessel, with a beam of 4 metres, the value derived from Formula 3 would be: Hs_{IMO} = 1.24 metres, and the following values would result:

Zone Boundary	Green/Amber	Amber/Red
Hs_{crit}, metres	1.24	0.6
Freeboard, metres	0.5	0.25

The mark might serve a number of functions. It will enable the fishermen to relate the values of freeboard presented on the Notice to their vessel, and will indicate the normal margin of safety. Because it's distance above, or in some cases below, the normal waterline is visible to the crew, and indeed the whole community, it might help to improve the safety culture. It is not practical to measure freeboard at sea, nor expected that fishermen will do so. The hope is that they will become familiar with the marks and the levels of safety they represent, encouraging greater awareness of the relationship between residual freeboard and safety.

14. SUMMARY & CONCLUSION

The conventional system of stability assessment discourages fishermen from considering their stability, because they go to sea confident in the knowledge that it complies with the relevant requirements in all operating conditions. Inadequacies of the conventional system are that it does not necessarily address the effects of operational loads or moments, does not address safety in terms of the size of the vessel in relation to the seastate, does not provide practical guidance on varying levels of safety, and does not present information in a simple format.

It is proposed to provide information that stability is variable, may be inadequate and is under the control of the fishermen. The format is intended to be concise and simple, so that it may be memorised by the crew rather than require reference to documents during operation.

The system enables simple but accurate information to be derived where calculations are being conducted, and provides simple estimates based on length, beam and residual freeboard for all other vessels.

Although the method was developed for the UK fishing industry, it is hoped that it may be of value elsewhere, perhaps with some adjustment to the formulae, to improve the level of safety without recourse to costly assessment and regulation.

15. SUMMARY OF FORMULAE

1) Three safety zones are defined:

Green: "Safe" in all but extreme seastates
Amber: "Low level of safety" and should be restricted to low seastates
Red: "Unsafe, and danger of capsize" unless restricted to calm conditions and with extreme caution.

Green/amber boundary:

$$Hs_{amber} = \sqrt{1+0.4LOA} - 1$$

Amber/red boundary:

$$Hs_{red} = (Hs_{amber})/2$$

2a) Minimum stability for vessels with full stability analysis:

Green/amber zone boundary:

$$Range\sqrt{RM_{max}} = 20B(Hs_{amber})$$

Amber/red zone boundary:

$$Range\sqrt{RM_{max}} = 20B(Hs_{red})$$

2b) Minimum freeboard for vessels with no stability data:

Decked vessels:
Freeboard at green/amber zone boundary:

$$F_{amber} = \frac{B}{L}(Hs_{amber})$$

Freeboard at amber/red zone boundary:

$$F_{red} = (F_{amber})/2$$

Undecked vessels:
Freeboard at amber/red zone boundary:

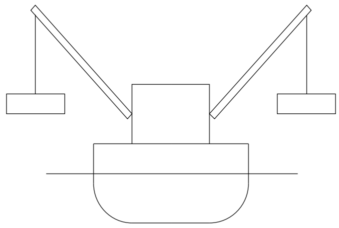
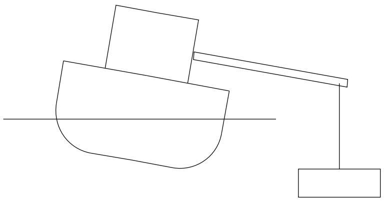
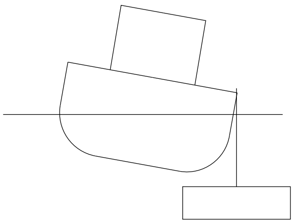
$$F_{red} = \frac{2.6B}{L}(Hs_{red})$$

16. REFERENCES

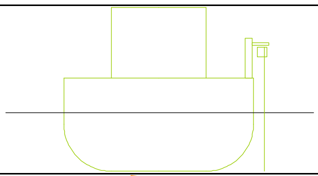
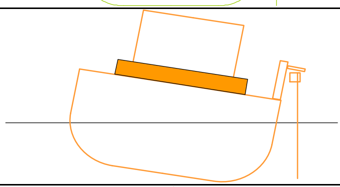
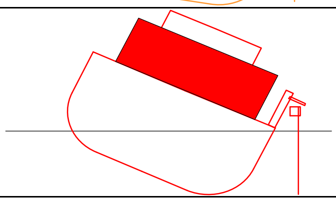
1. Deakin, B, 2005 "An Experimental Evaluation of the Stability Criteria of the HSC Code", FAST'2005, St.Petersburg, Russia.

2. Womack, J, 2002 "Small Commercial Fishing Vessel Stability Analysis. Where are we Now? Where are we Going?", 6th International Ship Stability Workshop, Webb Inst.

STABILITY NOTICE – Example 1

BONNIE LASS AB123 LOA: 24m Owner: John Fisher	**Lifting Guidance**		
	Good margin of safety	**Low level of safety** Max recommended seastate 2.2 metres	**Danger of capsize** Max recommended seastate 1.1 metres
 Double lift from raised derricks	Less than 4.5 tonnes each side	4.5 – 7.5 tonnes each side	More than 7.5 tonnes each side
 Lift from single lowered derrick	Less than 5.5 tonnes Deck edge above waterline Heel angle less than 12^{o}	5.5 – 7.5 tonnes Deck edge immersion less than 20cm Heel angle 12^{o} - 17^{o}	More than 7.5 tonnes Deck edge immersion more than 20cm Heel angle more than 17^{o}
 Lifting from bulwark	Less than 10 tonnes Deck edge above waterline Heel angle less than 10^{o}	10 – 15 tonnes Deck edge immersion less than 20cm Heel angle 10^{o} - 16^{o}	More than 15 tonnes Deck edge immersion more than 20cm Heel angle more than 16^{o}

STABILITY NOTICE – Example 2

Name: Jolly Polly **No: AB789** **LOA: 10.6m** **Beam: 3.85m** **Owner: John Potter**	LOADING & LIFTING	SAFETY GUIDANCE		
		Zone	Minimum Freeboard	Maximum recommended seastate
	Good margin of residual freeboard	Good margin of safety	At least 47cm	
	Loading or lifting reduces minimum freeboard to less than 47cm	Low level of safety	24 to 47 cm	1.3 metres
	Excessive loading or lifting reduces minimum freeboard to less than 24cm	Danger of capsize	Less than 24cm	0.6 metres