

**MARITIME & COASTGUARD AGENCY**

**Research Project 560**  
**Simplified Presentation of FV Stability Information for Vessels 12m Registered Length and Over**  
**Phase II**

**Final Report**

**EXECUTIVE SUMMARY**

This report describes phase II of a research project, commissioned by the MCA, to develop a method of presenting simplified information to fishermen regarding their stability and safety. The remit of phase II was to develop the method recommended in phase I of the project.

In this study, a method of providing stability guidance, in the form of a single page notice or poster, has been developed to bring the subject to the attention of the whole crew. It is designed to emphasise the fact that stability is a variable characteristic of the vessel, and that it is within their control to maintain it at a satisfactory level.

The safety of the vessel is affected by operational factors, particularly the movement of weights on board, lifting and overloading. These effects may not be addressed in the standard stability booklet conditions, but the residual stability during such operations is fundamental to safety.

The safety guidance information presents the relationship between the size of vessel, its residual stability when lifting or with additional loading, and the seastate in which the vessel might be vulnerable to capsize. The relationship is based on the findings of extensive model tests on a wide range of hull forms, where the minimum wave height to capsize was determined for various configurations of upright and heeled vessels. During this work it was determined that the residual range of positive stability is the most important parameter governing the safety from capsize. The residual range of stability therefore is the primary parameter considered here.

The guidance information has been harmonised with the level of safety provided by the standard stability criteria applied to UK fishing vessels.

The information will be presented on a single page that will be posted in a prominent position on the vessel.

A heeling test is proposed to monitor the condition and configuration of the vessel and its lifting arrangements. This is a simple test, using fishing gear or weights, not in accordance with predetermined criteria, but conducted in a way that is convenient and repeatable.

The presentation should be used in conjunction with on board measurement systems to enable the fishermen to monitor their level of safety. An inclinometer is recommended for all vessels, to monitor their angle of heel. Warp tension monitoring systems are recommended for new beam trawlers to monitor the lifting loads, and load cells are recommended for lifting equipment on all other vessels.

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## **1 INTRODUCTION**

This report describes phase II of a research project to develop a method to provide fishermen with simplified guidance on loading and stability. The contract, Ref. MSA 10/9/227, was issued on 13<sup>th</sup> June 2005. The programme of work followed that outlined in Wolfson Unit proposal no. 2798bd dated 4<sup>th</sup> May 2005. Phase I of the work was conducted in 2004, and presented in Wolfson Unit report no. 1773 dated July 2004.

## **2 BACKGROUND**

The MCA has agreed with fishing industry representatives at the Fishing Industry Safety Review Group (FISG) Stability Review Group that the information contained within the MCA's recommended format for fishing vessel freeboard and stability information needs to be presented in a simplified format for ease of understanding and use.

The UK fishing fleet includes a wide range of vessel types and fishing methods. The remit for this research was to address vessels over 12m registered length, for which stability booklets already exist. During the course of the research it became apparent that, because of recent changes in regulations and Codes of practice, some vessels between 12 metres registered length and 15 metres overall length may not have stability information. The precise application of this method is not considered to be of relevance to its development, and it is assumed that it may be applied to any fishing vessel for which stability calculations are required.

## **3 OBJECTIVE**

The objective arose from Phase I of this Research Project, and was stated in the MCA Invitation to Tender: To create a 'Stability Notice', the emphasis of which will be on portraying the fact that the stability is variable and that a fishing vessel can be loaded in ways which reduce the stability.

Phase I of the study highlighted the differences between operational hazards, which are under the direct control of the crew and can be avoided, and environmental hazards, over which the crew have only indirect control and cannot necessarily be avoided. The Stability Notice should address these various hazards and provide the fishermen with appropriate information with which to judge their level of safety in relation to them.

## **4 WORK PROGRAMME**

An outline programme of work was proposed and agreed with the MCA, comprising the following elements:

1. Categorise vessel types and fishing methods.
2. Develop relationship between freeboard and level of safety.
3. Develop relationship between lifting and level of safety.
4. Design generic formats of Stability Notices.
5. Develop instructions for preparation of information.
6. Consult with industry.

These elements were broken down further as the work progressed, and are described here in a different order, for clarity of the report.

## **5 CONSULTATION WITH INDUSTRY**

The development of these proposals has been assisted by discussions with representatives of a number of organisations associated with the fishing industry in the UK and overseas. Whilst the proposals have not been prepared for application outside the UK, it was considered that those conducting stability research, or involved with regulatory developments, in other countries might offer useful criticisms, contributions or advice.

Discussions have taken place, or correspondence exchanged, with representatives of the following organisations:

UK

Fishing Industry Safety Group – Stability Sub Group  
The Sea Fish Industry Authority  
Marine Accident Investigation Branch  
UK fishing vessel designers  
UK fishing vessel builders  
UK fishing vessel owners  
UK fishing vessel skippers

Overseas

Russian Maritime register of Shipping  
United States Coastguard  
Canadian Coastguard  
Icelandic Maritime Administration  
Independent researchers

International

Food and Agriculture Organisation  
IMO - Intersessional Correspondence Group on the Safety of Small Fishing Vessels  
International Standards Organisation – Working Group 22, Stability

## **6 COMPILATION OF A DATABASE**

A number of existing databases of UK fishing vessels were collected. The data were combined so that names, identification numbers, fishing methods and some principle dimensions could be collated. The information was limited but enabled some statistical analysis of the fleet.

Stability information was obtained from existing databases, Wolfson Unit files, directly from designers, and from MCA files. Data on stability casualties were obtained from MAIB reports and from their database.

One of the existing databases that provided a useful starting point was that compiled in the Seaspeed study in 1994, Ref. 1. It contains principal dimensions and stability characteristics for 60 vessels in the range 11 to 26 metres, some flush decked and some with shelters.

After the initial collation of the databases, it was observed that vessels engaged in a particular fishing method are typified by a certain range of lengths, and in some cases certain length/beam ratios. Using this information, a number of vessels were selected to represent each fishing method and the full distribution of lengths and beams. The vessels were chosen by selecting data points on a distribution plot, of beam against length. They were subsequently identified from the database, and their MCA stability files inspected to obtain the required data. Some compromise was required on the selected vessels because the files for more than 50% of those selected were not available from the MCA. In some cases the files were unavailable because they were being used by an MCA surveyor, but in many cases the response was that no stability file could be traced. Some of the selected vessels were old and may have ceased fishing, but others were of recent construction and a reason for the lack of stability files was not given.

Rather than a single database, a number of databases were used. These included the general database of the fleet with minimal data, the stability database with various levels of detail of stability characteristics, and other databases resulting from published research. A summary of the information contained in the various databases is presented in Appendix 1, Database Summary. The principal data of the stability database are presented in Appendix 2, Stability Database. These databases were used for this project and the associated Research Project 559, and therefore contain references to vessels under 12 metres.

Figure 1 presents a plot of the vessels used in the stability database, superimposed on the data for the whole fleet. Most of the fleet lie in a narrow envelope with a linear relationship between the mean beam and the length. The mean beam increases from about 5 metres for a 12 metre vessel, to about 14 metres for a 70 metre vessel. The length/beam ratio increases from about 2.4 at 12 metres to about 5 at 70 metres. Some vessels, however, lie well outside this envelope, with relatively wide or narrow beam. The beam variation is most pronounced for vessels less than 40 metres. At a length of 27 metres for example, the extreme beam values are 4.5 and 9.5 metres, giving a variation in the length/beam ratio from 6.0 to 2.8.

The vessels used in the stability database illustrate the grouping of fishing methods within the overall distribution, and are believed to be representative. Most of the largest vessels are engaged in pelagic trawling or purse seining, and most demersal trawlers are under 40 metres. The latter may be divided into beam trawlers, which tend to be below average beam, twin rig trawlers, which tend to be of wide beam, and other trawlers of varying proportions. Only one example each of a gill netter and a mussel dredger were included. Both were of relatively narrow beam. The mussel dredger in particular was of extremely low beam/length ratio, and it is understood that this type of vessel is now in decline.

## **7 CASUALTY ANALYSIS**

### **7.1 Scope of the Data**

Figure 2 presents the documented proportions for those casualties included in the database. It is apparent that casualties are not confined to a particular length/beam ratio, but spread throughout the envelope of data on the upper graph.

On the lower graph there is an indication that vessels of low tonnage are more vulnerable to capsize. Only one casualty, the largest, lies in the upper part of this envelope of data. Enquiries were made to MAIB, who supplied the tonnage data, regarding this apparent trend, but no reasons were identified. Some of the casualties, such as the 27 metre vessel with very low beam, are thought to be representative of types now being phased out, and this might contribute to an improvement in casualty statistics in the future. The data might reflect a general trend for many modern vessels to be of relatively high tonnage, with stability incidents being more common on the older vessels. This trend is not present in the casualty data for under 12 metre vessels, which are not presented here. Casualties in that group are spread throughout the length and tonnage envelope.

Because of the varying nature of the incidents, the data available to the MAIB, and the object of their analysis, the stability data presented in reports varied in terms of its representation of the accident. In some cases the available stability data represented the condition of the vessel just prior to the incident, or in a standard operating condition. In other cases the data had been calculated to determine the stability in the accident condition, for example, the residual stability with a known load being lifted. For some of the casualties, both sets of data were available. In some cases they are the same because the accident occurred while the vessel was in its normal operating condition with no additional moments or loads applied. These two types of data have been referred to in this report as “became a casualty” and “casualty”. All of those which “became casualties” did so as a result of attempting to make a heavy lift or free fastened gear, with one exception thought to have suffered flooding.

Examples of the first type are useful in providing an indication of the level of stability of vessels that may be vulnerable. Examples of the second indicate the levels of residual stability at which capsizes have occurred.

For some vessels no stability data were available, but their freeboard data were included in the database.

Most of these casualties capsized in moderate conditions, typically force 5, or in some cases in calm conditions. Whilst some of the casualties are very small vessels, these should not be regarded as extreme survival conditions for a seaworthy vessel. The loading, flooding or heeling moments applied to the vessels were major contributory factors.

Some casualty data were provided in the form of a database with minimal information. Those for which more detailed information was available are described briefly below. Vessels less than 12 metres are included because, although they would not be the target of this study, their details have been used in some aspects of the work to increase the amount of useful casualty data.

## **7.2 Identity and Nature of the Casualties Over 12 metres Registered Length**

Amber Rose: 26.3m LOA Pair trawler. Capsized while on passage in a force 5-6. Modified and overloaded such that stability did not comply with MCA requirements. Model tests indicated some flooding. Stability calculated in accident condition with assumed flooding.

Majestic: 22.9m LOA pair trawler. Capsized in force 3-4 while attempting to free fastened gear. No stability data reported.

Margaretha Maria: 22.8m LOA beam trawler. Capsized in force 2-3, handling heavily loaded gear. Stability calculated with and without gear loading.

Pescado: 22m LOA beam trawler. Capsized in moderate conditions when lifting two sets of gear that had become entangled. Stability calculated in the upright condition.

Sapphire: 22m LOA pair trawler. Capsized while on passage in force 4-5 following downflooding. Stability calculated for the intact and flooded conditions.

Westhaven: 20m LOA twin rig trawler. Capsized in force 5 while attempting to free a trawl door from a pipeline. Stability calculated in the accident condition without the trawl warp loading.

Angela: 17m LOA twin rig trawler. Listed due to a large quantity of fish in an offset hopper, and capsized, in a force 5 with a 2m swell, following flooding of the shelter through jammed tonnage valves. Stability calculated for the intact condition with fish in the hopper.

Chelaris J: 16.8m LOA trawler. Capsized in force 6, when the trawl snagged the seabed in a strong tide. Stability calculated in the accident condition, upright.

## **7.3 Identity and Nature of the Casualties Under 12 metres Registered Length**

Catrina: 13.9m LOA am trawler. Broached and capsized in force 5, with steep 2m seas. Stability estimated from calculations on a sister vessel in the accident condition and the MAIB concluded that Catrina must have had lower stability. The data for this vessel therefore are unreliable.

Sally Jane: 13.6m LOA beam trawler. Capsized while handling gear alongside in harbour. Stability calculated with and without lift.

Charisma: 10.7m LOA trawler/mussel dredger. Overloaded with mussels bagged on deck. Capsized, in calm conditions, perhaps following some flooding. Stability calculated in the overloaded intact condition.

Amber: 10m LOA trawler. Capsized in calm conditions while towing a large rock in the net. Stability calculated with and without the rock.

Sundance: 9.1m LOA trawler. Capsized in force 4 due to lifting excessive load in net, from a high point. No stability analysis conducted.

Tetsuko: 9.0m LOA scallop dredger, IOM registered. Capsized in force 3-4 while handling gear. No stability analysis conducted.

Donna M: 8.8m LOA potter. Capsized while on passage overloaded with creels. Freeboard was negligible and water ingress eliminated stability. No stability analysis conducted.

Gorah Lass: 8.2m LOA netter. Capsized in a force 5, with a swell and a steep chop in wind against tide, having shipped water on deck and into net bins. Stability calculated in the intact accident condition.

Kirsteen Anne: 6.5m LOA potter. Capsized in calm conditions, on passage while overloaded with creels, perhaps following some downflooding. Stability calculated in the intact accident condition.

## **8 RELATIONSHIP BETWEEN FISHING METHOD AND STABILITY CHARACTERISTICS**

The databases were studied for the existence of any trends of stability with the size or form of the vessel or the fishing method. Figure 3 presents some stability characteristics for the three principal categories of database vessels, together with the casualties. The parameters are plotted in relation to the vessel length. Whilst this project was aimed at vessels over 12 metres registered length, a significant proportion of the casualties are smaller. It was considered that their inclusion was of value in this project, and the smaller trawlers in the stability database were included for comparison. Not all parameters were available for all vessels, and so the number of data points on each graph varies.

On the graphs of downflooding angle, and the area under the GZ curve up to the downflooding angle, the data points are disappointingly sparse. It was surprising that most of the stability booklets inspected contained no information on the downflooding angle, or the openings through which it might occur. It is possible that in all cases the downflooding angle is greater than 40 degrees, and therefore does not need to be considered with regard the regulatory minima. Even if this is the case, the fishermen should be provided with information on the most critical downflooding openings, which are the openings most likely to become immersed if undertaking a heavy lift.

It is known that fishermen do not always appreciate the importance of closing doors and hatches but it appears that, perhaps in the majority of cases, they may not have access to any information on the issue with reference to their vessel. It is recommended that the MCA ensure that all stability information booklets contain information on the critical downflooding openings and their angles of immersion.

In general these graphs reveal two significant results.

1. That there is no clear difference between the stability characteristics of these three types of trawler, despite the fact that they fall into distinct groups with respect to their beam/length proportions, as shown in Figure 1.
2. There is no discernible trend of GZ values with length. Downflooding angle and range of stability are non-dimensional, but GZ is not a non-dimensional parameter. Constant regulatory minima, regardless of length, reflect the observation supported by these data that, in practice, GZ values do not tend to vary significantly with size. It should be borne in mind, however, that the righting moments are greater for larger vessels, because of their higher displacements.

## **9 RELATIONSHIP BETWEEN STABILITY AND SAFETY**

### **9.1 Characteristics of the GZ Curve**

The casualty data on Figure 3 present some valuable information.

The graph of GM values supports a view, now widely held by researchers and consultants, that the initial stability is not a good measure of safety. Indeed, the vessel in the database with the highest GM became a stability casualty, albeit with a residual GM reduced by flooding to 40% of its original value. Some of the casualty conditions had low GM values, but some were well in excess of the minimum requirement of 0.35 metres. Casualty data, presented in Ref. 2, similarly indicate a wide range of GM values for capsized fishing vessels, from 0.26 to 0.94 metres. These data were collated by IMCO when fishing vessel stability was being researched during the 1970's. It is interesting to note their proposal that a minimum GM of 0.35 metres should be required, when in fact more than 70% of the casualties studied had a GM of more than 0.35 metres. Prior to this work, the use of GM as a measure of safety was dismissed as '*insufficient*

and can easily lead astray' by Rahola in his ground breaking work in 1939, Ref. 3. His suggestions have formed the basis of conventional criteria, but most include a requirement for minimum GM in spite of his advice. The basis of most current stability assessments, IMO Resolution A.167, incorporated a minimum GM requirement of 0.15 metre, and all of the casualties in Figure 3 would comply with this very low value.

In contrast, the graphs of maximum GZ, and the area under the GZ curve up to 30 degrees, show that the residual stability of all casualties was well below the minimum requirements for these parameters. Some of the vessels that became casualties were characterised by high GZ values in their normal conditions, and this demonstrates that the residual stability is the relevant characteristic. This was one of the important findings of the experimental work conducted in MCA Research Project 509, Ref.4, which, we believe, may be applied to all vessel types. No amount of stability will guarantee safety if it can be eroded to a low level by lifting, adverse loading or flooding.

None of the vessels that became casualties had downflooding angles greater than 40 degrees, and none of the casualties had downflooding angles greater than 23 degrees. The areas under the GZ curves up to downflooding were correspondingly low.

The graph of range of stability shows wide variation and, for some vessels, ranges of up to 180 degrees were indicated, although they are not presented here. These values have been defined in the absence of any downflooding openings, assuming a hull, and in some cases a superstructure, watertight at all angles of heel. In practice the range will be limited to the downflooding angle, particularly if the vessel is held at that angle for a prolonged period, or rolled to it repeatedly. It is notable that none of the vessels that became casualties had a range greater than 67 degrees, and none of the casualties had a range greater than 41 degrees.

## 9.2 Predicted Critical Wave Heights

MCA Research Project 509, Ref.4, comprised model tests to determine the level of safety provided by IMO minimum criteria. The tests indicated that, while the stability parameters used in conventional criteria generally ensure reasonable stability, they are not the best measures of safety and do not necessarily provide adequate safety. The most important stability parameter was found to be the range of positive stability.

The work resulted in the derivation of a method to predict the minimum wave height required to capsize a vessel, on the basis of its beam, range of stability and maximum righting moment. Following tests on a number of model hulls, stationary in regular waves, it was found that the minimum wave height required to capsize could be estimated by the formula:

$$\text{Critical Wave Height, } H_{\text{crit}} = \frac{\text{Range} \sqrt{\text{RMmax}}}{10B} \quad \text{Formula 1}$$

Where  $H_{\text{crit}}$  is the minimum, or critical, wave height that might capsize the vessel

Range is the residual range of positive stability in degrees

RMmax is the maximum residual righting moment, having taken account of any heeling moments due to offset weights, lifting or wind, in tonne.metres

B is the maximum beam in metres

The model test results are presented in Figure 4. They indicate the minimum wave height that capsized each model configuration, following tests at a range of wave heights, periods and headings. Also presented is the line corresponding to Formula 1. It represents a simple linear relationship, passing through the origin and with a round number as the gradient, which passes through the lower part of the envelope of data.

The models tested were of high speed craft, but their stationary condition, and the fact that the wide variety of forms, intact and damaged, upright and heeled, were mixed within the same envelope indicated that the results probably can be applied to any type of vessel.

Subsequent tests on two fishing vessels, conducted in MCA Research Project 557, produced similar results, which are also plotted on Figure 4. The results fell below the line recommended in RP 509, but the test method was significantly different. In RP 509 the models were floating unrestrained, while in RP 557 they were tethered by light lines and springs to maintain a constant heading to the waves. In RP 509 it was found that any tension on a restraining line was likely to induce a capsize, and the lower wave heights suggested by RP 557 are consistent with this.

For the purposes of estimating the wave height that may capsize a vessel it is considered that Formula 1 represents a suitable method. The model tests were designed to determine the minimum possible wave height, at the worst possible wave period and heading, in regular waves, and it is very unlikely that a vessel will encounter such a worst case scenario. For the purposes of estimating likely capsize conditions for real vessels at sea, it is not considered necessary to use a formula that bounds the lowest data points.

Formula 1 was applied to the stability database vessels and casualties, and the results are presented in Figure 5. The vessels span a wide range of critical wave heights, from less than 1 metre to over 20 metres, principally because some have large ranges of stability, but also because the critical wave height increases with the size of the vessel. Bigger vessels tend to have higher values of  $H_{crit}$ , principally because of their greater displacement. The casualties all have  $H_{crit}$  values of about 2 metres or less.

### 9.3 Predicted Critical Seastates

Rather than advise fishermen of the wave height to which a vessel may be vulnerable, it may be preferable to advise them of the seastate. This method of estimating the minimum wave height to capsize a vessel may be related to the limiting operational seastate, using the probability of encountering a wave of that height in a particular seastate.

In a well developed seastate, waves of 60% greater than the significant wave height can be expected once in every 100 wave encounters, and waves of twice the significant once in every 2000 encounters. In practical terms, a vessel on a sheltered route, operating in a spectrum with a modal period of 4 seconds, might expect to encounter a wave of twice the significant height about once in every 2 ½ hours. In exposed conditions, in a fully developed spectrum with a modal period of 10 seconds, one might expect to encounter a wave of twice the significant height about once in 5 ½ hours. It must be understood, however, that if such a wave is expected to occur once in 2000 waves, it may be encountered as the first wave, or not at all.

For the purposes of advising on levels of safety, or recommending maximum operational seastates, this level of probability is considered appropriate. On this basis the critical seastate may be defined as that with a significant height of half the critical wave height, or as given by Formula 2.

$$\text{Critical Seastate, } H_{s_{crit}} = \frac{\text{Range} \sqrt{RM_{max}}}{20B} \quad \text{Formula 2}$$

The seastates predicted by this method are presented in relation to length, in Figure 6. Presenting the seastates in non-dimensional form eliminates the trend with size that is apparent in Figure 5. All but one of the casualties have an  $H_{s_{crit}}/L$  value of 0.05 or lower. This indicates that they might be vulnerable to capsize in a seastate of significant wave height equal to 5% of their length.

It should be understood that, whilst this relationship between critical wave height and seastate is recommended here, it could be adjusted readily, by adjusting the value 20 in the denominator, to provide a different level of safety if desired. For example, if the value were increased from 20 to 25, implying a critical wave 2.5 times the significant height, it would reduce the probability of encountering a critical wave in that seastate to 10% of the recommended value. This demonstrates the value of size and good

stability characteristics, because the level of safety increases in greater proportion than the value of Formula 2.

## **10 RELATIONSHIP BETWEEN FREEBOARD AND LEVEL OF SAFETY**

### **10.1 Scope of the Work**

This was considered to be an important aspect of this study, and of the related Research Project 559. Accordingly, an extensive analysis was conducted with two objectives in mind:

1. To investigate relationships between freeboard and stability of those larger vessels for which stability data were available, to address the effects of overloading.
2. To consider the extrapolation of the relationships to smaller vessels, in the search for a simplified measure of safety for vessels with no stability data.

### **10.2 Definitions of Freeboard**

In these attempts to identify relationships between stability and freeboard, three different measures of freeboard were considered:

1. Minimum freeboard. This is the simplest definition of freeboard, the minimum height of the lowest part of the weather deck above the waterline. This is also the simplest definition for the fishermen to recognise but, where the lower part of the deck extends over only a small proportion of the length, one might expect it to have little bearing on the stability.
2. Mean freeboard. This is the mean freeboard, taking account of trim, sheer of the deck, and raised decks in way of a poop, focsle or watertight shelter that extends to the side of the vessel.
3. Effective mean freeboard. Although the mean freeboard value incorporates volumes that contribute to the stability, the presence of a high focsle, for example, which extends over a short length, will result in a relatively high mean freeboard but with little stability benefit. If such a vessel heels to a large angle, it is likely to trim to such an extent that the aft part of the deck is submerged, and the benefits of additional volume forward are negated. In their study in 1994, Ref. 1, Seaspeed Technology Ltd. calculated a freeboard value by distributing the volume of a focsle or shelter over the full length of the deck, up to a limiting height of  $B/4$ . In this study a similar formula was used, but simplified so that the contribution of raised decks was limited to a height of  $B/4$  over the length of the raised part only.

### **10.3 Relationship between Stability and Freeboard for Documented Vessel Conditions**

Stability characteristics of the vessels in the database were plotted against their freeboard to determine whether any trends were apparent. No relationships were found between freeboard and fishing method.

Figure 7 presents the variation of two stability parameters with the three different measures of freeboard. Area under the GZ curve up to 30 degrees and range of stability were selected for presentation, as they appear to relate well to safety on the basis of the casualty data, and are representative of the relationships of other parameters.

The data show considerable scatter but, for vessels with low freeboard, there appears to be a trend that the area under the GZ curve increases with freeboard. The trend is most distinct when plotted with respect to minimum freeboard. This relationship does not extend to vessels with moderate or high freeboard. The range of stability data show a stronger relationship, with range increasing with freeboard and, in this case, the trend is most distinct when plotted with respect to mean freeboard.

Figure 8 presents the same data with respect to the non-dimensional ratio of freeboard/beam. The differences between the two presentations are subtle, but the non-dimensional form reduces the scatter in the cases of the two relationships described above.

To summarise, the area under the GZ curve up to 30 degrees appears to be related to the ratio of minimum freeboard/beam. The range of stability appears to be related to the ratio of mean freeboard/beam. The formulation of effective mean freeboard does not appear to reduce the scatter in the data.

The casualty data all exhibit low minimum freeboards, in one case negative, because the data refer to residual values under the influence of heeling moments. Some, however, had moderate mean freeboards.

This suggests that mean freeboard may not be an effective measure of safety, despite the evidence that it is related to the range of stability for the normal vessel conditions of the non-casualty data.

#### **10.4 Relationship between Stability and Freeboard on Specific Vessels**

In an attempt to quantify, in general terms, the relationships between stability and freeboard, the stability of a number of vessels was calculated at a range of draughts. Some vessels were defined on the Wolfson Unit's own software, and for others the calculations were based on KN data presented in stability booklets.

The effects of increasing the draught and reducing the freeboard, whilst maintaining a constant KG, are presented for six different vessels in Figure 9. The magnitude of the variations is not consistent, but governed by the range of draughts over which KN data were available. In most cases the dominant effect is to reduce the maximum GZ value and, in some cases, the range of stability is reduced substantially. In one case, the 24m trawler, the effects appear small, but for this vessel the extent of the KN data was the most limited. In every case a reduction in freeboard results in a reduction in the righting arm. It is not necessarily the case that the righting moment is reduced, because it is the product of displacement and righting arm, but the range of stability is always reduced.

The nature of the effect is dependent, to some extent, on the arrangement and lengths of focsle, poop and watertight shelter. Where there is a low minimum freeboard over a significant length, a modest focsle or poop results in a large trim developing with heel, and dramatic changes in the GZ curve may result from a reduction in freeboard. This is the case for the 14m, 30m and 45m trawlers. With a focsle and poop, or a continuous deck, the effects are less dramatic, as illustrated by the 24m and 86m trawlers. The 55m trawler has a forward shelter extending over half the length of the vessel, so trim effects are less than they would be with a short focsle.

Collation of the variation of range of stability with mean freeboard indicated a strong trend, as illustrated in Figure 10. The six vessels in Figure 9 are included here, with additional trawlers of 10 and 14 metres, and two more of 28 metres. The data fall into a distinct envelope, with one exception, a trawler with an enclosed poop. KN data were obtained for this vessel from the stability booklet, and their validity could not be checked. The trend reinforces that suggested by the plot of range against mean freeboard/beam in Figure 8. The individual data sets indicate that the range of stability is likely to reduce to near zero if the mean freeboard is reduced to zero, although of course the vertical centre of gravity will affect this critical freeboard in each case.

Another interesting characteristic illustrated by Figure 10 is that the rate of change of range of stability with freeboard increases as freeboard reduces. This means that, if freeboard is reduced progressively by overloading, the range of stability reduces ever more rapidly. This would not be intuitive to the fishermen.

## **11 RELATIONSHIP BETWEEN LIFTING AND LEVEL OF SAFETY**

The Technical Advice Project TA 16/99(b) conducted for the MCA in 1999 demonstrated the implications of lifting on the stability of beam trawlers. These vessels are required to comply with minimum requirements 20% greater than those for other types of fishing vessel, but typically this margin is less than the reduction in stability that results during normal gear handling operations.

An example of how the residual stability reduces when lifting is given by Figure 11. The upper graph illustrates lifting over the side of a 24 metre beam trawler. The maximum GZ value, area under the curve and range of stability all decrease progressively as the lifting load is increased. The initial heel angle, or list, under the influence of the applied heeling moment increases steadily at first, but with very heavy lifts the rate of change of heel angle with load becomes non-linear. This is a characteristic of the situation that is likely to surprise the crew. If they had consulted their stability booklet, it would indicate a range of positive stability of over 70 degrees, but a heavy lift or an attempt to free fastened gear would result in a capsize at a much lower angle, in this case if the vessel were heeled beyond 40 degrees. The lower graph illustrates the much more onerous case of lifting from the outboard end of the horizontal derrick. The characteristics of the curves are the same, but the longer lever results in much higher moments for a given load, or warp tension. A lift of 8 tonnes would bring the vessel very close to capsize, and a gear weight of

3 to 4 tonnes is typical for this size of vessel. If the two sets of gear were to become tangled, therefore, recovery would be an extremely hazardous operation.

An illustration of the effects on residual freeboard and range of stability, of lifting, compared with loading, is given in Figure 12. The plots show, for two configurations of trawler, the effects of lifting over the side of the vessel. For the lifting cases, the lift was increased in increments of 4 tonnes, and the data for the hull and poop configuration correspond to those of the upper graph of Figure 11. The reduction in the residual stability is dramatic when compared with the reduction that would result from a symmetric increase in the loading of the same vessels. This is illustrated by the broken line on each plot, with data points shown at increments of 40 tonnes displacement. In both examples, as the residual freeboard reduces towards zero the range reduces towards zero, regardless of whether the reduction is due to symmetric or asymmetric loading. The difference is that a very small load being lifted over the side results in a similar reduction to a very large load placed symmetrically on the vessel.

Figure 13 presents similar data for other beam trawlers, to illustrate the effects of gear handling. The effects of lifting on the reduction in the maximum GZ value are also presented. All of these vessels show similar trends. The data were calculated for the gear on deck, and then with the gear on one side lifted with the derrick at 45 degrees, as is typical when boarding the gear. Their heel angles were in the range 9 to 14 degrees, and this is not uncommon for vessels in the UK fleet.

Figure 14 presents data to show the effects of lifting on a small twin rig trawler. In this case a weight of 1 tonne was transferred from the centreline to a point 2.5 metres off centre, for a vessel with a beam of 4.8 metres. Data are presented for three displacement conditions. It is apparent that a lift of 1 tonne gives a reduction in the range of stability similar to that resulting from an increase in displacement from 58 to 74 tonnes, which is 16 tonnes.

It is apparent from casualty reports that lifting represents a significant operational hazard, and these data help to quantify the effects. At present, however, there is no requirement for fishing vessel stability booklets to include information on the effects of lifting, and so fishermen have no information with which to judge their level of safety.

## **12 METHODS CONSIDERED FOR THE BASIS OF GUIDANCE**

In order to provide guidance on the level of safety of a vessel in different load cases, a number of methods are available, each based on different parameters. The options considered were:

1. Freeboard, referred to existing freeboard regulations or some function of them.
2. Stability, referred to IMO criteria or some function of them.
3. Predicted critical wave height or seastate.
4. Heel angle, to advise the maximum safe lift.

### **12.1 Safety Guidance Based on Freeboard**

The minimum freeboards of the vessels in the stability database are compared with some freeboard regulations in Figure 15. Most vessels comply with the basic load line rules for the minimum freeboard of merchant vessels, although the relationship between this rule and the casualties does not inspire confidence. The minimum freeboard required for new fishing vessels of 15 to 24 metres is equal to LBP/40 and represents a much higher standard. Most of the casualties would not comply with it, so it appears to provide a better measure of safety. An intermediate standard is set in Russia for vessels under 24 metres.

These standards all provide a pass/fail limit, but offer no indication of the variation of safety with freeboard, or of the seastates in which it should be safe to operate. It is apparent from section 10 that freeboard is an important factor for safety, and that reduced freeboard generally results in a reduction in stability, but freeboard alone does not incorporate any consideration of the height of the loads applied.

The freeboard regulations address the normal upright freeboard when loaded symmetrically, and have not been developed to address residual freeboard when heeled as a result of offset loading or lifting.

## **12.2 Safety Guidance Based on Conventional Criteria**

Since the stability booklet presents stability data for a range of freeboard values, taking into account the centres of gravity of the anticipated loads, it is preferable to incorporate this information into any method of guidance.

As with freeboard regulations, the conventional methods of assessment against stability criteria provide a pass/fail system but do not provide information on the variation of safety with the stability parameters assessed. One could define levels of safety by applying factors to the standard criteria values but, as discussed in section 9, the parameters used in the current method of assessment of UK fishing vessels do not provide a reliable method of measuring the level of safety, or provide information on the seastates in which it should be safe to operate.

As for the freeboard regulations, stability criteria address the normal upright case when loaded symmetrically, and have not been developed to address residual stability when heeled as a result of offset loading or lifting. Some standards incorporate criteria to determine the adequacy of stability when lifting but, again, they provide a pass/fail mechanism rather than offering information on the variation of the level of safety when lifting.

## **12.3 Safety Guidance Based on Estimated Critical Wave Height**

The safety measurement method described in sections 9.2 and 9.3 enables the provision of guidance relating the level of safety, defined by the stability, to the seastate. Whilst a similar method could be used with a combination of the standard IMO criteria, the level of safety associated with the formula proposed in this method incorporates the effects of asymmetric loading or lifting, and has been quantified with model tests. It offers a scale for the variation of safety with residual stability, within which can be defined a number of safety zones that relate to the operational seastate.

## **12.4 Safety Guidance Based on Heel Angle**

A proven system of guidance based on heel angle is used for sailing vessels, and is defined in the Large Commercial Yacht Code, MSN 1792. It advises the maximum recommended heel angle in a steady wind, assuming a gust factor that would result in heeling the vessel to the downflooding angle. A simple inclinometer is all that is required to monitor the heel angle under sail. A similar system could be used to provide guidance on the maximum recommended heel angle when lifting, as illustrated in Figure 16.

If the downflooding angle and GZ curve are known, one can define the heeling moment required to cause downflooding or capsize, whichever would occur first. Application of a suitable safety factor will give the maximum safe heeling moment, and the associated heel angle. The safety factor would need to make allowance for the effects of wave action, and these would depend on the damping effects of the gear being lifted. These effects might be different in the case of a vessel attempting to break out fastened gear.

For sailing vessels, the maximum probable gust factor is known. Unfortunately we have no information on the required safety factor associated with lifting in a seaway and so, at present, it is not straightforward to provide reliable guidance using this method.

# **13 DEVELOPMENT OF SAFETY ZONE DEFINITIONS**

## **13.1 Selected Method**

Of the options discussed in section 12, guidance based on the method of estimating the critical wave height or seastate from the residual stability characteristics is preferred. It is hoped that it will encourage consideration of the environmental conditions together with the risks associated with operational hazards, by providing information that links the two.

Observers' estimates of average wave height have been compared with wave buoy measurements and it has been found that the observations correspond closely to the significant wave height, which is the mean of the highest third of the waves. Ref.5. This correlation is maintained for all seastates. The significant wave height therefore represents a measure of seastate to which fishermen are most likely to relate, albeit

without knowledge of the mathematical definition of the term. Formula 2, defined in section 9.3, therefore has been used in developing this method.

The benefit of such a system is that the level of safety can be associated with a critical seastate,  $H_{s_{crit}}$ . The skipper of a vessel therefore can operate in an “unsafe” condition, provided he takes appropriate precautions and restricts such activities to seastates below the critical value.

### 13.2 Definition of Safety Zone Boundaries

The proposed format of the Stability Notice is to have coloured safety zones as follows:

Green: “safe” in all but extreme seastates  
 Amber: “low safety” and should be restricted to low seastates  
 Red: “unsafe” unless restricted to very low seastates and with extreme caution.

### 13.3 Boundaries Defined by Constant $H_{s_{crit}}$

Consideration of the casualties in Figure 5 suggests that a constant value of  $H_{crit}$  or  $H_{s_{crit}}$  might be used to define the safety zone boundaries. It seems likely that, if larger casualties had occurred, they might have done so in higher seastates. The trend of increasing  $H_{crit}$  with length, and the fact that small vessels tend to operate in more sheltered waters, mean that this method would not provide a good solution.

### 13.4 Boundaries Defined by Constant $H_{s_{crit}}/L$

In Figure 6, to which Formula 2 relates, all but one of the casualties are characterised by the value of  $H_{s_{crit}}/L$  being 0.05 or less, while all of the database vessels have a value greater than this. Most of the database vessels have a value of  $H_{s_{crit}}/L$  greater than 0.1. It should be borne in mind that the values for the database vessels refer to standard stability booklet conditions, whereas the casualty data refer to the casualty condition, in some cases with a heeling moment applied. The data show that most fishing vessels normally operate with stability characteristics such that  $H_{s_{crit}}/L$  is much greater than 0.1 but it is apparent from these casualty data that they may reduce this significantly, and in some cases to below 0.05, albeit perhaps in accidental circumstances.

$H_{s_{crit}}/L = 0.05$  appears to represent an unacceptable level of safety and was considered as the definition of the boundary between operational conditions that have a low level of safety, and those that are considered unsafe.

It is possible that a very large vessel, over 100 metres, could operate in compliance with the IMO criteria but have a value of  $H_{s_{crit}}/L$  as low as 0.05. This implies that a standard stability booklet condition could be categorised as unsafe by this method, although it would be associated with a seastate with a significant height of 5 metres. This is typical of gale force conditions, and considered very rough.

For a 15 metre vessel, representing the minimum length of the regulated fleet,  $H_{s_{crit}}/L = 0.05$  would imply stability characteristics well below the minimum IMO requirements, with advice that it would be acceptable to operate in a seastate with a significant wave height of 0.75 metres. This might be expected in Beaufort force 3-4 conditions, when fishermen in a vessel of this size would not expect to restrict their operations.

The difference between the stability characteristics and the associated levels of safety for these different sizes appears to be somewhat anomalous on this basis.

It is perhaps more difficult to define a boundary between “good” and “low” levels of safety. In Figure 6, all of the casualties have values of  $H_{s_{crit}}/L$  below 0.1, and so that was considered as a potential boundary. It has the attraction of being a round number, with a value twice that of the lower boundary proposed.

For the smaller vessels to which this guidance applies, a value of  $H_{s_{crit}}/L$  of 0.1 could be achieved without compliance with the IMO minimum criteria. Although the systems of regulation and guidance need not be directly related, it is considered desirable that they be related if it is practical, and not detrimental to the system of guidance.

For a 15 metre vessel, this corresponds to a seastate with a significant height of 1.5 metres, with the likelihood of encounters with occasional waves of 3 metres. These conditions might be expected in Beaufort force 5, which is a frequent occurrence, and in which fishermen in vessels of this size would not expect to cease their operations. It would appear reasonable for this length.

For large vessels, however, this value appears less reasonable.  $H_{s_{crit}}/L = 0.1$  represents a seastate with a significant height of 10 metres for a vessel of 100 metres, and it would not be sensible to advise the fisherman that his vessel has low safety but can operate in such seastates.

### 13.5 Boundaries Defined by Variable $H_{s_{crit}}/L$

Figure 17 presents values of  $H_{s_{crit}}$  calculated for the database vessels, not for their actual stability, but assuming the minimum stability with which they could achieve compliance with the IMO criteria. Although range of stability is not regulated in the standard criteria, the minimum values of the area under the GZ curve, together with the requirement for a GZ of 0.2 metres at 30 degrees, ensure that the range of stability is likely to be at least 50 degrees, and almost certainly greater than 45 degrees. This is borne out by the data presented in Figure 3, where the lowest range of stability for a vessel over 15 metres is 47 degrees. In producing Figure 17, the values; range = 45 degrees and  $GZ_{max} = 0.2$  metres have been assumed.

This presentation provides an insight into the level of safety implied by the IMO criteria, for typical fishing vessels. The fit to the data is defined by the formula:

$$H_{s_{IMO}} = \sqrt{1 + 0.4LOA} - 1 \quad \text{Formula 3}$$

Where  $H_{s_{IMO}}$  represents the seastate in which a vessel might be vulnerable if it just complies with the IMO minima.

It should be possible to harmonise the system of guidance with that of assessment, so that all vessels, regardless of size, are provided with safety guidance in line with the IMO minimum requirements. Since the requirements are regarded as safe in terms of the stability assessment of upright vessels, it may be argued that this line is a reasonable level at which to set the green/amber zone boundary.

The line represents seastates of 1.65 metres and 5.4 metres significant height, for vessels of 15 and 100 metres respectively. These are perhaps more reasonable than those derived from constant  $H_{s_{crit}}$  or  $H_{s_{crit}}/L$ , in terms of the seastates in which such vessels might be expected to be safe. This relationship therefore is proposed to define the boundary between the green and amber zones.

Figure 18 shows the variation of  $H_{s_{crit}}$  with length for the database vessels in their actual operating conditions and the casualties. Superimposed is the proposed green/amber boundary defined using Formula 3, representing typical values for vessels just complying with the IMO criteria. Some vessels apparently have very high levels of safety, with values of  $H_{s_{crit}}$  well above the boundary line. It should be borne in mind, however, that these values are for the upright vessels, not for residual stability when lifting. Furthermore, they may be based on a range of stability that requires doors to a superstructure or shelter to remain closed, while it is well known that such is not necessarily the case when at sea. Some of the smaller vessels, particularly those below 15 metres, lie below the proposed boundary. Many of them do not comply with the IMO minima, so this is to be expected with this method of boundary definition.

The boundary between the amber and red zones should be set with due regard to the casualty data. The option shown on Figure 18 is defined by the line  $H_{s_{crit}} = 0.5 H_{s_{IMO}}$ . The red zone thus defined contains all but two of the casualties. One of these lies just outside the boundary and the other in the lower third of the amber zone.

Figure 19 presents the predicted critical seastates for the casualties, and the proposed safety zones, together with the actual wave heights in which the capsizes are thought to have occurred. The data points for each vessel are labelled with a common number to facilitate comparison of the two values in each

case. The values of significant height for the actual seastates are estimates based on eyewitness accounts and therefore cannot be regarded as precise. The incidents all occurred in seastates higher than the predicted critical values, which are minimum values as explained in section 9. In most cases the actual seastates were very much higher than the predicted critical values, while in one case the estimated seastate was only 35% greater than the predicted  $H_{s,crit}$ . The latter is vessel no.3 on the graph, Charisma, plotted with a seastate of 0.5 metre, but this is a very approximate estimate of the actual seastate which was described simply as “calm”.

This presentation suggests that the two casualties that are in the amber zone on the basis of  $H_{s,crit}$  might not have capsized had they restricted their operation to appropriate seastates.

## 14 EXAMPLE DATA

Calculations were conducted to determine the loading and lifting configurations that would form the basis of guidance for a 24 metre beam trawler, assuming the green/amber and amber/red boundaries defined as described in section 13.5.

Four loading cases were considered, using the Depart Grounds condition in the stability booklet as a basis:

1. Lifting from the normal towing and lifting block on the horizontal derrick on one side.
2. A heavy lift on one side, undertaken with the warp taken to the side of the vessel.
3. Lifting both trawls, with the derricks topped to 45 degrees.
4. Overloading the vessel by filling the hold.

Loading Case	Lifting Point	Green/Amber, $H_{s,crit} = 2.26\text{m}$			Amber/Red, $H_{s,crit} = 1.13\text{m}$		
		Load tonnes	Min. Fbd metres	Heel degrees	Load tonnes	Min. Fbd metres	Heel degrees
Lifting one side	Lowered derrick	5.5	-0.05	12	7.5	-0.20	17
Lifting one side	Ship's side	10	0.03	10	15	-0.21	16
Twin lift	Derricks 45 deg.	2 x 4.5	0.63	0	2 x 7.5	0.61	0
Hold Filling	No lift	75	0.20	0	92	0.04	0

In this example, when lifting on one side, the level of safety enters the amber zone when the minimum residual freeboard is reduced to zero, that is when the deck edge is at the waterline. The level of safety passes into the red zone when the deck edge is 0.2 metres below the waterline. These freeboards correspond to angles of heel of around 10 and 16 degrees respectively. These angles and freeboards could be remembered by the crew, and would provide simple guidance on the level of safety in the absence of any load measuring device to quantify the lift. With the warp brought to the vessel's side the capacity to lift is increased by a factor of two compared with a lift from the outboard end of the horizontal derrick.

When lifting both trawls with the derricks topped, freeboard and heel angle are unaffected by the lift, and the loads would need to be quantified if there was any possibility that such lifts might be attempted. Lifting from topped derricks is undertaken to board the trawls or to gain access to the cod ends to release debris. It is possible that a very heavy lift might be undertaken to empty heavy loads of sand, stones, weed, starfish, or other debris that might accumulate in both trawls. It will be helpful to know the level of safety in such cases, so that alternative measures can be used if the trawls are dangerously overloaded. In this example the loads are similar to those for a single lift on a lowered derrick.

Beam trawlers do not normally load large quantities of catch, but it might be useful to provide the information on the maximum loading of the hold if it is feasible that it could be achieved in practice, perhaps with a change in fishing method. In this example 75 tonnes of catch in the hold would reduce the stability to the amber zone boundary, and 92 tonnes would bring it to the red zone boundary. If the hold capacity was insufficient for these loads it would not be appropriate to include them on the Stability Notice. The relatively small difference between these two loads supports the finding described in section 10.4, that stability reduces ever more rapidly as loading is increased.

This example has been used as the basis for an example Stability Notice, which is presented in Figure 20.

## **15 INSTRUMENTATION**

### **15.1 Draft Monitoring and Stability Monitoring**

Draft and stability monitoring systems are in use on other vessel types, and on some fishing vessels in other countries. For vessels loading at sea these may offer the most effective means of monitoring the loading, freeboard and initial stability of the vessel, and should be encouraged. It is believed that Seafish are considering the application of such instrumentation. It may become more common in the future as a result of technical developments, more attractive pricing and perhaps increased awareness and pressure from organisations such as Seafish.

It is not recommended at this stage as a requirement to be imposed by the MCA because overloading of fishing vessels over 12 metres does not appear to be a significant cause of stability related incidents. It is recognised as a potential operational hazard, but one that will be addressed by the Stability Notice.

Such monitoring would also indicate flooding of the hull, which is a frequent factor in fishing vessel losses, but it is not known whether it would prove more reliable than bilge alarms, which have a poor record. If reliability is adequate, this valuable advantage should be considered by those promoting these systems to the industry.

### **15.2 Warp tension monitoring systems**

Excessive heeling moments due to lifting overloaded or fastened trawls are one of the most common serious operational hazards for fishing vessels over 12 metres. In many cases the behaviour of the winch machinery gives an indication that an extreme lift is being attempted, but the magnitude of the lift is not quantifiable without dedicated load monitoring instrumentation.

Warp tension monitoring equipment has been in use on a large scale in other countries for many years but has been less popular in the UK fleet. The safety benefits are very worthwhile, but the fishermen have found significant efficiency benefits, which have helped with the acceptance of the systems and widened their use within a fleet.

Excessive heeling moments represent a particular threat to twin beam trawlers and dredgers, because their gear is towed and lifted from derricks. When lowered, these extend well beyond the side of the vessel and increase the heeling moment resulting from a given load. When topped, they raise the effective centre of gravity of the lifted load well above the location of the gear that is assumed in the stability assessment.

The heel angle can be used to assess the safety when lifting on one side but, without some form of load monitoring instrumentation, it is difficult to assess it with a high degree of accuracy. When lifting similar loads on both sides, the heel angle will be negligible but the loads might represent a severe hazard, and load monitoring instrumentation is the only accurate means of determining the level of hazard.

Warp tension monitoring systems have been developed to display instantaneous and mean loads on the warps and the length of warp off the winch drum, and to provide feedback to the winch and engine controls to enable an efficient and safe operation. They represent a substantial capital investment, of the order of £10,000, but this is a relatively small percentage of the cost of a new vessel. It is understood that the larger new vessels that are being equipped for beam trawling are being fitted with comprehensive systems.

It is proposed that all new vessels equipped for beam trawling should be fitted with warp tension monitoring systems.

### **15.3 Load cells**

Whilst warp tension monitoring systems provide extensive information, sufficient information on the loads being lifted can be obtained at a fraction of the cost using simple load cells and displays. A variety of models is available, including shear pin and shackle types, which have been designed for harsh environments, including immersion in salt water. Comprehensive load ranges are available which are

adequate for the full range of vessels in the UK fleet, at a cost of the order of £1000. At this level of investment it is considered a worthwhile addition to existing trawlers and beam trawlers because of the benefits in terms of enhancing the accuracy of the information presented on the Stability Notice.

Load cells would be required on all lifting points which are capable of applying hazardous moments to the vessel. This could be determined simply by calculation, using the lifting equipment capacity and location of the lifting block in conjunction with the stability information, to determine whether a lift could reduce the residual stability to the level of the amber or red zone. Typically, a trawler might need a load cell on each towing or gallows block, and one on the derrick used for boarding the cod end.

It is understood that the introduction of revised regulations for lifting equipment may result in load cells being required on fishing vessels at some time in the future. Such a development will make requirements on the grounds of stability superfluous, and duplicated requirements might result in some lack of harmony within the details.

Their value should be appreciated, and their use should be encouraged, but requirements for fitting load cells on the grounds of stability do not form part of these recommendations.

The situation should be reviewed in, perhaps, one or two years, and, if the requirement for load cells within the lifting equipment regulations does not affect fishing vessels, this recommendation should be considered again.

Where load cells are fitted, the loads corresponding to the safety zone boundaries should be presented on the Stability Notice, unless they exceed the capacity of the lifting equipment.

#### **15.4 Inclinometers**

An inclinometer would enable the heel angle due to lifting to be monitored, and compared with heel angle information on the Stability Notice. Whilst it is unlikely to be as accurate as lifting load monitoring instrumentation, it has the advantage that measurement of heel angle incorporates any reduction in the stability of the vessel or movement of the lifting point. If the stability has been adversely affected by unreported modifications to the vessel, poor loading or flooding, the heel angle resulting from a given moment will be greater than predicted in the stability calculations conducted when preparing the Stability Notice. If the lifting point has been relocated, the lifting guidance presented on the Stability Notice may be invalid, but heel angle guidance is unlikely to be affected.

Inclinometers come in a variety of forms and levels of complexity. It would be advantageous to have a display with an efficient averaging system to eliminate the roll motion and present the mean heel angle, but even a simple device will provide valuable information. A bead in a fluid filled tube is perhaps the simplest type, obtainable at yacht chandlers for a few pounds. Whilst it will not give a steady reading on a rolling vessel, the observer can obtain a mean reading with reasonable accuracy, and such a device would enable the fishermen to become more familiar with the feel of their vessel at different heel angles. They would then be better able to relate to the information on the Stability Notice.

A permanent inclinometer would facilitate conducting a heel test to monitor the stability.

Because simple instruments are cheap, readily available, and trivial to fit, it is recommended that all fishing vessels should be equipped with some form of inclinometer, mounted athwartships to measure the heel angle.

## **16 PREPARATION OF STABILITY NOTICES**

### **16.1 Loading Cases**

It is anticipated that consultants will use software that will automate the calculation to such a degree that it can be based on all of the standard loading conditions, in the same way as maximum allowable KG calculation might be performed. It should, therefore, be possible to identify the worst conditions as those with the lowest loads at the safety zone boundaries.

If it is not practical to consider a range of conditions, the alternative approach would be to base the information on the worst stability condition. There are some potential disadvantages of this method. The condition with the lowest stability might have the highest freeboard, and it is not always possible to identify by inspection which condition might have the lowest level of safety when additional loads are applied, particularly when lifting. Conventional assessment does not consider righting moment and so the condition with the lowest GZ values might not be the condition with the lowest righting moment.

It will be necessary to consider all possible loading cases that might be hazardous to the vessel. These might include overloading holds, filling hoppers, holding catch on deck, and lifting from all blocks with large capacity. It may be necessary to consider combinations of loading and lifting, particularly where it is likely that a combination of the two will take place, or where normal operations result in very large variations of loading condition and stability. Examples of possible presentations are shown in Figure 21 and Figure 22.

It is anticipated that, in most cases, such a study will provide redundant information, and every effort should be made to simplify the Stability Notice by minimising the number of loading cases presented. Redundant information will occur if maximum possible loads or lifts do not result in a reduction of stability to the amber zone. Simplification of the information may also be possible where different loading cases have similar critical loads, and therefore may be grouped together with a common value.

The potential for significant downflooding should be considered, and the stability curve terminated at the downflooding angle.

### 16.2 Accuracy of Data

When operating with minimal stability, small changes to the loading case can result in large changes to the predicted value of  $H_{S_{crit}}$ . This is because the range of stability, which is the dominant parameter, can reduce rapidly, particularly with asymmetric loading, or lifting, cases. Whilst accuracy of the calculations is necessary to ensure that reliable information is provided, it should be borne in mind that the information is based on estimates of vulnerability which depend on many variables. This method does not offer a precise prediction of capsizing, and so presentation of information to a high degree of accuracy is not appropriate.

Calculated values should be rounded to levels that are reasonable, bearing in mind the instrumentation or observations to which they relate. As a general rule of thumb, rounding of values to within 10% should be appropriate. The following examples are offered for guidance:

Parameter	Units	Decimal Places
Seastate	metres	0 or 1
Load	tonnes	0 or 1
Freeboard	metres	1
Heel angle	degrees	0

### 16.3 Maximum Seastate Recommendations

The relationship between the stability and the predicted critical seastate is a progressive one, and one might argue that it should be presented graphically so that, for any given loading case, the maximum recommended seastate could be looked up. Such information might provide more accurate and detailed information, but could not be memorised. To provide the fisherman with a single value of the maximum recommended seastate, which applies to the range of loadings within each safety zone, one must make some judgement on whether to advise the value corresponding to the upper boundary, the lower boundary, or some intermediate value.

Consider the example given in section 14. If a heavy lift is attempted at the vessel's side, and the load cell indicates 12.5 tonnes, the level of safety would be in the middle of the amber zone, and the vessel might

be vulnerable in a seastate of about 1.7 metres, because that is the value mid way between the boundary values calculated.

Adopting the conservative philosophy normally inherent in a regulatory regime, one would advise the fisherman that he should not undertake any operation within the amber zone if the seastate is above that corresponding to the lower, red, boundary value. In this case that would be 1.1 metres.

The basis of this method of guidance is a predicted minimum seastate that might result in capsizing. Capsizing will occur, if the vessel responds in a similar way to the worst configurations in the model test programme, and the circumstances combine encounters with waves of twice the significant height of the seastate, having the worst possible wave period and wave heading, in sufficient number to excite the vessel. The likelihood of all of these circumstances occurring simultaneously is low, and so a margin of safety is inherent in the method, in terms of a probability.

For this reason it is recommended that the seastate value presented for the amber safety zone should be that corresponding to the upper, green/amber, boundary. Similarly, the value presented for the red zone should correspond to the amber/red boundary.

Considering again the scenario of a 12.5 tonne lift described above, the Stability Notice would advise not to undertake the lift in seastates above 2.2 metres. The fisherman might interpolate intuitively between the presented values of load and seastate, and thus obtain an approximate intermediate value for the maximum recommended seastate, but this is not necessarily expected.

The casualty data presented in Figure 19 support this apparently optimistic approach, with capsizing seastates generally significantly higher than the predicted minima.

Presentation of too conservative a value will result in a lack of respect for the information, and it will be disregarded.

#### **16.4 Vessel Illustrations**

Simple illustrations should be incorporated to clarify the nature of the information provided. These may be simple diagrammatic line drawings of the profile or cross section of the vessel, as appropriate to identify each loading case considered. Whilst it is not necessary for these to be scale drawings of the vessel, the fisherman will be more likely to relate to them if they bear a close resemblance to the vessel.

#### **16.5 Notes on Maintaining Stability**

The notice should include notes entitled “Simple Efforts for Maintaining Stability” or similar. These notes should be relevant to the vessel, its gear and catch handling arrangements and the fishing method. Suggestions for notes follow, and relevant ones might be selected from, or based on, this list but it is not intended to be exclusive.

- § To maintain the approved stability, ensure that external doors and hatches are not left open at sea. (Those assumed to be closed in preparation of the Notice should be identified clearly here).
- § Ensure that scuppers and freeing ports are open and clear of obstructions to allow water to drain quickly from the deck.
- § Before attempting a heavy lift, inform the coastguard, bring the warp as far inboard and as low as possible, close all doors and hatches and ensure that all crew are on deck, wearing life jackets.
- § If the maximum recommended lift from the vessel’s side is exceeded, abandon the lift immediately. The position of the gear should be marked for retrieval by a larger vessel.
- § The vessel may become unsafe if heavy items are moved up, heavier gear is fitted or lifting points are moved.
- § Secure all gear and catch against shifting.

#### **16.6 Photograph**

A photograph of the full profile of the vessel should be included, and labelled with the date it was taken. The date should correspond with the preparation of the Stability Notice.

## 17 HEELING TESTS

Common findings in the analysis of fishing vessel stability casualties are that the stability of the vessel had been degraded by modification, or that the operational moments applied had been increased by changes to the gear or its handling arrangement. If significant changes are made to any of these aspects their effect on the stability should be checked, MCA notified, and the stability booklet revised accordingly. Such a procedure is not always followed, as the accident investigations reveal. The vessels that are particularly vulnerable to such alterations, because the gear weight and lifting arrangements have the potential to apply very large heeling moments, are twin beam trawlers and dredgers. For these vessels a heeling test is proposed to highlight any significant alterations.

Various procedures for heel tests have been incorporated into stability assessment procedures for other types of vessel, or in other countries. Typically a specified weight is used, determined by formulae that incorporate vessel parameters or stability. A heel test with specified weights requires assumptions regarding the types of lift undertaken, calculations of the weights to be used, sourcing and checking of the weights, getting the weights on and off the vessel, moving them, and getting the vessel into a specified loading condition for the test.

Whilst there is no doubt that such a controlled test can provide accurate data, it will not necessarily relate to the lifts undertaken during fishing operations. The test does not need to be conducted to determine the stability of the vessel because that is done by an inclining experiment. The aim of the heeling test proposed is to indicate whether modifications are significant and therefore require revision of the Stability Notice, and perhaps the stability booklet, in which case an inclining experiment will be required.

All of the practical problems and inconveniences of a controlled heeling test with specified weights can be dispensed with if components of the actual gear, lifted from the vessels blocks in their highest or furthest outboard locations, give a measurable heel angle. Such a heel test will relate directly to the fishing operation. More importantly, it will enable the fisherman to relate his operation to his stability.

For a beam trawler this is straightforward because lifting one beam trawl from the horizontal derrick on one side, typically, will result in a heel angle of about 10 degrees. Any increase in the trawl weight or derrick length, or decrease in the stability, will result in a larger angle. Small differences are not important, because they are inevitable with wear of the gear and small variations in loading condition. It is not considered necessary to specify the vessel loading condition precisely but some level of repeatability in the righting moment is required. Because the righting moment is proportional to the product of displacement and GM, and both tend to increase with increased tank contents, variations of around 30% are to be expected between the depart port and arrival conditions. A convenient loading condition, such as a nominal depart port condition, should be selected. Empty hold, no ice and full tanks might be a practical condition, for example. Preferably this should be agreed by the skipper and the surveyor well in advance of the first test. The vessel should be trimmed upright by movement of loose gear or tank contents, or the heel test could be conducted on both sides, and a mean value recorded to eliminate the effects of any initial list.

The heel angle can be measured with a simple inclinometer, provided it enables a suitable level of accuracy. If the heeling test is conducted at the same time as an inclining experiment it may be convenient to use a damped pendulum. If the heel angle is significantly greater than that recorded when the Stability Notice or stability booklet were prepared, it will be necessary to determine the reason for the increase. It is suggested that a suitable criterion for acceptability, or margin of variation, in the measured heel angle is within 10% of the original value. It should be noted that such an increase in the heel angle may be gradual, so that successive heeling tests might be within the acceptable margin of each other, while the cumulative effect results in an increase from the original that is unacceptable.

There are three possible reasons for an increase in heel angle, and each one that applies will require appropriate revision of the stability documents for the vessel. In some cases a combination of reasons will apply.

Reason for increase in heel angle	Revisions required
Increased weight of fishing gear	Stability booklet – gear details and loading conditions
Longer derricks, or a higher lifting point	Stability booklet – derrick details Stability Notice – maximum recommended lifting loads
Reduced vessel stability	Conduct new inclining experiment Stability booklet – loading conditions Stability Notice – all data

## 18 SUMMARY OF GUIDANCE AND ASSESSMENT PROCEDURE

### 18.1 Guidance and Assessment Flow Chart

Figure 23 presents a flow chart to assist with understanding the application of the system of assessment and guidance proposed. It includes the proposals made in Research Project 559 for smaller vessels.

### 18.2 Heel Test for Condition Monitoring

All vessels equipped for lifting should undergo a heel test with some component(s) of the fishing gear, or a known weight, suspended from the highest or furthest outboard block. The lifting configuration and heel angle, which should be at least 5 degrees and preferably about 10 degrees, should be recorded on the Stability Notice.

### 18.3 Guidance Information

The safety zone boundaries are defined as:

Green/amber boundary, 
$$H_{S_{IMO}} = \sqrt{1 + 0.4LOA} - 1$$

Amber/red boundary, 
$$H_{S_{crit}} = H_{S_{IMO}}/2$$

The loading and lifting cases that are most likely to occur, and which reduce the stability to these values, should be presented on the Stability Notice.

### 18.4 Instrumentation

All vessels should be equipped with an inclinometer to monitor the heel angle.

New beam trawlers should be equipped with warp tension monitoring systems.

It is understood that load cells soon will become a safety requirement of all industrial lifting equipment. If such a requirement is not applied to fishing vessels within the near future, the MCA should consider the introduction of requirements for load cells to monitor the loads lifted. This will simplify and enhance the lifting guidance.

## 19 WAVE FORECAST INFORMATION

The guidance information relates to seastates, and it would be beneficial if fishermen were to consult wave forecast information when planning their voyage. That would enable them to make some judgement regarding the likely level of safety of the proposed trip, and whether an alternative fishing ground might be preferable.

Such wave forecast information is available from European meteorological services, but currently is not used by UK fishermen. A system to make such information available has been developed by the Icelandic maritime Administration (IMA). It provides five day forecasts of wave periods and wave heights, together with the latest measurements from weather stations and wave buoys. Weather forecasts and tidal information are also provided. The information is used widely by fishermen in the Icelandic fleet, and is recognised as providing a valuable contribution to safety at sea, as is the Shipping Forecast in the UK.

The wave forecasts have been proven to give a high level of accuracy, and therefore are respected by the fishing industry.

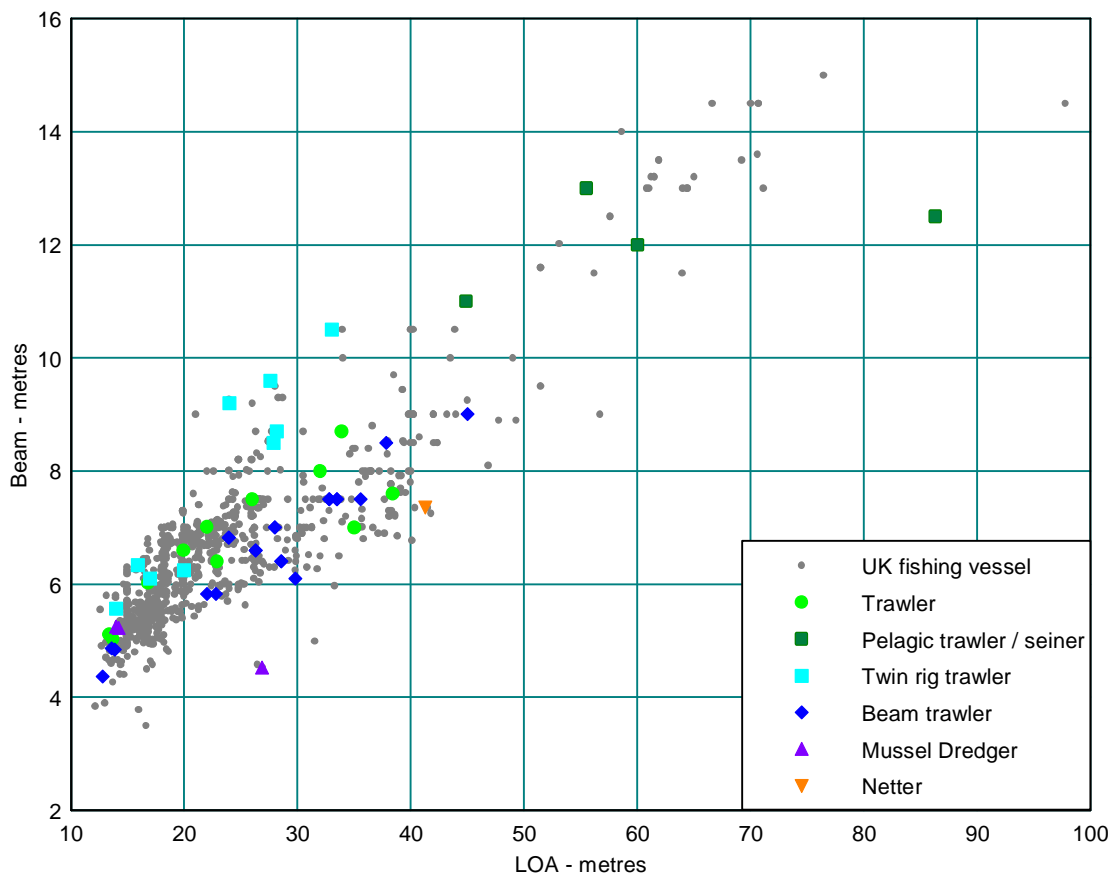
The system can be accessed on the IMA website: <http://vs.en.sigling.demo.innn.is/>

Since both the wave forecasting system, and a working presentation system exist, it should be relatively straightforward to implement a similar information system for the UK fleet's fishing grounds. Even without the implementation of a UK system, the Icelandic system could be used now by some fishermen because the sea area extends over a large part of the North Atlantic, from Greenland to the North West coast of Scotland.

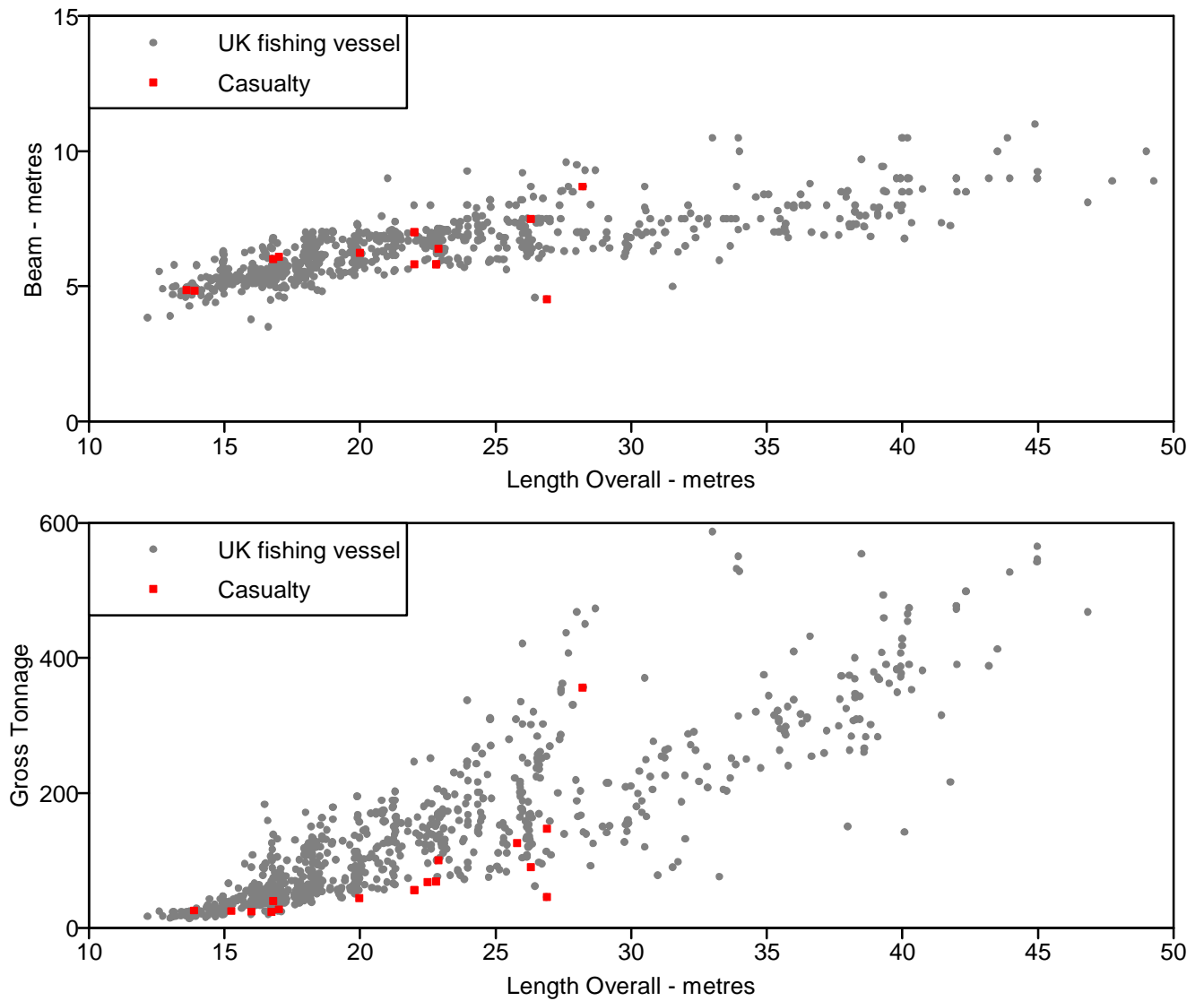
## 20 REFERENCES

1. An Investigation into Simplified Stability Assessment Methods for Small Fishing Vessels. Report by Seaspeed Technology Ltd. For the MCA, September 1994.
2. Intact ship stability criteria. Dr. A. Morrall, in the proceedings of a seminar 'Small Ships' Survival', held at the National Maritime Institute, on 26 May 1978. Published by Department of Industry, 1979.
3. The Judging of the Stability of Ships and the Determination of the Minimum Amount of Stability. J Rahola, PhD Thesis, University of Finland, Helsinki, 1939.
4. MCA Research Project 509, HSC – Evaluation of Existing Criteria, Wolfson Unit MTIA report 1807, March 2005.
5. Ocean Wave Statistics. N. Hogben & F.E. Lumb, HMSO, 1967.

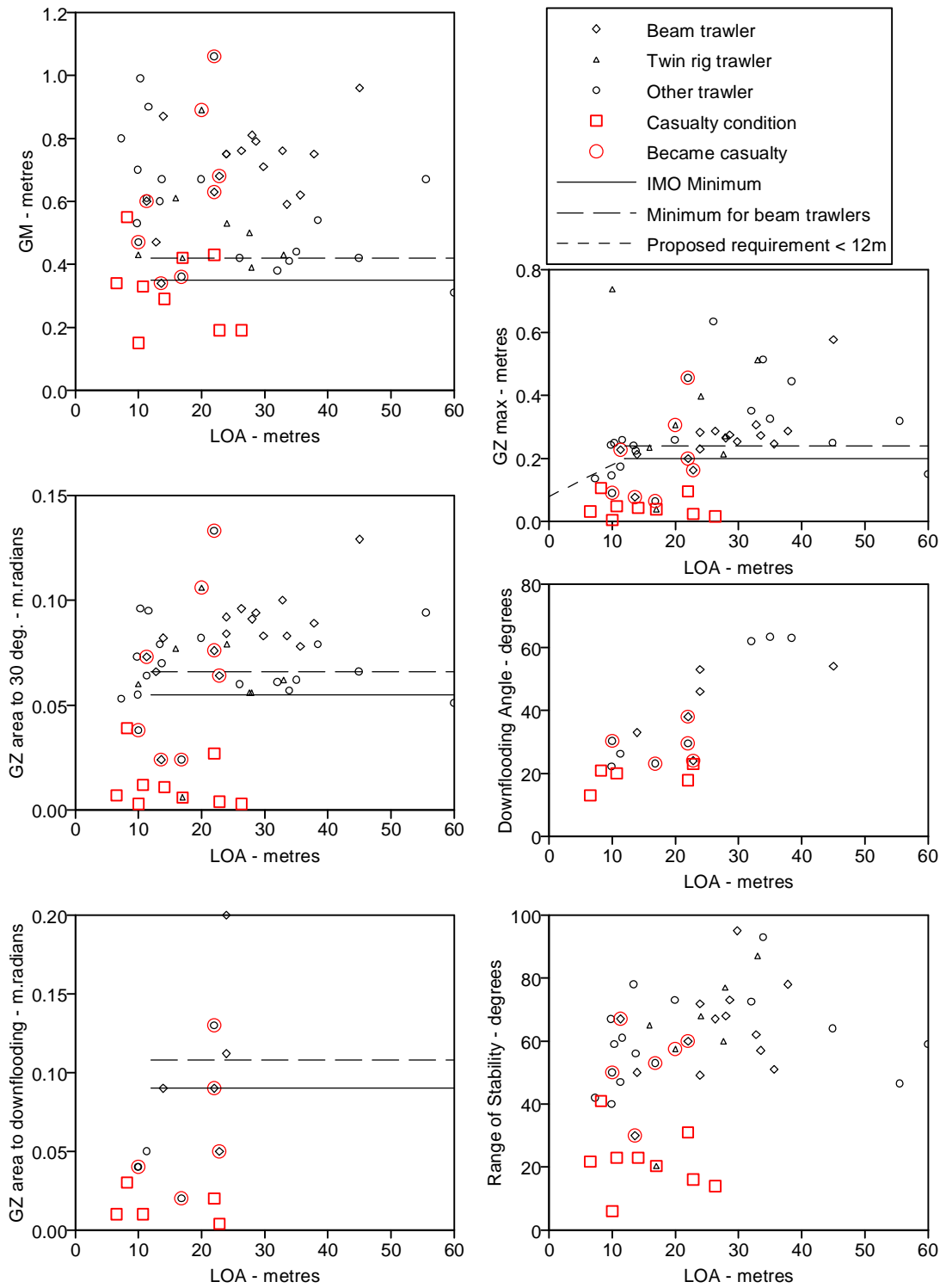
**Figure 1. Length and beam characteristics of the UK fleet**



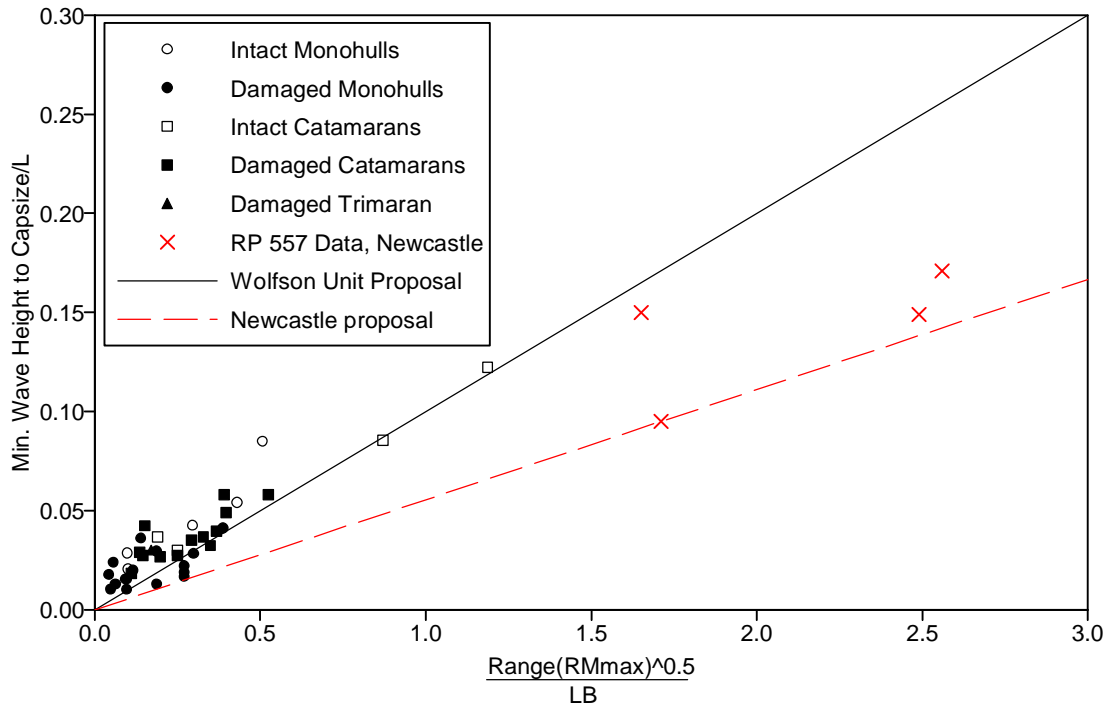
**Figure 2. Length, beam and tonnage of the documented casualties**



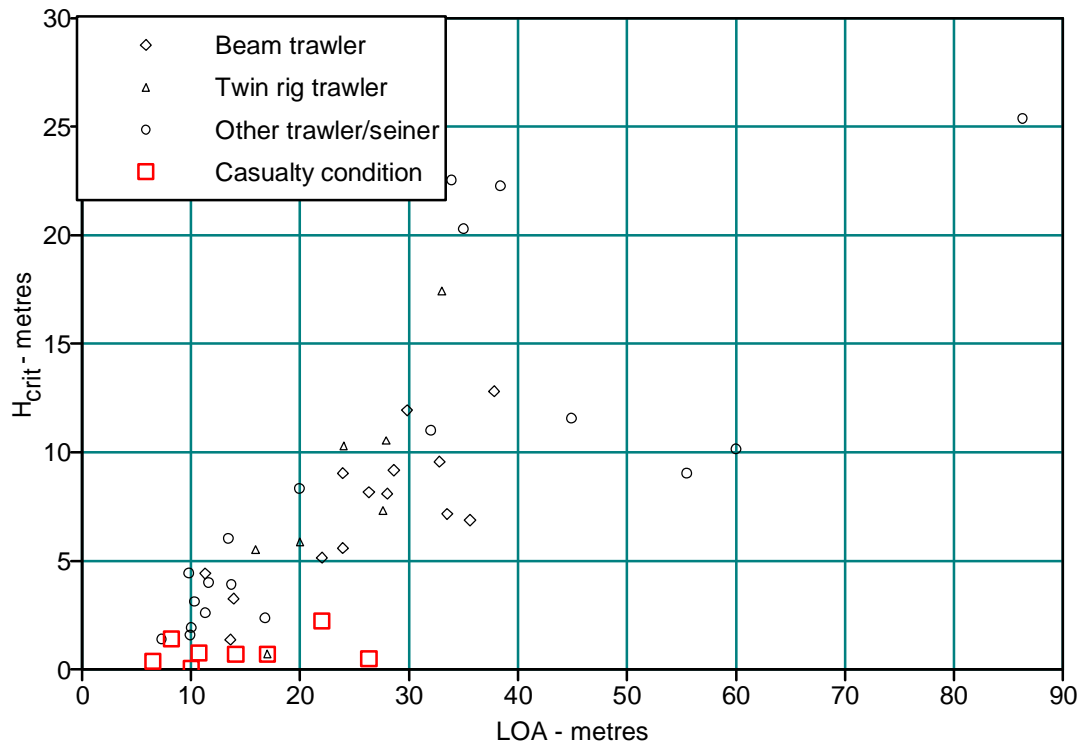
**Figure 3. Stability characteristics of three trawler types, and casualties**



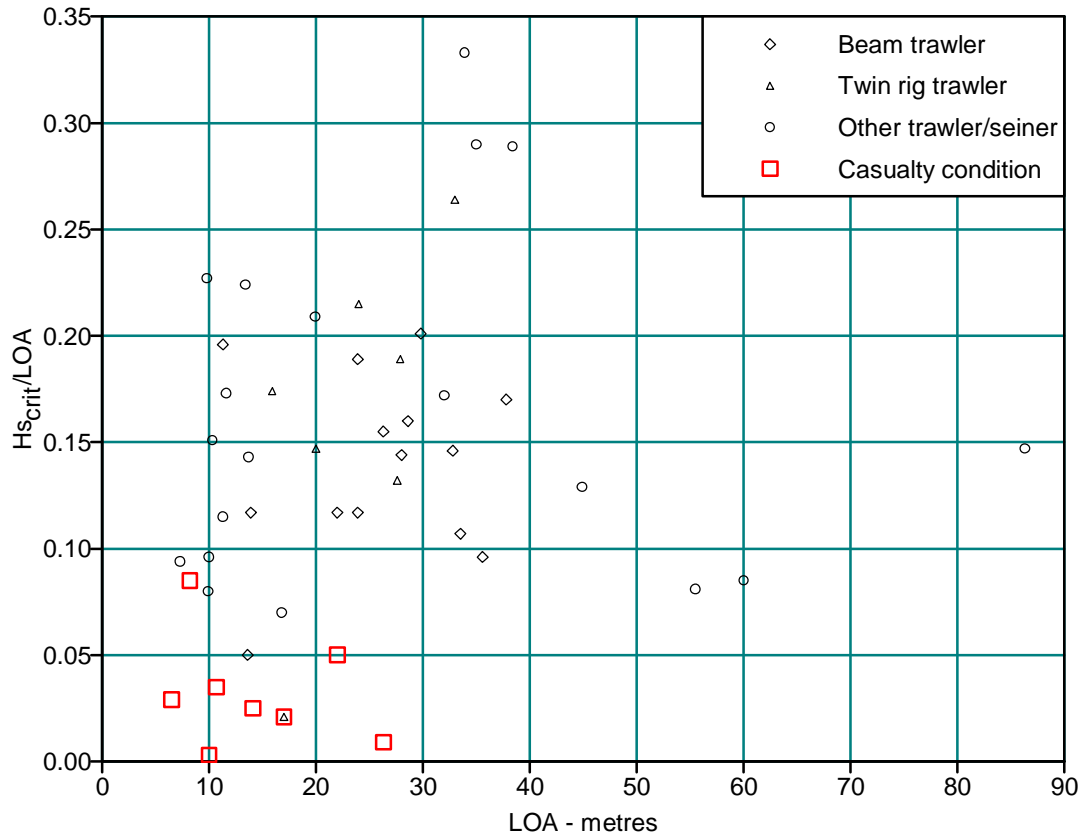
**Figure 4. Results of model capsizing tests, relating wave height to stability**



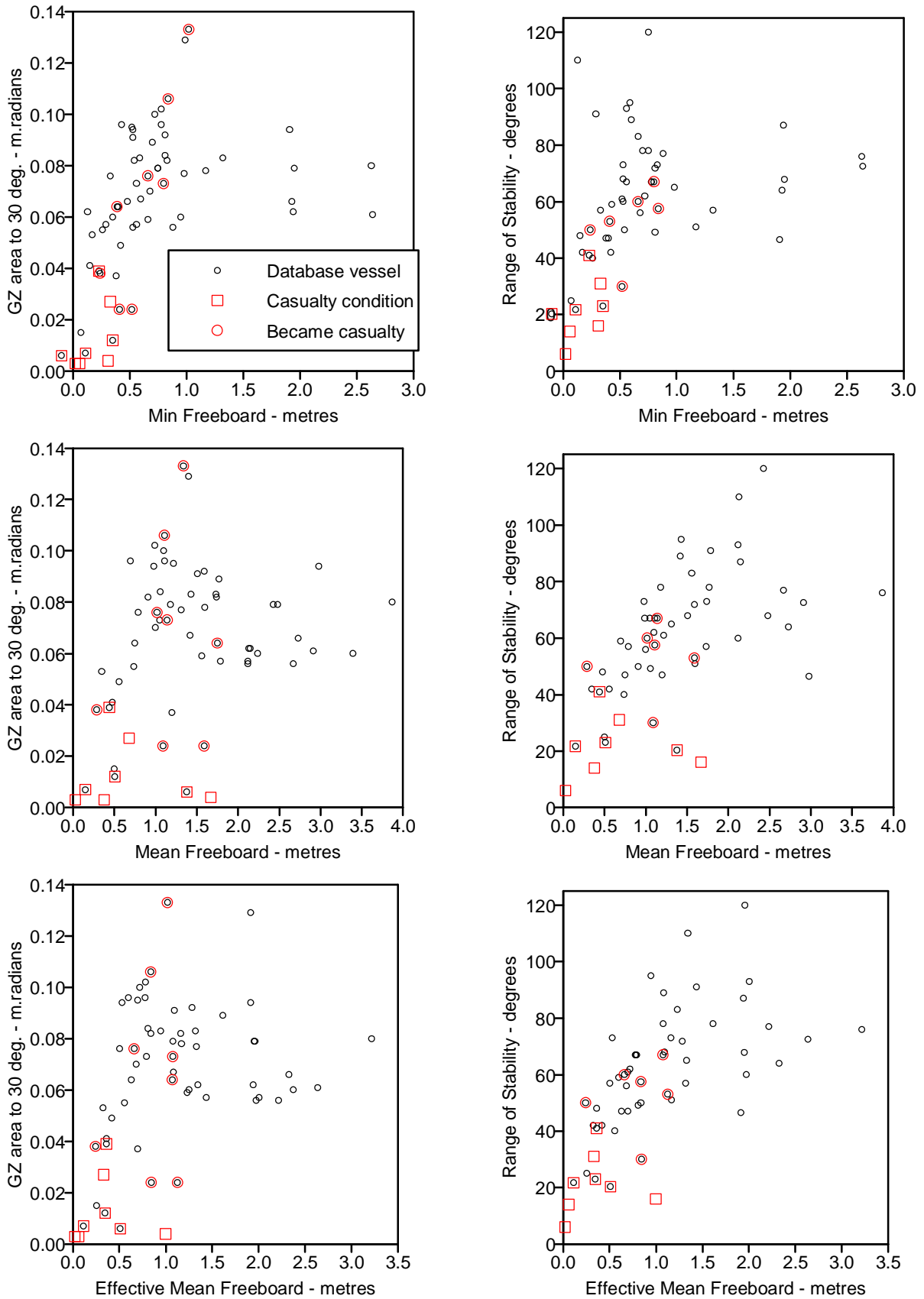
**Figure 5. Critical wave height predicted for the stability database vessels and casualties**



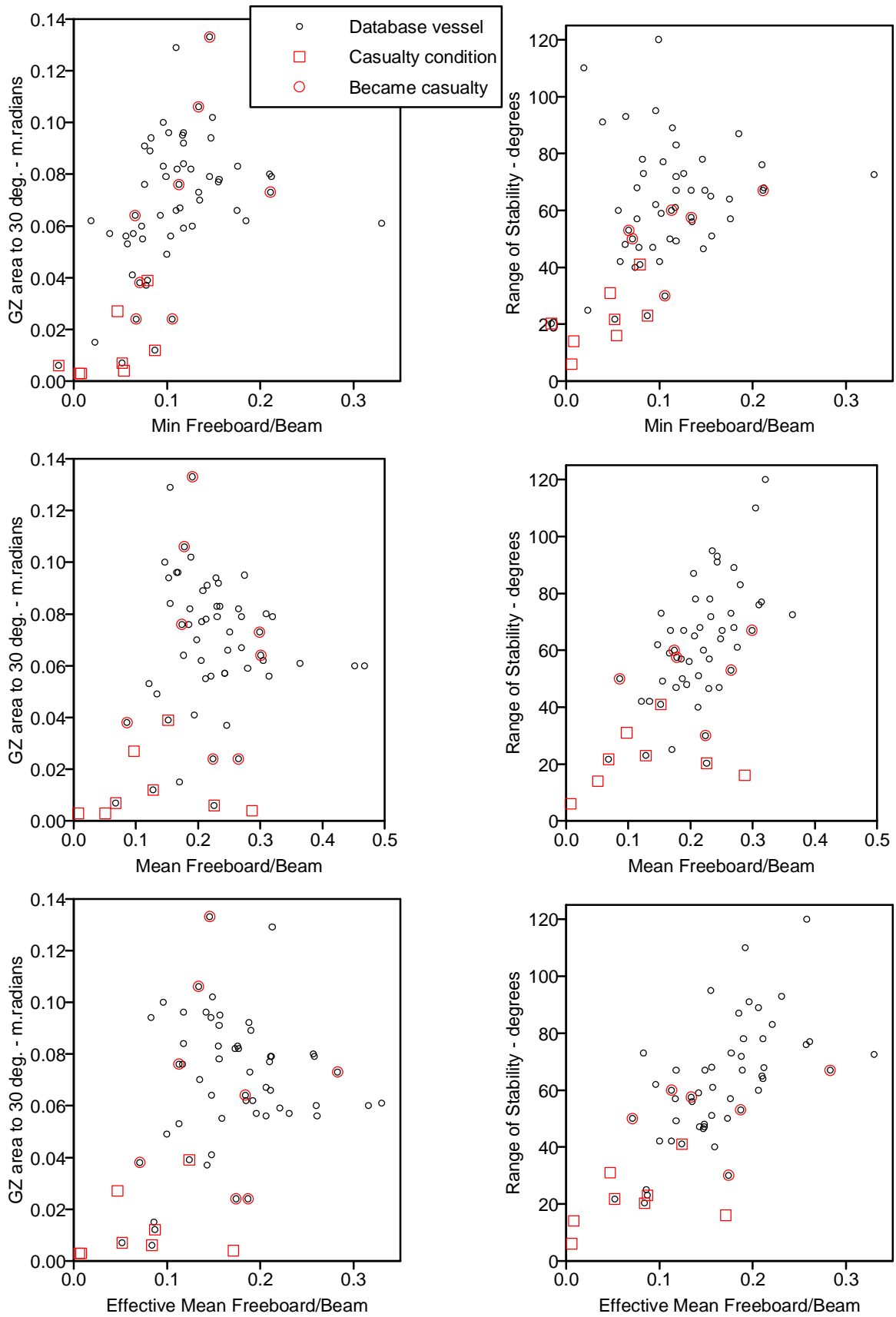
**Figure 6. Critical seastate/length predicted for the stability database vessels and casualties**



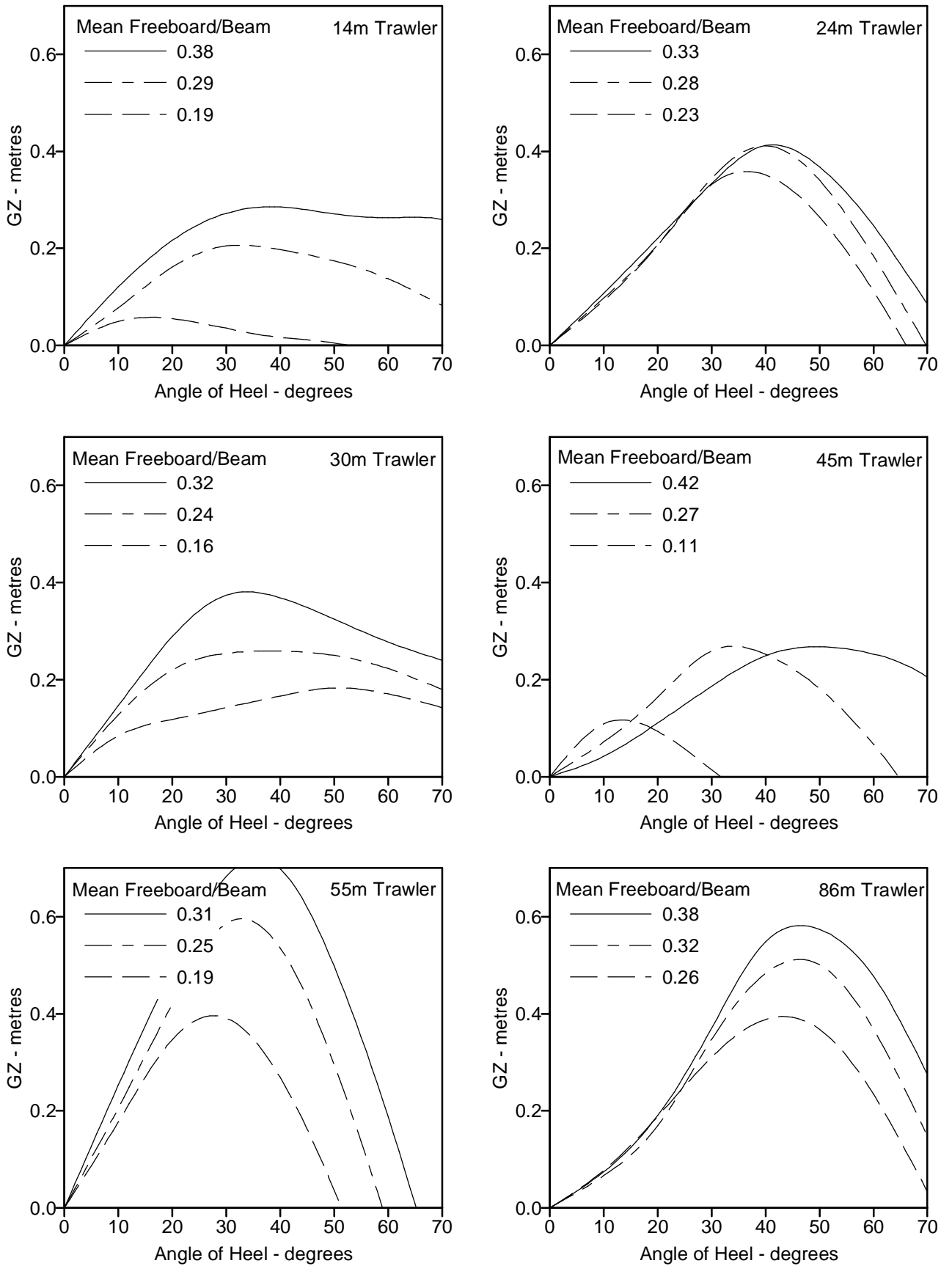
**Figure 7. Variation of stability with freeboard**



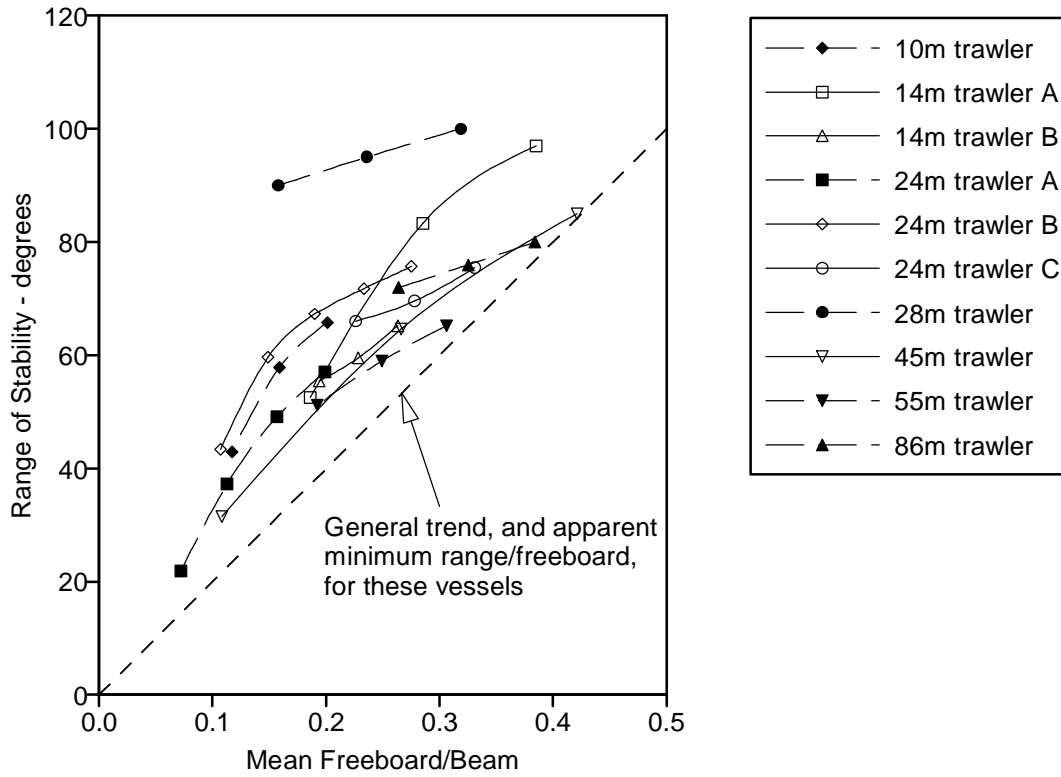
**Figure 8. Variation of stability with freeboard/beam ratio**



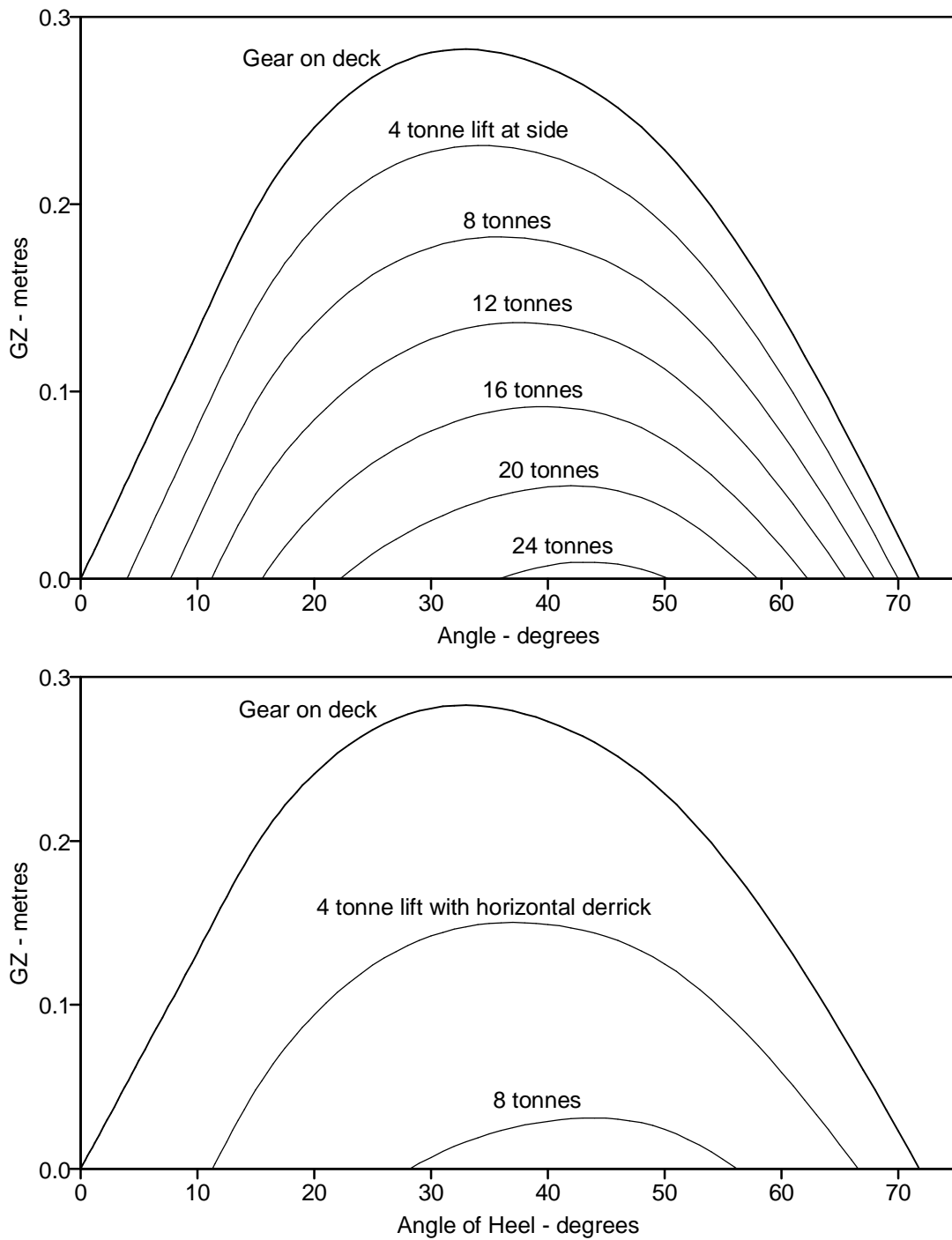
**Figure 9. Variation of stability with freeboard for six trawlers**



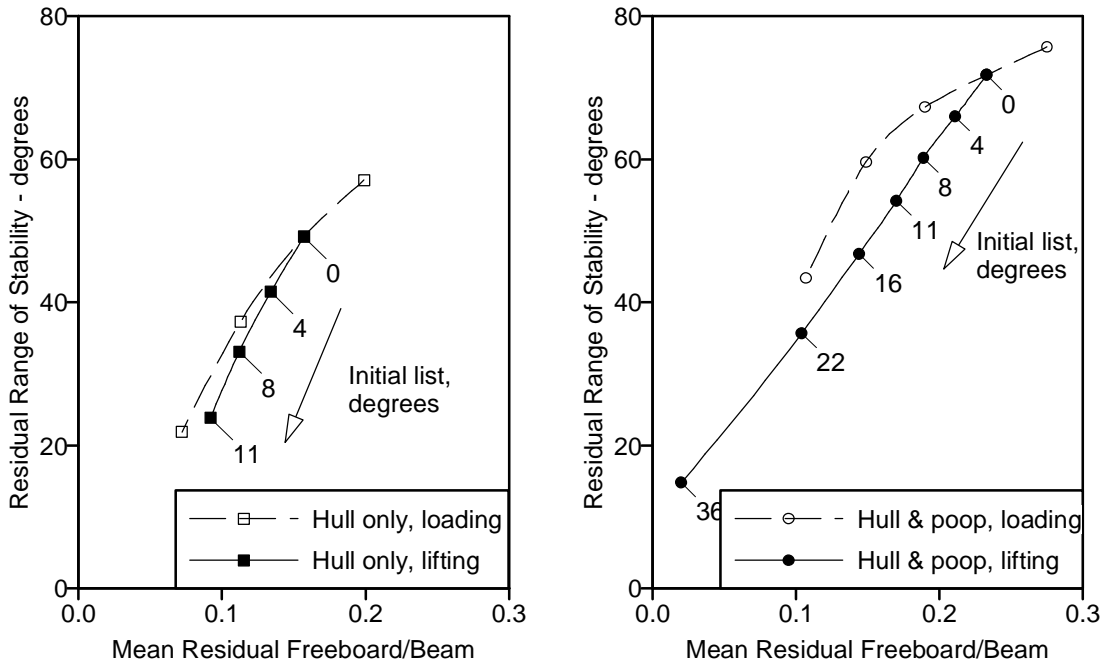
**Figure 10. Variation of range of stability with mean freeboard/beam for ten trawlers**



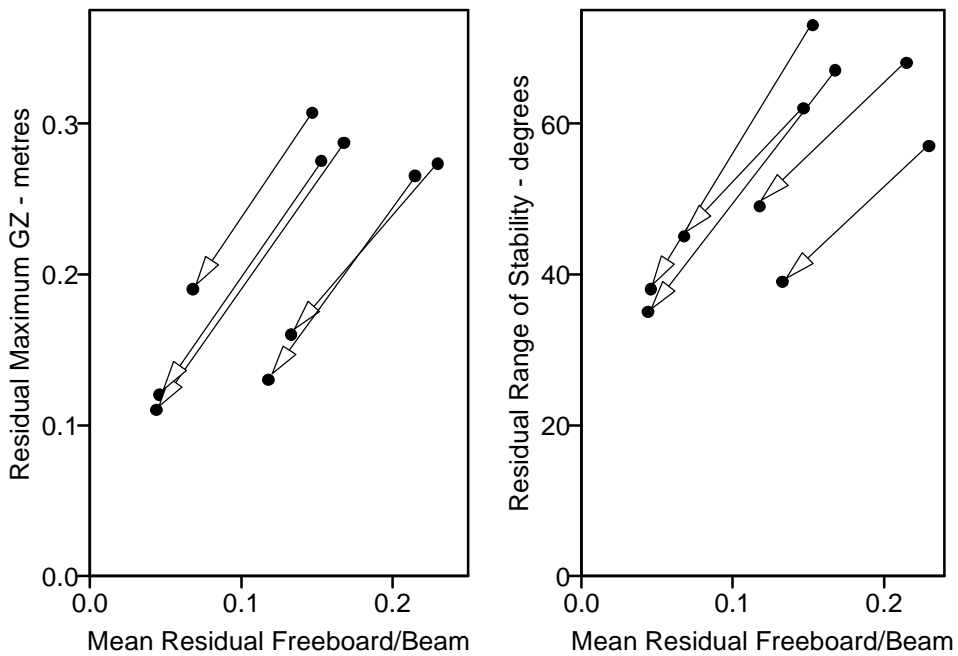
**Figure 11. The effects of lifting from the side or the derrick on the stability of a beam trawler**



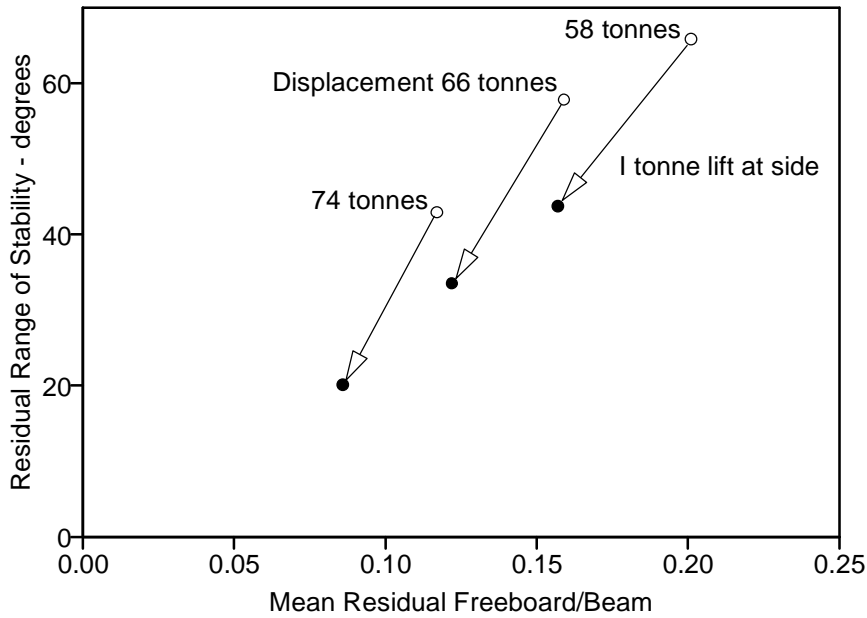
**Figure 12. Comparison of the effects of loading and lifting on the residual stability of a beam trawler**



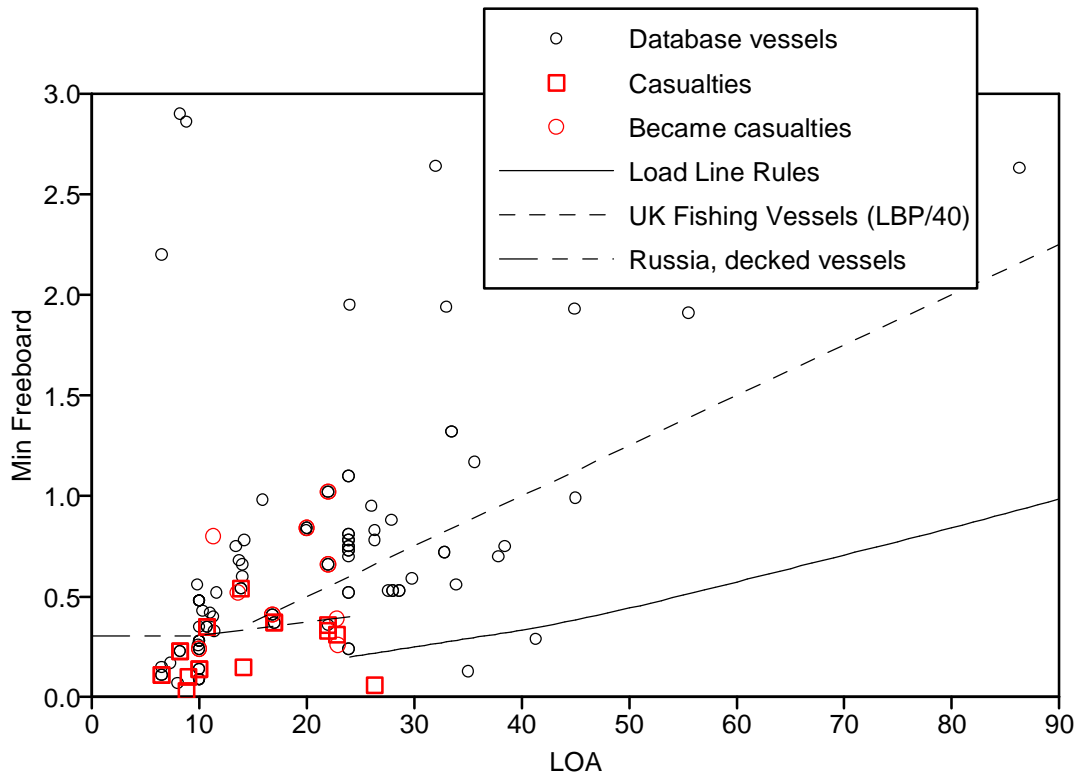
**Figure 13. The effects of boarding the gear on one side, for 5 beam trawlers**



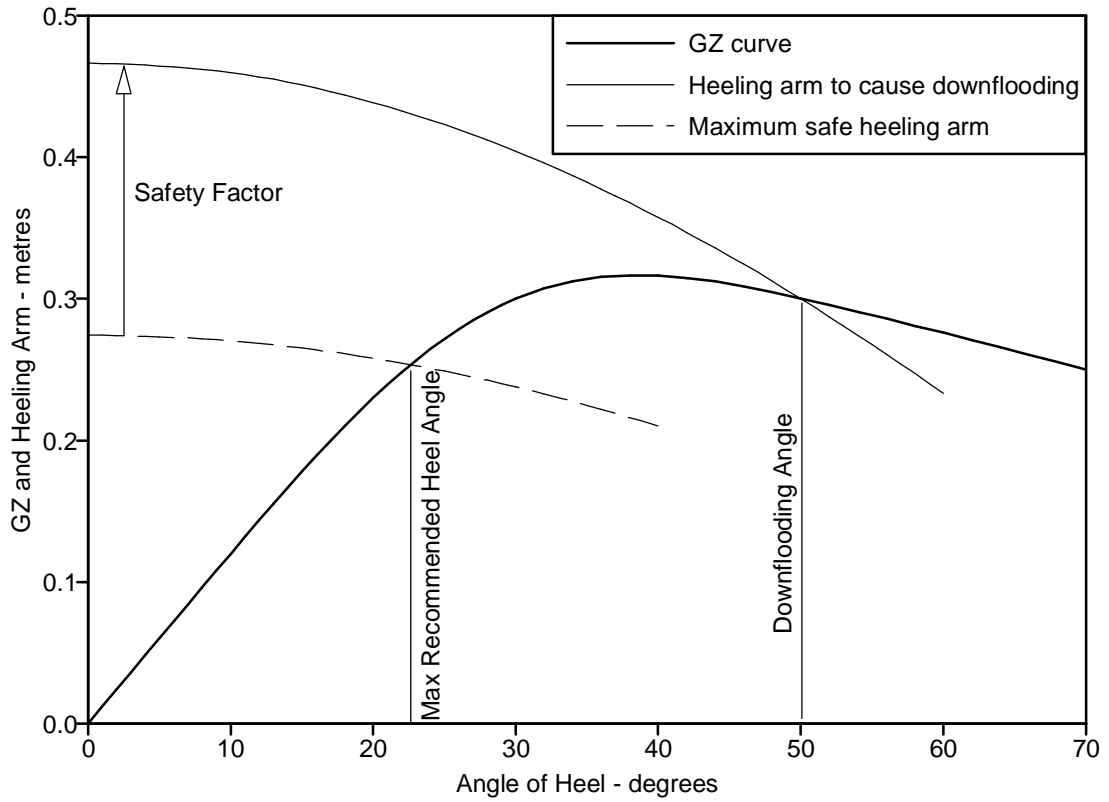
**Figure 14. The effects of lifting over the side on a small twin rig trawler**



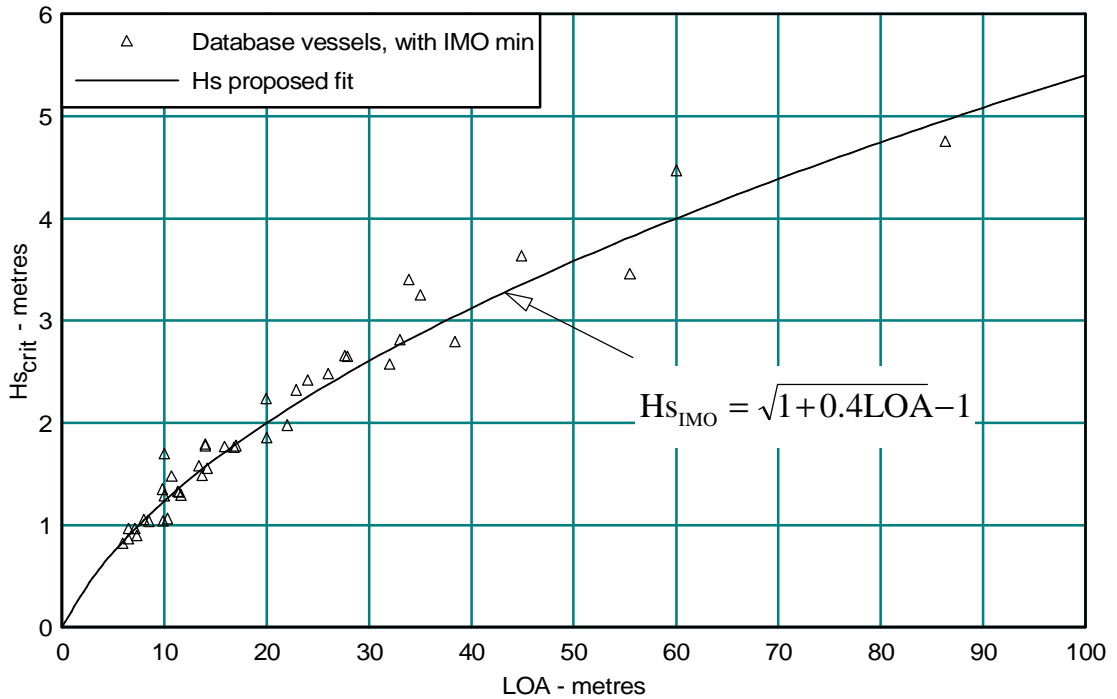
**Figure 15. Minimum freeboard of the database vessels compared with some freeboard regulations**



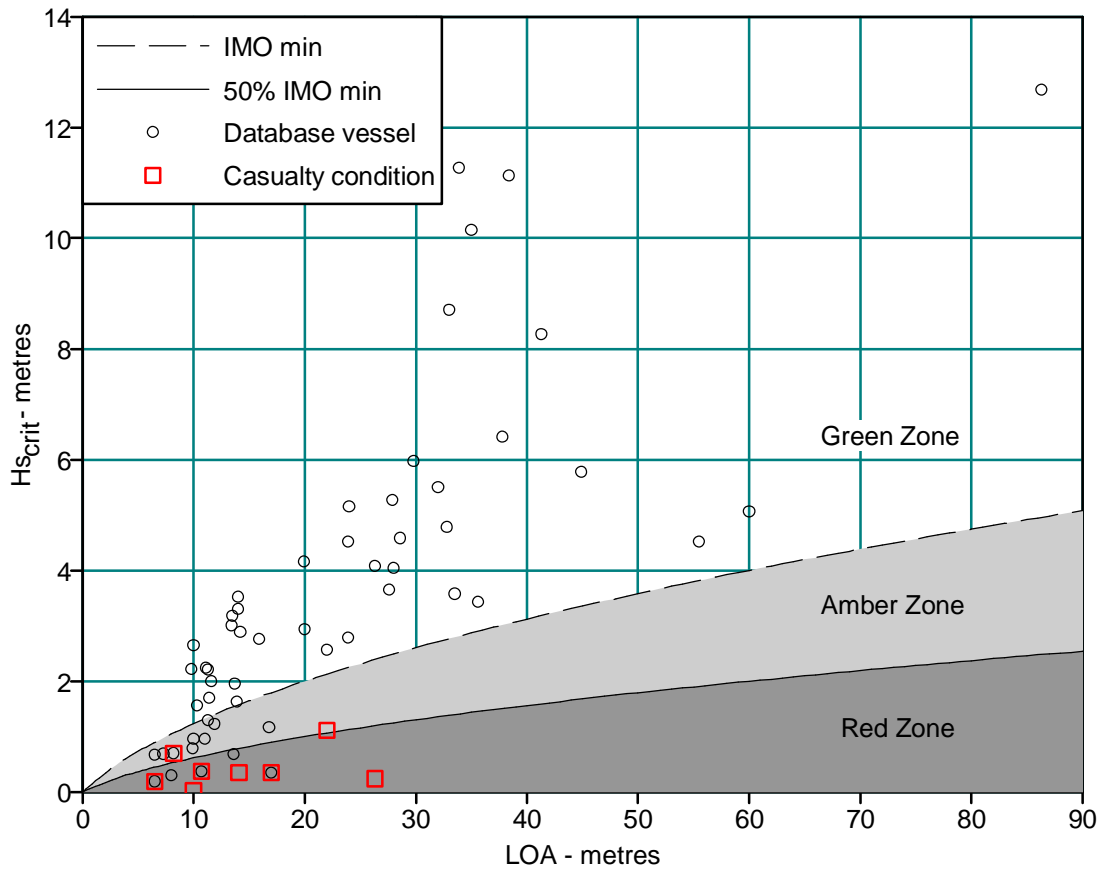
**Figure 16. Possible method of guidance based on heel angle when lifting**



**Figure 17. Variation of  $H_{s_{crit}}$  with length, assuming stability equal to IMO minimum criteria**



**Figure 18. Relationship between the database vessels, the casualties and the proposed safety zones**



**Figure 19. Comparison of predicted critical seastates and actual capsizes wave heights for the casualties**

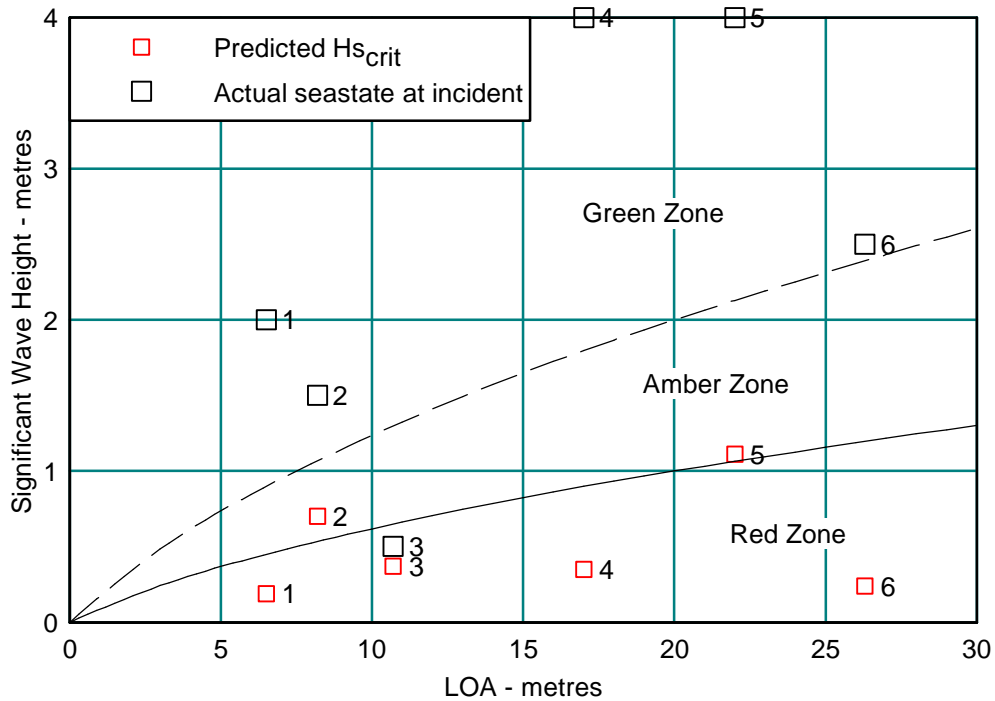


Figure 20 Example Stability Notice for a 24m beam trawler

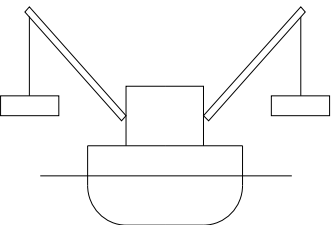
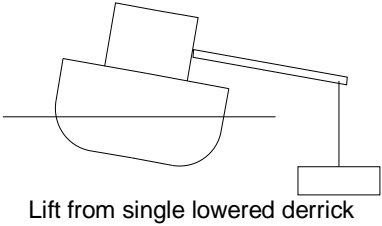
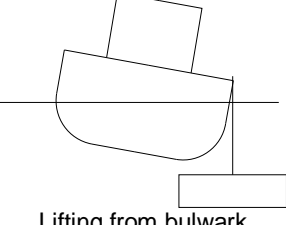
<b>STABILITY NOTICE</b>			
<b>BONNIE LASS AB123</b> <b>LOA: 24m</b> <b>Owner: John Fisher</b>	<b>Lifting Guidance</b>		
	<b>Good margin of safety</b>	<b>Low level of safety</b>	<b>Danger of capsizing</b>
	Max recommended seastate 2.2 metres	Max recommended seastate 1.1 metres	
 Double lift from raised 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°	5.5 – 7.5 tonnes  Deck edge immersion less than 20cm  Heel angle 12° - 17°	More than 7.5 tonnes  Deck edge immersion more than 20cm  Heel angle more than 17°
 Lifting from bulwark	Less than 10 tonnes  Deck edge above waterline  Heel angle less than 10°	10 – 15 tonnes  Deck edge immersion less than 20cm  Heel angle 10° - 16°	More than 15 tonnes  Deck edge immersion more than 20cm  Heel angle more than 16°
<p><b><u>Simple efforts for maintaining stability:</u></b></p> <p>§ Before attempting a heavy lift the coastguard should be informed, the warp should be brought to the vessel's side, all hatches should be closed and all crew should be on deck, wearing life jackets.</p> <p>§ If maximum recommended lift from the bulwark is exceeded the lift must be abandoned immediately. Position of gear should be marked and noted for retrieval by a larger vessel.</p> <p>§ Ensure scuppers are open and clear of obstructions to allow water to drain from the deck.</p> <p>§ Vessel may become unsafe if longer derricks or larger beams are fitted.</p> <p style="text-align: center;"><b>Heel Monitoring Test</b></p> <p style="text-align: center;">This vessel heeled 9 degrees with starboard gear on lowered derrick, port derrick topped and port gear on deck. The residual freeboard was 33cm. 5<sup>th</sup> February 2006.</p> <div style="border: 1px solid black; height: 100px; width: 100%; text-align: center; padding: 20px;"> <p>Photograph of vessel profile Dated 5<sup>th</sup> February 2006</p> </div>			

Figure 21 Example of the loading guidance for the Stability Notice on a pelagic trawler

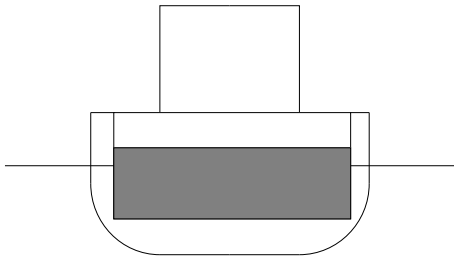
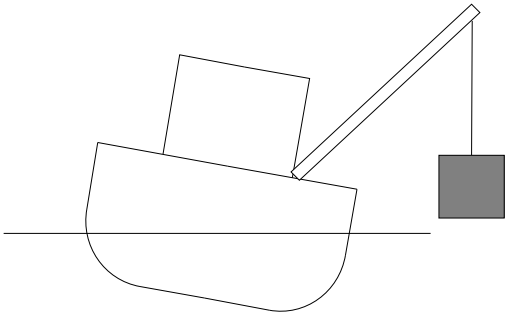
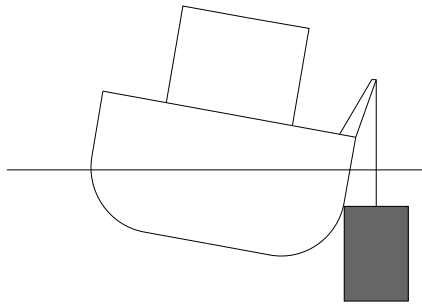
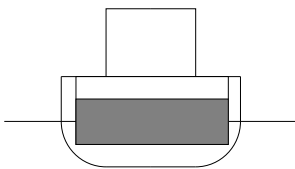
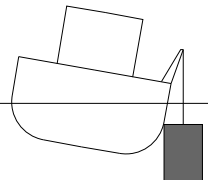
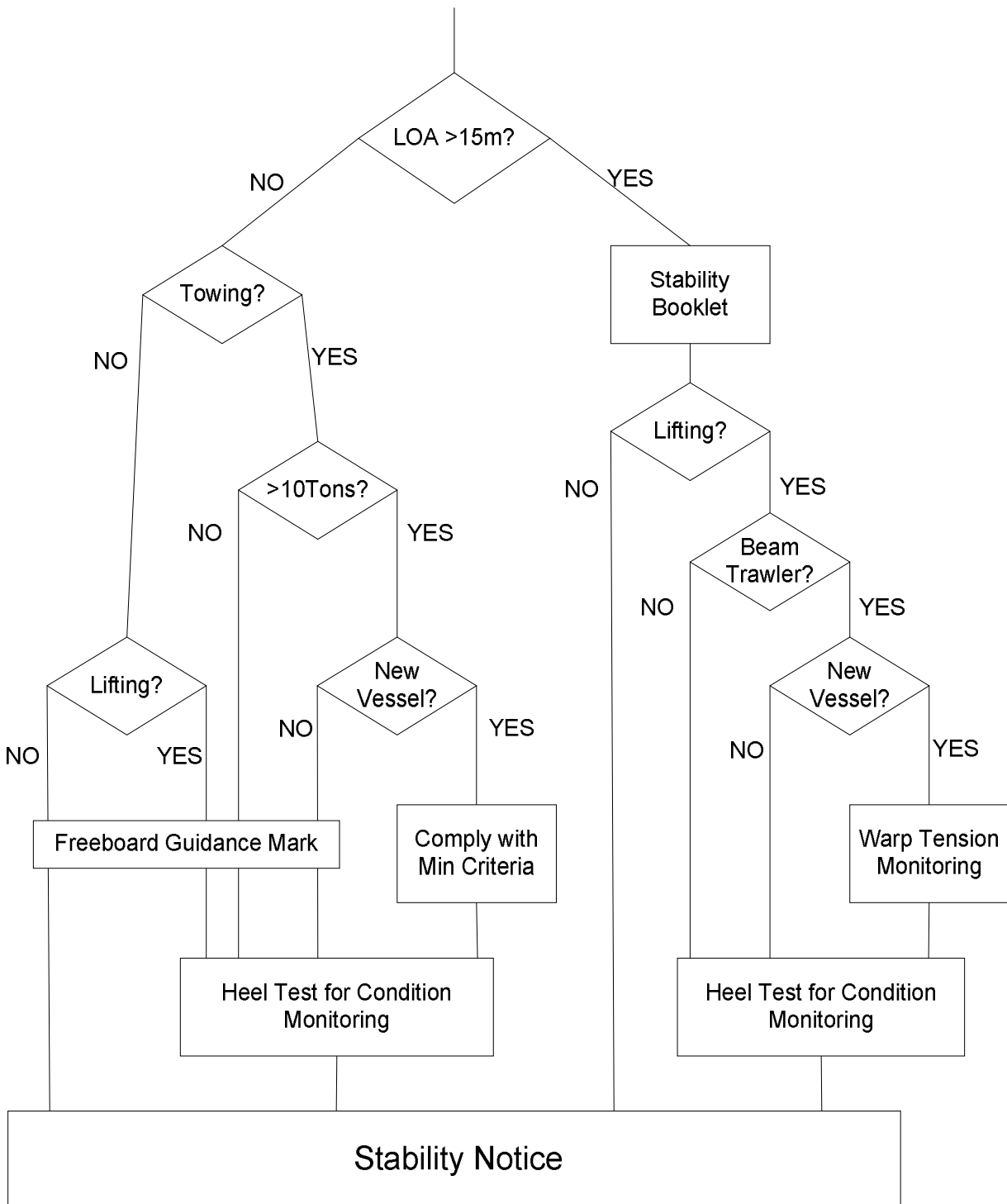
<b>STABILITY NOTICE</b>			
<b>BONNIE LADD AB456</b> <b>LOA: 32m</b> <b>Owner: Mike Fisher</b>	<b>Loading and Lifting Guidance</b>		
	<b>Good margin of safety</b>	<b>Low level of safety</b>	<b>Danger of capsize</b>
	Max recommended seastate 3.5 metres	Max recommended seastate 1.5 metres	
 Loading bulk fish in hold	Less than half depth of hold  Min freeboard at least 50cm	1/2 – 3/4 depth of hold  Min freeboard 25 – 50cm	More than 3/4 depth of hold  Min freeboard less than 25cm
 Lifting from derrick	Less than 2 tonnes  Min freeboard at least 40cm	2 – 4 tonnes  Min freeboard 20 - 40cm	More than 4 tonnes  Min freeboard Less than 20cm
 Lifting from towing blocks	Less than 6 tonnes  Min freeboard at least 30cm	6 - 10 tonnes  Min freeboard 15 - 30cm	More than 10 tonnes  Min freeboard Less than 15cm

Figure 22 Example of the loading guidance for the Stability Notice on a pelagic trawler, with combined loading and lifting

<b>STABILITY NOTICE</b>				
<b>BONNIE LADD AB456</b> <b>LOA: 32m</b> <b>Owner: Mike Fisher</b>		 Loading bulk fish in hold		
		Less than half depth of hold	1/2 – 3/4 depth of hold	More than 3/4 depth of hold
 Lifting from towing blocks	Less than 6 tonnes	Min freeboard at least 40cm	Min freeboard 20 - 40cm Max seastate 3.5m	Min freeboard Less than 20cm Max seastate 1.5 m
	6 – 10 tonnes	Min freeboard 20 – 40cm Max seastate 3.5 m	Min freeboard Less than 20cm Max seastate 1.5 m	
	More than 10 tonnes	Min freeboard Less than 20cm Max seastate 1.5 m		
		<b>Good margin of safety</b>	<b>Low level of safety</b>	<b>Danger of capsiz</b>

**Figure 23** Flow chart of the proposed system of assessment and guidance for fishing vessels



## 21 APPENDIX 1, DATABASE SUMMARY

The following table presents a summary of the databases used, and the principle ones created, in this project and the associated Research Project 559. The shaded cells indicate the relevant information they contain.

Database	Size	No. of Entries	Vessel Name	Official No. (RSS No.)	Home Port	Year of Build	Hull Material	Reg Length	Overall Length	Depth	Beam	Tonnage	Power	VCU	Fishing Method	Freeboard	Stability
<b>Existing Databases</b>																	
RSS	<>12	6496															
DEFRA	<10	4515															
DEFRA	>10	1432															
DEFRA Effort	<12	2113															
Fishing Vessels of UK	>10	~2000															
Seafish Capsize Study	<12	76															
Seaspeed Study	>12	60							(LWL)		(BWL)						
MAIB Casualties	<12	229															
MAIB Casualties	>12	233															
<b>Created Databases</b>																	
Stability Database	<>12	85															
Estimated Freeboards	<12	26															

### Information Sources

RSS, DEFRA and DEFRA Effort databases were supplied by the MCA.

Fishing Vessels of UK: from “Fishing Vessels of Britain & Ireland” compiled annually by Fishing News and published by Heighway.

Seafish Capsize Study: from “Final Report of the Capsize Safety Specialist Sub-Group to the Seafish Working Group” Seafish Technology, June 1997.

Seaspeed Study: from Ref.1.

MAIB casualty databases were supplied by MAIB.

**22 APPENDIX 2, STABILITY DATABASE**

Vessel Type	LOA	BOA	Depth	Draft	Min F	Mean F	Erection/L	Disp	KG	GM	List	qf	GZmax	GZarea30	GZareaf	GZarea	AVS	Range
<b>Decked</b>																		
Beam trawler	22.0	5.83	3.00	2.34	0.66	1.02	0.00	124.70	3.10	0.63	0.00	38.0	0.200	0.076	0.094	0.125	60.0	60.0
Beam trawler	23.9	6.82	3.56	2.75	0.81	1.06	0.00	260.00	2.75	0.75	0.00	46.0	0.230	0.084	0.112	0.112	49.2	49.2
Beam trawler	23.9	6.82	3.56	2.75	0.81	1.59	0.28	260.00	2.75	0.75	0.00	53.0	0.283	0.092	0.195	0.233	71.8	71.8
Beam trawler	26.3	6.60	3.77	2.94	0.78	1.11	0.00	224.59	3.21	0.76	0.00		0.287	0.096		0.194	67.0	67.0
Beam trawler	28.0	7.00	3.10	2.79	0.53	1.51	0.32	261.67	2.79	0.81	0.00		0.265	0.091		0.206	68.0	68.0
Beam trawler	28.6	6.40	3.20	2.51	0.53	0.98	0.00	234.95	2.47	0.79	0.00		0.275	0.094		0.181	73.0	73.0
Beam trawler	29.8	6.10	3.10	2.55	0.59	1.43	0.24	231.20	2.43	0.71	0.00		0.254	0.083			95.0	95.0
Beam trawler	32.8	7.50	4.07	3.25	0.72	1.10	0.00	435.42	3.09	0.76	0.00		0.307	0.100		0.201	62.0	62.0
Beam trawler	33.5	7.50	4.10	3.11	1.32	1.73	0.00	324.21	3.31	0.59	0.00		0.273	0.083		0.161	57.0	57.0
Beam trawler	35.6	7.50	4.10	3.24	1.17	1.60	0.00	414.60	3.32	0.62	0.00		0.246	0.078		0.132	51.0	51.0
Beam trawler	37.8	8.50	4.50	3.80	0.70	1.77	0.43	679.05	3.54	0.75	0.00		0.287	0.089		0.265	78.0	78.0
Beam trawler	45.0	9.00	5.10	4.34	0.99	1.40	0.41	893.00	3.56	0.96	0.00	54.0	0.577	0.129				0.0
Beam trawler	11.9	4.88	2.82	2.33	0.38	1.20	0.26	66.13	2.33	0.37	0.00		0.098	0.037		0.048	47.0	47.0
Beam trawler	12.8	4.37	2.90	2.42	0.48			62.39	2.40	0.47	0.00			0.066				0.0
Mussel dredger	26.9	4.53	2.45															
beam trawler	13.6	4.86	2.10		0.52	1.09	0.27	63.20	2.25	0.34	0.00		0.077	0.024		0.024	30.0	30.0
Beam trawler	22.8	5.82	2.70	2.30	0.39	1.75	0.47			0.68	0.00	24.0	0.163	0.064	0.047	0.120	>70	
Beam Trawler	11.3	3.80	2.35	1.66	0.80	1.14	0.29	27.52	2.08	0.60	0.00		0.228	0.073		0.163	67.0	67.0
Beam trawler/Trawler	13.9	4.84	2.12	1.59	0.54	0.91	0.25	46.66	1.95	0.87	0.00	33.0	0.213	0.082	0.091	0.113	50.0	50.0
Netter	8.2	2.90	1.28	1.05	0.23	0.44	0.18	9.14	1.29	0.55	0.00	20.8	0.106	0.039	0.027	0.045	41.0	41.0
Netter	11.0	4.20	1.86	1.52	0.42	0.56	0.00	28.35	1.78	0.52	0.00		0.131	0.049		0.063	42.0	42.0
Netter	41.3	7.35	4.15	4.05	0.29	1.79	0.63	663.80	3.46	0.46	0.00	52.0	0.269	0.057			91.0	91.0
Potter	6.5	2.46	0.90	0.74	0.15	0.48	0.34	4.49	1.00	0.54	0.00	31.0	0.105	0.041	0.042	0.052	48.0	48.0
Potter	6.5	2.20	1.15	1.04	0.11	0.15	0.00	4.49	1.26	0.34	0.00	13.0	0.032	0.007	0.005	0.007	21.7	21.7
Potter	8.0	2.96	1.24	1.05	0.07	0.50	0.25	9.65	1.28	0.52	0.00	14.7	0.051	0.015	0.010	0.015	25.0	25.0
Potter	11.4	4.30	2.13	1.72	0.33	0.79	0.16	32.08	1.80	0.73	0.00	18.0	0.204	0.076	0.035	0.124	57.0	57.0
Potter	14.0	5.25	3.02	2.51	0.60	1.42	0.37	87.80	2.40	0.58	0.00		0.196	0.067		0.219	89.0	89.0
Potter	14.2	5.23	3.02	2.28	0.78	0.99	0.00	65.24	2.43	0.84	0.00		0.311	0.102		0.240	67.0	67.0
Trawler	7.3	2.89	1.08	0.92	0.17	0.35	0.22	6.68	1.23	0.80	0.00		0.136	0.053		0.061	42.0	42.0
Trawler	9.8	4.18	2.30	1.74	0.56	1.05	0.22	31.50	1.85	0.53	0.00		0.243	0.073		0.188	67.0	67.0
Trawler	9.9	3.49	1.46	1.20	0.26	0.74	0.34	13.08	1.62	0.70	0.00	22.2	0.146	0.055	0.040	0.062	40.0	40.0
Trawler	10.0	3.40	1.74	1.45	0.24	0.29	0.00	18.99	1.73	0.47	0.00	30.3	0.090	0.038	0.038	0.055	50.0	50.0
Trawler	10.3	4.21	1.93	4.46	0.43	0.70	0.16	19.87	1.80	0.99	0.00		0.249	0.096		0.157	59.0	59.0
Trawler	11.3	4.24	2.11	1.71	0.40	0.75	0.22	31.43	1.94	0.61	0.00	26.2	0.174	0.064	0.053	0.087	47.0	47.0
Trawler	11.6	4.44	2.27	1.72	0.52	1.22	0.16	32.62	1.95	0.90	0.00		0.259	0.095		0.167	61.0	61.0

Vessel Type	LOA	BOA	Depth	Draft	Min F	Mean F	Erection/L	Disp	KG	GM	List	qf	GZmax	GZarea30	GZareaf	GZarea	AVS	Range
<b>Decked (contd.)</b>																		
Trawler	13.4	5.11	3.06	2.32	0.75	1.18	0.26	64.63	2.37	0.60	0.00		0.241	0.079		0.197	78.0	78.0
Trawler	13.7	5.03	2.90	2.16	0.68	1.00	0.00	55.20	2.47	0.67	0.00		0.224	0.070			56.0	56.0
Trawler	16.8	6.02	3.62	3.16	0.41	1.59	0.48	111.01	3.28	0.36	0.00	23.1	0.064	0.024	0.019	0.039	53.0	53.0
Trawler	19.9	6.55	3.60	3.30	0.83	1.74	0.21	215.60	3.26	0.67	0.00		0.259	0.082			73.0	73.0
Trawler	22.0	7.01	3.98	2.90	1.02	1.34	0.00	189.70	3.25	1.06	0.00	29.5	0.456	0.133	0.133		>70	
Pair trawler	22.9	6.40	3.20	3.09	0.26			218.20										
Trawler	32.0	8.00	3.50	3.58	0.52		0.00	419.50	3.73	0.38	0.00	62.0	0.351	0.061			72.5	72.5
Trawler	33.9	8.70	7.50	5.71	0.56	2.12	0.67	864.95	4.11	0.41	0.00		0.514	0.057			93.0	93.0
Trawler	35.0	7.00	3.95	3.81	0.13	2.13	0.69	511.40	3.29	0.44	0.00	63.3	0.326	0.062			110.0	110.0
Trawler	38.4	7.60	3.81	3.06	0.75	2.43	0.64	446.50	3.15	0.54	0.00	63.0	0.445	0.079			120.0	120.0
Trawler	55.5	13.00	8.00	5.65	1.91	2.98	0.00	1998.00	6.45	0.67	0.00		0.319	0.094			46.5	46.5
Trawler (mussel dredger)	10.7	4.00	2.12	2.11	0.35	0.51	0.00	34.67	2.33	0.33	0.00	20.1	0.048	0.012	0.012	0.012	23.0	23.0
Trawler, pelagic	86.3	12.50	8.00	4.99	2.63	3.87	0.19	3489.00	5.36	0.38	0.00		0.499	0.080			76.0	76.0
Trawler/Purse seiner	44.9	11.00	7.80	6.10	1.93	2.73	0.14	1579.00	5.29	0.42	0.00		0.250	0.066			64.0	64.0
Trawler/Purse seiner	60.0	12.00	6.92	7.18				2841.00	5.88	0.31	0.00		0.150	0.051			59.0	59.0
Trawler/Seiner	26.0	7.50	4.25	3.71	0.95	3.39	0.76	341.80	3.28	0.42	0.00		0.635	0.060			>90	
Twin rig trawler	10.0	4.80	3.20	2.77	0.35	2.24	0.75	65.93	2.18	0.43	0.00		0.737	0.060			180.0	180.0
Twin rig trawler	14.0	5.57	3.20	2.99	0.66	1.56	0.41	96.89	2.71	0.42	0.00		0.202	0.059		0.179	83.0	83.0
Twin rig trawler	15.9	6.34	3.10	2.67	0.98	1.31	0.22	123.80	3.00	0.61	0.00		0.234	0.077			65.0	65.0
Twin rig trawler	17.0	6.10	2.97	2.88	0.37	1.85	0.40	116.24	3.70	0.42	8.73		0.039	0.006		0.006	29.0	20.3
Twin rig trawler	20.0	6.25	3.60	2.75	0.84	1.11	0.00	133.10	3.00	0.89	0.00		0.306	0.106		0.185	57.5	57.5
Twin rig trawler	28.2	8.70	7.40															
Twin rig trawler	24.0	9.20	6.00	4.54	1.95	2.48	0.00	490.00	3.98	0.53	0.00		0.397	0.079			67.9	67.9
Twin rig trawler	27.6	9.60	4.80	4.76	0.53	2.12	0.60	642.00	4.16	0.50	0.00		0.213	0.056			60.0	60.0
Twin rig trawler	27.9	8.50	4.00	4.22	0.88	2.67	0.63	501.30	3.71	0.39	0.00		0.270	0.056			77.0	77.0
Twin rig trawler	33.0	10.50	6.65	4.71	1.94	2.15	0.00	863.90	5.10	0.43	0.00		0.512	0.062			87.0	87.0
Trawler	14.6	5.03	2.26	1.83	0.43			59.90	3.03	1.04	0.00		0.351	0.120		0.256		69.0
Unknown	13.5	5.00	2.63	2.41	0.51	0.86	0.00	44.75	2.36	0.99	0.00		0.371	0.126		0.314		78.0
Unknown	11.1	4.14	1.87	1.62	0.42	0.80	0.28	21.33	1.87	0.93	0.00	55.4	0.252	0.094	0.175	0.202		80.0
Unknown	10.3	4.04	2.47	2.06	0.73	1.18	0.33	17.45	2.07	0.87	0.00		0.510	0.108			>90	
Catamaran	10.0	4.24	1.55	0.89	0.66	0.79	0.00	7.03	1.52	5.05	0.00		1.179	0.459				78.0
<b>Undecked</b>																		
Potter	5.9	2.26	1.05	0.59	0.46	0.60	0.00	3.40	0.88	0.39	0.00	23.9	0.163	0.030	0.032	0.030	23.9	23.9
Netter/Liner	7.1	2.58	1.63	0.89	0.74	0.84	0.00	6.15	1.03	0.62	0.00	32.5	0.263	0.075	0.086	0.086	32.5	32.5
Netter	5.3	2.19	0.91		0.70	0.79	0.00											
Netter/Liner	8.5	3.20	1.80	1.00	0.80	1.03	0.00	10.91	1.13	0.84	0.00	28.8	0.350	0.098	0.098	0.098	28.8	28.8
Unknown	6.7	2.49	0.90	0.25	0.61	0.68	0.00	1.44	0.66	2.32	0.00	37.2	0.479	0.153	0.210	0.210		37.2

Vessel Type	LOA	BOA	Depth	Draft	Min F	Mean F	Erection/L	Disp	KG	GM	List	qf	GZmax	GZarea30	GZareaf	GZarea	AVS	Range
<b>Casualties</b>																		
Pair trawler	26.3	7.46	3.32	4.25	0.06	0.38	0.00	423.80	3.60	0.19	0.00		0.016	0.003		0.003	14.0	14.0
Twin rig trawler	17.0	6.10	2.97	2.88	0.37	1.85	0.40	116.24	3.70	0.42	8.73		0.039	0.006		0.006	29.0	20.3
Trawler (mussel dredger)	10.7	4.00	2.12	2.11	0.35	0.51	0.00	34.67	2.33	0.33	0.00	20.1	0.048	0.012	0.012	0.012	23.0	23.0
Trawler	10.0	3.40	1.74	1.47	0.14	0.14	0.00	18.99	1.85	0.15	4.00		0.005	0.003	0.003	0.003	10.0	6.0
Netter	8.2	2.90	1.28	1.05	0.23	0.44	0.18	9.14	1.29	0.55	0.00	20.8	0.106	0.039	0.027	0.045	41.0	41.0
Potter	6.5	2.20	1.15	1.04	0.11	0.15	0.00	4.49	1.26	0.34	0.00	13.0	0.032	0.007	0.005	0.007	21.7	21.7
Trawler	22.0	7.01	3.98	3.61	0.33	0.68	0.00	263.70	3.71	0.43	0.00	17.8	0.095	0.027	0.018	0.030	31.0	31.0
Scallop dredger	9.0	3.05	1.04		0.10													
Potter	8.8	2.86	1.41		0.03	0.70	0.51											
Trawler	9.1	3.20			-0.10													
Beam trawler	22.8	5.82	2.70	2.38	0.31	1.67	0.47			0.19	0.00	23.0	0.023	0.004	0.004	0.004	16.0	16.0
Twin rig trawler	28.2	8.70	7.40															
Trawler	14.1	5.00	2.57	2.42	0.15	0.64	0.34	54.89	2.78	0.29	0.00	0.0	0.043	0.011		0.011		23.0
Mussel dredger	26.9	4.53	2.45															

Shaded cells indicate vessels that became casualties.