WOLFSON UNIT
FOR MARINE TECHNOLOGY & INDUSTRIAL AERODYNAMICS

Report No. 1903/2 **May 2006**

MARITIME & COASTGUARD AGENCY

Research Project 559
Loading Guidance for Fishing Vessels Less than 12m Registered Length
Phase II

<u>Final Report</u>

EXECUTIVE SUMMARY

The remit of this study was to develop effective methods of assessing the stability of fishing vessels, which do not unduly disadvantage the existing fleet. Based on this assessment, to provide clear guidance on loading, freeboard and operation, in a simplified format for ease of understanding and use by fishermen, which will enhance safety.

The fleet comprises about 6000 vessels and prescriptive regulation of their stability is not considered to be a viable option. The enforcement of such a system would require substantial administrative effort and would be unlikely to deliver any safety benefits without being seen to disadvantage significant sectors of the industry. Previous attempts at the introduction of regulations to small fishing vessels have met with strong opposition in the UK and overseas.

A minority of the vessels tow heavy gear, in similar fishing grounds to larger vessels, and these are considered to be particularly vulnerable. A method of assessment is recommended for new vessels over 10 tons registered which are equipped for towing, which is similar to that used currently for larger vessels, but applies adjusted criteria. For the remaining majority of the vessels, a more valuable option is believed to be the development of guidance information based on simple determination of the minimum safe freeboard and maximum safe over side lift.

The safety guidance information presents the relationship between the size of vessel, its residual stability, where it is known, or residual freeboard, 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, and the relationship between it and the residual freeboard provides the basis of guidance for those vessels without stability data.

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

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

It is recommended that guidance freeboard marks be placed on fishing vessels for which the guidance information is based on freeboard alone. These will enable the fishermen to relate the guidance information to his vessel directly.

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.

WOLFSON UNIT
FOR MARINE TECHNOLOGY & INDUSTRIAL AERODYNAMICS

CONTENTS

1 INTRODUCTION

This report describes Phase II of a research project to advise the MCA of methods that might be developed to present fishermen, in vessels under 12 metres registered length, with guidance regarding the safe loading and operation of their vessels. The contract, Ref. MSA 10/9/226, was issued on 13th June 2005. The work programme followed that outlined in Wolfson Unit proposal Ref. 2798bd, dated 4th May 2005. Phase I of the work was conducted in 2004, and presented in Wolfson Unit report no. 1778 dated September 2004.

2 BACKGROUND

The MCA accepted a recommendation made by the Marine Accident Investigation Branch (MAIB), *That the MCA, in consultation with the fishing industry, develop and promulgate guidance for the loading of fishing vessels under 15 metres LOA.* Ref.1. This project was commissioned to address that recommendation.

Vessels of 12 metres registered length and over are required to carry approved stability information booklets, and were not included in this project.

There are over 5,000 small vessels in the UK fleet, ranging from open inshore boats to shelter deck trawlers, some of which have similar fishing capability to that of larger vessels. The remit for this research was to address vessels under 12 metres registered length, for which stability approval is not required. During the course of the research it became apparent that, because of recent changes in fishing vessel Codes of Practice, some vessels between 12 metres registered length and 15 metres overall length may not have stability information. The findings of the study therefore may be applied to vessels under 15 metres overall, as originally recommended by the MAIB. The precise application of this method is not considered to be of relevance to its development and both length definitions have been used in this study.

3 OBJECTIVES

The objectives arose from Phase I of this Research Project, and were stated in the MCA Invitation to Tender. They are summarised as:

1. Compile a database of vessels.
2. Select suitable criteria for use in assigning minimum freeboard and maximum load carrying capability, to ensure that vessels have adequate stability for the fishing methods used.
3. Recommend a simple physical check of the stability.
4. Develop a criterion to provide clear guidance on the maximum lift and associated safe angle of heel or freeboard.
5. Develop guidance on carrying out the calculations and tests, and marking freeboard or maximum load limits.
6. Establish a limit based on a volumetric parameter, above which to apply existing criteria, as set out in MSN 1770 paragraph 3.1.2.1and develop an additional criterion for vessels at high risk of capsize.
7. Determine the application of the requirements and criteria to existing and new vessels.

Although these stated objectives do not specify the development of a Stability Notice, this was the recommendation of Phase I of the study.

Phase I 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. Obtain vessel data with which to test and assess the methods and criteria developed.
2. Obtain accident data from MAIB.
3. Design a suitable Stability Notice to convey information to fishermen.
4. Consult with fishermen on the effectiveness of the proposed notice.
5. Validate the method on UK fishing vessels.
6. Draft suitable guidance for the calculation and application of a lifting criterion.

These elements were broken down further as the work progressed.

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:

<u>UK</u>
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

<u>Overseas</u>
Russian Maritime Register of Shipping
United States Coastguard
Canadian Coastguard
Icelandic Maritime Administration
Independent researchers

<u>International</u>
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 THE 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 previous surveys by Seafish. Data on stability casualties were obtained from MAIB reports, where details generally are comprehensive, and from their database, in which case fewer details are available. One casualty report was obtained from the Isle of Man Marine Administration.

Although there are no requirements for stability approval for small vessels, it is known that calculations frequently are conducted for the satisfaction of the designer, builder or owner. In some cases inclining experiments are conducted. All known designers, builders and stability consultants in the UK were approached with an appeal for stability data on small vessels. Unfortunately the response was very disappointing, with just three respondents adding less than ten vessels to the stability database.

Because stability data on small vessels are scarce, data obtained from MCA stability files for larger vessels were included in the database to expand the amount of information available for this project. Although the vessels are not of direct relevance to this project, their inclusion was considered valuable in determining trends and relationships, such as between stability and freeboard.

A database was compiled in 1997 by Seafish Technology for the purpose of developing a simplified method of stability assessment for small fishing vessels, Ref. 2, but although it contains useful freeboard data, no stability data were calculated.

Some estimates of freeboards were obtained from published photographs of vessels. Although they do not represent accurate records, they were useful in expanding the database of freeboards.

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.

Because data have been derived from many sources, there is considerable variation in the number of dimensions or parameters known in each case. For this reason the number of data points appearing on the graphs in this report is variable.

7 VARIATION OF HULL FORM AND RELATIONSHIP WITH FISHING METHOD

Figure 1 presents the distribution of the UK fleet of fishing vessels under 12 metres registered length, in terms of the length and beam. Deviations from the traditional length/beam ratio are apparent at the regulatory boundaries, as discussed in the report on Phase I of this project.

The distribution of vessel size, in terms of length overall and registered tonnage, is presented in Figure 2, for five principle fishing methods. There appears to be no clear distinction between the sizes of vessels employed for each fishing method. Other design parameters were considered, including beam and depth, and a similar result was found, with vessel form apparently independent of fishing method.

8 CASUALTY ANALYSIS

8.1 Scope of the Data

Casualty data were obtained from the MAIB regarding 46 under 12 metre fishing vessel capsizes since 1991. Investigation reports were available for 7 of these.

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.

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 over 12 metres registered length 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.

8.2 Identity and Nature of the Casualties Under 12 metres Registered Length

Catrina: 13.9m LOA beam 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. Report supplied by the Isle of Man Marine Administration.

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 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.

Most of these casualties capsized in calm conditions. Some occurred in moderate conditions, but none could be regarded as extreme survival conditions for a seaworthy vessel. The loading or heeling moments applied to the vessels were major contributory factors.

In some cases the classification “casualty” or “became casualty” is debatable. In the case of Gorah Lass, for example, the MAIB concluded that wave action may have resulted in water on deck or swamping of the net bins. This would have reduced the stability considerably, perhaps resulting in static instability. The calculated loading condition has been classified within this report as “casualty” because no additional fixed loads or heeling moments were applied by the crew, and the capsize resulted purely from wave action with the vessel in that loading condition. With regard to most of the measures of stability considered in this study, this vessel has the highest stability of the casualties considered. It appears also to have capsized in the worst environmental conditions.

8.3 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.

8.4 Distribution of Casualties within the Fleet

Casualty data are highlighted in Figure 1, and show a fairly uniform spread through the fleet, although beam is not known for all the casualties listed in the database.

The casualties are also presented on the distribution plots of Figure 2. For the trawlers, the data suggest that vessels just under 10 metres are particularly vulnerable, while beam trawlers and dredgers of 10 to 15 metres appear more vulnerable. For potters and netters, the vulnerable groups are between 6 and 8 metres. These results should be treated with caution, however, because the numbers of casualties in each group do not necessarily make such statistical analysis reliable. The final plot shows all vessels and casualties together. It suggests that the casualties are evenly distributed through the fleet. There are more casualties shown in this final graph because the fishing method is not known for all of the casualties.

9 RELATIONSHIP BETWEEN STABILITY AND SAFETY

Although this study targets a fleet in which most vessels have no stability data, it is important to quantify the safety in terms of stability parameters before considering simplified methods of guidance.

9.1 GZ Characteristics

Some stability characteristics the vessels in the stability database are presented, in relation to their overall length, in Figure 3, together with the available casualty data. Not all of these vessels are under 12 metres registered length, indeed some are much larger, but extending the scope of the data increases the number of casualties and helps to reveal the relationships between stability and safety. Not all parameters were available for all vessels, and so the number of data points on each graph varies. The standard minimum requirements for vessels over 12 metres have been included on the Figure for reference.

Above 12 metres there is no clear trend of GZ values varying with length, but it is notable that some of the small vessels would not comply with the criteria which have been applied to those over 12 metres. GZ is not a non-dimensional parameter so one might expect some dependence on length. Constant regulatory minima, regardless of length, reflect the observation supported by the larger vessel data that, in practice, GZ values do not tend to vary significantly with size, but the small vessels appear to contradict this independence. It is possible that there would be a natural variation of GZ values with size, but design of the larger vessels is constrained by the minimum criteria. Alternatively, it may be that the characteristics are independent of length, and the low values for small vessels are the result of a lack of regulation. The latter is considered unlikely because scale effects dictate that extremely small boats could not operate, with practical arrangements, with the GZ characteristics of large vessels.

It should be borne in mind that, if two vessels of different sizes have the same GZ values, the righting moments are greater for the larger vessel, because of its higher displacement.

Downflooding angle and range of stability are non-dimensional, and it is curious that they show some indication that they increase with size, although this may be an indirect result of the minimum GZ requirements for the larger vessels.

The graph of GM values supports a view, now widely held by stability 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.3, 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 conclusion 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. 4. 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.5, 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.5, 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 length, 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 approximated by the formula:

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

Where H_{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. Vessels under 15 metres span a wide range of critical wave heights, from less than 1 metre to over 7 metres, partly because some have larger 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 $_{Hcrit}$, principally because of their greater displacement. The casualties all have H_{crit} values of about 2 metres or less.

This method forms the basis of the recommendations for guidance information for larger vessels which are the subject of Research project 560. It is believed to be suitable for all vessels for which stability data are available, and so may be suitable for some small vessels.

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.

It is customary to define seastates by their spectral type, period and significant wave height. The significant wave height is the mean of the highest 33% of the waves. 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.

$$\text{Critical Seastate, } Hs_{crit} = \frac{\text{Range}\sqrt{\text{RMmax}}}{20B} \qquad \text{Formula 2}$$

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 Hs_{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 VARIATION OF KG WITHIN THE FLEET

One of the reasons for the wide scatter of the GZ data is the variation of the arrangement and outfit of the database vessels, and the resulting variation of the vertical centre of gravity, KG. Figure 7 presents the KG data as a ratio of the beam of the vessel.

There is no trend of KG/Beam variation with length. KG was plotted in combination with other parameters but, again, no useful trends were found. Most vessels have a KG/beam ratio in the range 0.4 to 0.5, while most of those that became casualties were in the range 0.45 to 0.55, and most casualties had a ratio between 0.5 and 0.6. Most of the small casualties for which stability was calculated were loaded excessively on deck, and therefore were operating with a KG higher than the designer might have anticipated. There is one casualty, Gorah Lass, with a KG/beam value of 0.44, but it is possible that the capsize was partially due to swamping of net bins on deck as a result of wave action. This would have raised the KG considerably.

As might be expected, the undecked vessels have relatively low KG values, because they have less, or lower, structures and equipment.

The data suggest that a method of quantifying the KG would be helpful in identifying those vessels, or operating conditions, that are most vulnerable. Unfortunately, the only reliable method involves the combination of a carefully controlled inclining experiment and detailed stability calculations.

11 RELATIONSHIP BETWEEN FREEBOARD AND LEVEL OF SAFETY

11.1 Scope of the Work

This was considered to be an important aspect of this study, and of the related Research Project 560. 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.

11.2 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.6, 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.

11.3 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 8 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 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. The range of stability data show a similar relationship, with range increasing with freeboard and, in this case, the trend is most distinct when plotted with respect to mean freeboard. Some vessels lie well outside the main envelope of data however. One example has a relatively high mean freeboard of 1.4 metres, but a range of stability of only 20 degrees. This is one of the casualties, and illustrates a potential danger of using the mean freeboard to estimate the range of stability.

Figure 9 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.

11.4 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.

For the simplest case, a rectangular box, the variation of range with freeboard is shown in Figure 10. Stability data were calculated for five boxes, each for a range of draughts, as listed in the following table.

The beam was held constant and the depth of the boxes varied. The KG was held constant, so the KG/D varied.

The deeper boxes are not representative of typical fishing vessel proportions, but help to illustrate the trends in the data. For the deepest box, the KG is at half the depth and the range of stability is 90 degrees, regardless of the freeboard, because the centres of buoyancy and gravity must always be aligned at that angle. For the shallower boxes, at the lower freeboards, the range of stability is roughly proportional to the freeboard. At higher freeboards the range becomes constant, and its magnitude becomes dependant on the KG rather than the freeboard.

Beam	Depth	Beam/Depth	Draughts	KG
metres	metres		metres	metres
6.5	3.0	2.17	2.0 – 2.9	2.5
6.5	4.0	1.63	2.0 – 3.9	2.5
6.5	4.5	1.44	2.0 – 4.4	2.5
6.5	4.9	1.33	2.0 – 4.8	2.5
6.5	5.0	1.30	2.0 – 4.5	2.5

The effects of increasing the draught and reducing the freeboard, whilst maintaining a constant KG, are presented for six different vessels in Figure 11. These are large trawlers, but serve to illustrate the variations that may occur with actual vessels. 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 as illustrated by the calculations on boxes.

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 12. The six vessels in Figure 11 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 9. 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 12 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.

11.5 Relationship between Stability and Freeboard for Undecked Vessels

In the absence of a deck, a boat will suffer uncontrolled flooding if the gunwale becomes immersed. The angle at which that occurs will represent the limit of the range of positive stability. This angle may be estimated very simply by assuming that the sin of the angle is equal to the ratio of minimum freeboard to half the beam. The accuracy of the estimate depends on the variation of beam and freeboard along the length, whether the vessel rolls about the intersection of the waterline and the centreline, and whether it trims as it heels. It is likely to be accurate for low values of freeboard.

Figure 13 illustrates the relationship between the range and the ratio of freeboard/beam for a rectangular box, for which the assumptions remain valid, and for two undecked vessels of different beam. Both are 10 metres in length and of conventional form. The simple estimate remains valid for these vessels for freeboards less than 15% of the beam. Available data for the fleet suggest that most vessels operate with an upright freeboard greater than 15% of the beam, so this estimate is likely to give conservative results in general.

This limitation on the stability does not depend on the KG, although with a low KG the moment required to heel a vessel to the gunwale immersion angle will be greater than with a high KG.

12 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 14. The data are for a 10 metre vessel of 18 tonnes displacement, lifting over the side from a point 1.8 metres above the waterline. The angle of list, maximum GZ value, area under the curve and range of stability all decrease progressively as the lifting load is increased. The upright stability curve indicates a range of positive stability of over 60 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 25 degrees.

Figure 15 illustrates the effect of lifting on the range of stability. The residual ranges of stability resulting from the lifting cases shown in Figure 14 are plotted with reference to the minimum residual freeboards to show the strong relationship between them. For comparison, the graph also shows the variation in range of stability with freeboard that would result with variations in symmetric loading, changing the displacement whilst retaining a constant KG. The lift was increased in increments of 0.5 tonnes, while the data points for varying displacement are at increments of 8 tonnes, ranging from 10 to 34 tonnes. The two curves show that, in this example, the relationship between the residual range of stability and residual freeboard remains virtually the same, regardless of whether the residual freeboard is reduced by loading or lifting.

The similarity between these curves is typical, although it depends on the height of the lifting point and the height of additional deadweight. A third curve on the graph shows the effect of lowering the lifting point by 1 metre, with the same loads applied. For the high lifting point with a lift of 2 tonnes, the highest load considered, the range is reduced to 14 degrees and the minimum freeboard is negative, so the water is just over the deck edge. With the lifting point lowered, the range increases to 27 degrees and a small positive freeboard is retained.

Figure 16 shows another example, with the effects of lifting 1 tonne, for the vessel at three displacement conditions. In this example the reduction in range is greater for an over-side lift than for a symmetric increase in displacement, for the same reduction in residual freeboard. 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. It is important that they should be conveyed to the fishermen in the simple guidance provided.

13 METHODS CONSIDERED FOR THE BASIS OF GUIDANCE FOR VESSELS WITH STABILITY DATA

Whilst the majority of small fishing vessels have no stability data, one of the objectives of this project is to advise new lower limits for assessment by the application of conventional stability criteria. The vessels which are to be assessed therefore will have stability calculations conducted as for larger vessels, and this information will enable safety guidance to be based on accurate data rather than estimates of the stability. 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.

13.1 Safety Guidance Based on Freeboard

The minimum freeboards of the vessels in the databases are compared with some freeboard regulations in Figure 17. Most vessels comply with the requirements of the workboat Code, although the relationship between the casualties and the minimum requirement for vessels with stepped or recessed decks does not inspire confidence in the potential use of this standard for fishing vessels. The standard set in Russia is more stringent for the smallest vessels, but the same as the UK workboat Code requirement for vessels with stepped decks at 15 metres. The Nordic standard for decked vessels is set at a rather lower level, and constant regardless of size. For undecked vessels it is more stringent for vessels under 10 metres, and it appears that a large proportion of vessels under 7 metres would not comply with it.

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 11 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.

13.2 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, if it is available.

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.

13.3 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.

13.4 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 UK Codes for Commercial Sailing Vessels. 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 18.

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.

14 DEVELOPMENT OF SAFETY ZONE DEFINITIONS FOR VESSELS WITH STABILITY DATA

14.1 Selected Method

Of the options discussed in section 13, 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.7. 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, Hs_{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.

14.2 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.

14.3 Boundaries Defined by Constant H_{crit} or Hs_{crit}

Consideration of the casualties in Figure 5 suggests that a constant value of H_{crit} or Hs_{crit} might be used to define the safety zone boundaries. 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.

14.4 Boundaries Defined by Constant Hs_{crit}/L

In Figure 6, to which Formula 2 relates, all but one of the casualties are characterised by the value of Hs_{crit}/L being 0.05 or less, while all but one of the database vessels have a value greater than this. Most of the database vessels have a value of Hs_{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 Hs_{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.

$Hs_{crit}/L = 0.05$ 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.

For a 15 metre vessel, representing the minimum length of the currently regulated fleet, $Hs_{crit}/L = 0.05$ 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.

It is possible that a much larger vessel, to which this guidance will also be applied, could operate in compliance with the IMO criteria but have a value of Hs_{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 typical of gale force conditions, and considered very rough

For a vessel of 5 metres, $Hs_{crit}/L = 0.05$ would represent extremely low stability properties and a wave height of only 0.25 metres, and even a value of Hs_{crit}/L of 0.1 could be achieved without compliance with the IMO minimum criteria.

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

14.5 Boundaries Defined by Variable Hs_{crit}/L

Figure 19 presents values of Hs_{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 19, the values; range = 45 degrees and GZmax = 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:

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

Formula 3

Where Hs_{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 0.7, 1.5 and 2 metres significant height, for vessels of 5, 12.5 and 20 metres respectively. These are perhaps more reasonable than those derived from constant Hs_{crit} or Hs_{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 20 shows the variation of Hs_{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 Hs_{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 20 is defined by the line $Hs_{crit} = 0.5\ Hs_{IMO}$. 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 21 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 Hs_{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 Hs_{crit} might not have capsized had they restricted their operation to appropriate seastates.

14.6 Example Data

Calculations were conducted to determine the loading and lifting configurations that would form the basis of guidance for sample vessels of about 10 metres, using the green/amber and amber/red boundaries defined as described in section 14.5. One is a shelter decked trawler, one a flush decked potter with very high freeboard, the other a low freeboard potter with a cat catcher aft.

Trawler: For the 10 metre trawler, a lifting case was considered, using the worst stability condition in the stability booklet as a basis. The single load was applied to one of the trawl gallows blocks located high on the stern quarter. In the stability booklet, the shelter is assumed watertight, and no downflooding is considered. The GZ curve is presented up to 90 degrees, at which it reaches a maximum. The most likely downflooding opening is the cod end hatch on the shelter top, and this would become immersed at about 50 degrees. In this configuration the vessel appears very safe, because the load required to reach even the green/amber boundary would result in an alarming heel angle and immersion of the main deck aft. Such a lift is unlikely to be attempted therefore. If the shelter door is assumed open, a very different result is obtained, and it would be prudent to display this on the Stability Notice. In all cases the aft deck would be submerged on the side at which the load was applied.

Downflooding Point	Green/Amber, Hs_{crit} = 1.2m				Amber/Red, Hs_{crit} = 0.6m			
	Load	Min. Fbd to opening	Min. Fbd to deck	Heel	Load	Min. Fbd to opening	Min. Fbd to deck	Heel
	tonnes	metres	metres	degrees	tonnes	metres	metres	degrees
Cod end hatch	3.5	1.08	-1.6	31	4.7	0.58	-2.1	38
Shelter door	1.3	0.79	-0.13	7	2.0	0.42	-0.56	14

High freeboard potter: For the high freeboard potter, a lifting case was considered with the load applied to the hauler, located 1 metre above the deck edge. The vessel carries pots on deck, and is expected to carry extra equipment on deck on some occasions, so a deck loading case also was considered, with the load assumed to be centred 0.25m above the deck on the centreline. The loading case shows that this vessel is safe in terms of additional deck loads, the values calculated being greater than those likely to be loaded on deck. This vessel has generous freeboard, and these values would reduce if the vessel was modified, with weight growth and a rise in its lightship centre of gravity.

Loading Case	Lifting Point	Green/Amber, Hs_{crit} = 1.3m			Amber/Red, Hs_{crit} = 0.65m		
		Load	Min. Fbd	Heel	Load	Min. Fbd	Heel
		tonnes	metres	degrees	tonnes	metres	degrees
Lifting one side	Hauler	0.5	0.51	5	1.25	0.22	12
Load on deck	None	2.5	0.52	0	6.5	0.27	0

Low freeboard potter: The low freeboard example, based on the same hull form, but with a lighter displacement and lower KG, shows again the benefits of freeboard. The arrangement is different, with a cat catcher aft to carry pots, but the hauler arrangement is similar. The loads that can be lifted with the same level of safety are much lower than for the high freeboard vessel.

Loading Case	Lifting Point	Green/Amber, Hs_{crit} = 1.3m			Amber/Red, Hs_{crit} = 0.65m		
		Load	Min. Fbd	Heel	Load	Min. Fbd	Heel
		tonnes	metres	degrees	tonnes	metres	degrees
Lifting one side	Hauler	0.2	0.24	1.5	0.75	0.10	5.5
Load on cat catcher	None	0.5	0.24	0	2.0	0.07	0

The GZ curves corresponding to these load cases for the two potters are presented in Figure 22. The curves corresponding to the green/amber boundary should provide similar levels of safety in the same wave heights because the two vessels are the same length. A characteristic of low freeboard vessels is the relatively low angle of maximum GZ, as is clear from the comparison of these two plots. For each zone boundary case, the magnitudes of the ranges and maximum GZ values are different for the two vessels because they have different displacements, and therefore different righting moments, and because there is a balance between range and maximum GZ in the formula.

15 APPLICATION OF MINIMUM STABILITY CRITERIA

The methods described above rely on the availability of calculated stability information, backed up by an inclining experiment. The following section presents the consideration of which vessels should be subject to detailed stability analysis and the application of IMO, or similar, minimum criteria.

15.1 Application of Regulations in Other Countries

All UK fishing vessels over 15 metres overall length are required to carry stability booklets, and comply with standard IMO criteria. Other countries use alternative lengths, or other measures, to define the vessels to which such requirements are applied. Figure 23 presents some of these graphically, superimposed on the UK under 12m fleet. Where a boundary is labelled IMO, all vessels above it are required to meet standard IMO stability criteria. Other boundaries are shown, above which vessels must comply with alternative requirements developed in that country. Length and tonnage are commonly used to define the minimum size at which regulations are applied, while in Denmark, some boundaries are defined by the product of length and beam.

The Figures demonstrate that the under 12m UK fleet includes boats up to 15m overall. Many of these would be required to comply with standard IMO criteria in some countries, such as France, New Zealand and Russia. In some countries, such as France, and those applying the Nordic Boat Standard, all vessels below the minimum size for application of IMO criteria are required to meet their small vessel standard. Other countries, such as New Zealand, Russia and Denmark, have a minimum size for application of their small vessel standard.

15.2 Options Considered

The Phase I study concluded that IMO criteria might be applied to vulnerable UK vessels under 12 metres, that is, those engaged in towing or dredging. Closer inspection of the fleet suggests that this would impose such regulation on a very large proportion of the fleet. Over 2100 vessels are cited as using some form of trawl or dredge in the DEFRA database, representing about a third of the total fleet. Even if the regulation were only applied to new vessels, it would require the assessment of some small vessels for which the cost would be a significant proportion of the capital cost of the vessel. Using only the fishing method to define the vessels to which a regulation should apply introduces a problem, because changing the fishing method is a very common occurrence. It would, therefore, be very difficult to regulate and enforce.

It is suggested that the limit should be based on fixed parameters of the vessel, preferably ones that relate to the size in terms of the fishing ability. Several measures are in use already, including linear dimensions, volumetric measurements such as tonnage, and combined measures including size and engine power, such as the Vessel Catch Unit (VCU = L × B + 0.45P). All of these options were considered in terms of ease of application, impact on the fleet, and possible influence on future designs.

On balance the use of tonnage is favoured for the following reasons.

1. It is an existing parameter which is documented for all vessels, and so requires no additional measurements or calculation.
2. In most cases it is representative of the capacity of the vessel in terms of its catch carrying ability.
3. Although it is possible that designers may work to the selected limiting value, it seems unlikely that this will conflict with safety because minimum stability requirements will be applied, and guidance on the level of safety during operation will be provided.
4. This measure does not include power, which frequently is quoted as being subject to error, and is difficult to validate.
5. A limiting value could be selected at a level that represented the “smallest” vessels over 15 metres overall and included the rule beating designs.

15.3 Selection of a Tonnage Limit

It is apparent from the envelope of data on Figure 23, that few vessels over 12 metres registered, or over 15metres overall and to which current stability requirements apply, are likely to have tonnage values below 10 tons. In fact, the RSS database lists only 9 vessels over 12 metres registered length measuring less than 10 tons gross so, for practical purposes, this represents the lower limit of the regulated fleet.

Figure 24 offers a magnified view of the 6 to 16 metre part of the fleet. The envelope of data below 10 tons has a high density zone, indicated by the broken lines, and some vessels outside this zone with atypical proportions that result in particularly high or low tonnage for their length. The rule beating vessels of just under 10 metres in length represent a particular group of such vessels, some with a tonnage two or three times the mean value. The upper boundary of the high density envelope at 10 metres is about 10 tons. This value therefore appears to offer a reasonable limit above which to regulate stability.

There are about 730 vessels in the under 12 metre fleet with a registered tonnage above 10 tons. Figure 24 shows their distribution in terms of length and tonnage in relation to the 10 ton line. Such a limit, if applied to the existing fleet, would require stability assessment of most of the vessels between 10 and 15 metres overall, and all of the vessels under 10 metres which have tonnage values above the upper boundary of the envelope of “normal” vessels.

15.4 Consideration of Fishing Method

Although fishing method alone was dismissed in section 15.2 as an inappropriate criterion for the application of regulations, the casualty data suggest that it is the trawlers that are the vulnerable group in this size range. It is therefore recommended that only vessels equipped for towing need be subjected to detailed stability assessment.

These vessels are more likely to be vulnerable to fastening of gear on the bottom, lifting heavy loads, lifting from blocks located high up or far outboard, and operating far from shelter.

15.5 New and Existing Vessels

To attempt stability assessment retrospectively for existing vessels doubtless would be advantageous in terms of safety, but is thought to be impractical for this large a sector of the UK small vessel fleet. The MCA currently may not have the resources to undertake such a task, many of the vessels would have no lines plans, and imposing such regulation on the industry would increase the level of hostility against the introduction of the system of guidance, perhaps jeopardising the principal objective of the scheme.

It is therefore recommended that stability assessment be applied only to new vessels.

15.6 Selection of Criteria

As discussed in section 9.1, GZ requirements are constant for all vessels over 12m but, if we scale vessels to very small sizes, it is not possible to maintain constant GZ values with reasonable arrangements. At some point it must become impractical for small vessels to achieve the IMO minimum requirements, and some reduced requirement might be more appropriate.

It is essential that the requirements harmonise with those for vessels above 15 metres. The IMO criteria ensure that GZmax is at least 0.2, and the minimum range is around 50 degrees in order to satisfy the criterion for GZarea between 30 and 40 degrees, with the minimum GZmax. Such a minimum curve is illustrated in Figure 25. The implied range requirement is non-dimensional, but we can perhaps scale the required GZmax so that it is proportional to vessel size.

One option would be a linear scaling, such as: Required GZmax = L/75. This would harmonise with the IMO requirements for a GZ of at least 0.2 metres for vessels of 15 metres LOA. Vessels of 5 and 10 metres would require GZmax to be at least 0.067 and 0.133 metres respectively. This relationship is illustrated in Figure 26, and corresponds to the value for one of the casualties. The criterion is for upright vessels rather than the residual stability of heeled vessels, and it was considered too low a requirement.

An alternative would be to use a minimum value of Hs_{crit} based on Formula 3, but this would not overcome the scaling effects because the formula was based on the assumption that all vessels, regardless of size, just complied with the IMO criteria.

For a typical 15m vessel, of 5.5m beam and 80 tonnes, representing the centre of the range of fleet statistics, the minimum values of range and GZmax equate to $Hs_{crit}/L = 0.121$. On the basis that smaller vessels are likely to operate in less severe seastates, we can adopt the principle that Hs_{crit}/L remains constant for all sizes, to maintain a consistent level of safety in waves of constant height relative to vessel size. Again, assuming that the non-dimensional parameter, range, remains constant, we can derive the required GZmax for each vessel in the database, given L, B and displacement. A fit to these data, fixed at the point GZ = 0.2 at a length of 15 metres, provides the relationship between required GZmax and length:

$$GZmax = (L+10)/125.$$

This would harmonise with the IMO requirements for a GZ of at least 0.2 metres for vessels of 15 metres LOA. Vessels of 5 and 10 metres would required GZmax to be at least 0.12 and 0.16 metres respectively. As shown on Figure 26, this provides a margin of safety above all of the available casualty data.

Thus, the recommended criteria, to provide equivalent levels of safety in waves of the same height/boat length, and to harmonise with the standard IMO criteria at 15 metres, are:

Range of stability must be at least 50 degrees,
Maximum value of GZ must be at least (L+10)/125

It is apparent that some of the small vessels in the stability database would not comply with these requirements, but they are not necessarily representative of the vessels that would be required to comply with them, that is, new vessels over 10 tons engaged in towing.

For the smaller vessels, it is possible that these minima will result in a value of Hs_{crit} that falls within the amber zone. This is not an anomaly in the system. It means that such a vessel has been assessed as having adequate stability to conduct towing operations but, because of its small size and marginal stability, such operations should be restricted to the appropriate seastates as presented on the Stability Notice. When lifting, the residual stability may be reduced to below these upright requirements, and the maximum recommended seastates will be lower as a result.

15.7 Stability Documentation Required for Submission to MCA

It is not suggested that a comprehensive stability booklet is required, because it is recognised that it will not be used in the operation of the vessel. The document to be submitted to the administration should be adequate to demonstrate compliance. This will require an inclining experiment report and stability curves or calculations at the extreme loading conditions, in the absence of lifting. These may include the lightest condition, heaviest condition, and a condition with a particularly high KG, but should include the worst stability condition in terms of the righting moment curve characteristics.

Note that these requirements are for the upright vessel in the absence of lifting, and therefore do not relate directly to the requirements for residual stability which govern the Stability Notice guidance. The stability documentation submitted should include the effects of lifting, to show the derivation of the safety guidance. The lifting loads assumed in the calculations should be based on the maximum capacity of the winch, warp or block, or the maximum recommended lift specified on the Stability Notice.

16 METHOD OF GUIDANCE FOR VESSELS WITH NO STABILITY INFORMATION

Without detailed stability data, most of the potential methods of guidance considered in Section 13 are not possible. One option which requires no stability data is to base the guidance on freeboard. This was dismissed as being inferior when vessels have stability data, and because there is not an existing system that relates freeboard to safety other than as a pass/fail limit. If such a relationship can be identified, freeboard will offer a simple means of estimating safety.

The close relationship between freeboard and stability was described in section 11. The residual range of stability has been shown to be the most important parameter, and was found to be dependent on the residual freeboard.

It is important to strive for harmony between the various methods, and so the safety zone boundaries described above for vessels with stability data should be used to form the basis of the method for vessels without stability data.

Although there is evidence that the mean freeboard provides the closest correlation with the range of stability, minimum freeboard is favoured as a basis for guidance for two reasons.

1. In the database, there are no examples of high minimum freeboard combined with a low range of stability, but this is not the case for the mean freeboard. See section 11.3 and Figure 9.
2. The fishermen would not be able to relate directly to the mean freeboard.

A number of relationships were investigated, using ratios of freeboard to beam, length, and other parameters, and the ratio of freeboard/beam appeared to give the most reliable trends in terms of the variation of stability with freeboard. The relationship between the minimum freeboard/beam and Hs_{crit}/length, for the under 15m vessels in the database, is presented in Figure 27. There is a clear relationship between the two, although it is not as strong as that between range of stability and freeboard. Two lines are indicated on the graph, representing proposals for formulae that might be used to estimate the value of Hs_{crit} from the minimum freeboard. The line $F/B = 2.6\ Hs_{crit}/L$ fits the data for undecked vessels very well, but there are few samples in this group and so this close correlation does not necessarily enable a high level of confidence that the formula will apply equally to the fleet in general. The formula proposed for decked vessels has been selected to provide a conservative estimate in most case, with the simplest relationship possible, $F/B = Hs_{crit}/L$.

The implications of applying this method of guidance are presented in Figure 28, where the available freeboard data are plotted in relation to the proposed guidance boundaries. Most of the casualties lie in the red zone, with two in the lower part of the amber zone. In their normal operating conditions, many vessels operate with freeboards in the proposed amber zone, and some in the red zone. This is appropriate if those vessels are relatively unsafe, and may be acceptable if they operate in the appropriate seastates with regard to the guidance provided.

Undecked vessels can never be as safe as decked vessels, being vulnerable to swamping in breaking waves and having limited range of stability, and it is recommended that only the amber/red zone boundary be defined for them, as indicated on Figure 28.

LOA	**B**	**Green/Amber**		**Amber/Red**	
		Hs_{crit}	**Freeboard**	**Hs_{crit}**	**Freeboard**
Decked vessels					
4	1.50	0.61	0.23	0.31	0.11
6	2.25	0.84	0.32	0.42	0.16
8	3.00	1.05	0.39	0.52	0.20
10	2.50	1.24	0.31	0.62	0.16
10	3.75	1.24	0.47	0.62	0.23
10	5.00	1.24	0.62	0.62	0.31
12	4.50	1.41	0.53	0.70	0.26
15	5.60	1.65	0.62	0.82	0.31
Undecked vessels					
4	1.5			0.31	0.30
6	2.25			0.42	0.41
8	3			0.52	0.51

The table above presents some example data for a range of vessel sizes. Typical beam values have been assumed for each length of vessel in the table, with additional extreme narrow and wide beam samples at a length of 10 metres.

Figure 29 indicates the range of stability variation with the freeboard/beam ratio. This is the same graph as in Figure 9, but with only the data for under 15m decked vessels plotted. It shows which zone each vessel would be in, on the basis of the proposed zone boundaries, in its normal upright condition. It is clear that the system is far from perfect in terms of identifying the range of stability, and this is inevitable if the vessel shape and centre of gravity cannot be incorporated in the estimation method. All of the vessels in the red zone have ranges of stability less than 50 degrees, and all of those in the green zone have ranges in excess of 50 degrees. This is encouraging, as 50 degrees is the approximate minimum range of stability implied by the IMO criteria.

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

The two potters used for the examples in Section 14.6 provide an illustration of this. With a length of 10.6 metres and beam of 3.85 metres, the freeboards defining their safety zone boundaries, in the absence of any stability calculations, would be 0.47 and 0.23 metres. These values lie between those determined through the full stability analysis for the high and low freeboard vessels, but closer to the high freeboard example. In fact the low freeboard vessel has less than 0.47 metres freeboard in its normal condition, and so would always be operating in the amber zone as defined by this approximate method, even without lifting or additional loading. By inspection of the two tables it can be seen that, for a residual freeboard of

0.23 metres, the high freeboard vessel could lift 1.25 tonnes while the low freeboard vessel could lift only 0.2 tonne.

17 INSTRUMENTATION

17.1 Load Cells – Vessels with Stability Data Only

To gain maximum benefit from the guidance information on lifting requires information on the loads being handled. This can be obtained 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.

17.2 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. Many small vessels will not have stability data, and therefore will have no reference to heel angles on the Stability Notice, and some will not require a heel test. The presence of an inclinometer on such vessels may seem superfluous, but its presence might help to promote an awareness of stability issues, in a similar way to the guidance freeboard mark.

18 PREPARATION OF STABILITY NOTICES

18.1 Loading Cases for Vessels with Stability Data

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.

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.

18.2 Accuracy of Data

When operating with minimal stability, small changes to the loading case can result in large changes to the predicted value of Hs_{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 capsize, 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 or 2
Heel angle	degrees	0

18.3 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 Figure 32. If a heavy lift is attempted at the vessel's side, and the residual freeboard is reduced to about 35cm, the level of safety would be in the middle of the amber zone, and the vessel might be vulnerable in a seastate of about 0.9 metre, 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 0.6 metres.

The basis of this method of guidance is a predicted minimum seastate that might result in capsize. Capsize 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 the lift described above, the Stability Notice would advise not to undertake the lift in seastates above 1.3 metres. The fisherman might interpolate intuitively between the presented values of freeboard 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 21 support this apparently optimistic approach, with capsize 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.

18.4 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.

18.5 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.

18.6 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.

18.7 Examples

Example Stability Notices are presented in Figure 32 to Figure 34, for three potters. Two correspond to the examples described in section 14.6, for which stability data would be used to define the loads and freeboards, and the third represents a similar vessel for which no stability data are available. There are differences in some details of the presentations, but it is considered that the format of the Notice should be flexible, and tailored to suit the vessel and its operation.

Notices for vessels without stability data should include the length and beam of the vessel, so that the derived values can be checked during an inspection.

19 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, and if stability information has been calculated it should be revised accordingly. Such a procedure is not always followed, as the accident investigations reveal, and a simple physical check on the stability is one of the objectives of this project specified by the MCA. Vessels equipped for towing and lifting are particularly vulnerable to such alterations. For these vessels a heeling test is proposed to highlight any significant alterations.

A heeling test is preferred to a rolling test because the latter is dependent on the hydrodynamic damping and inertia. These factors are highly variable on small fishing vessels, with a wide range of hull forms, appendages and types of outfit.

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. For vessels with stability data, the test does not need to be conducted to determine the stability of the vessel because that is done by an inclining experiment. For these vessels 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 information submitted to the MCA, in which case an inclining experiment will be required.

For vessels with no stability data, the test should provide an opportunity to monitor changes in the stability of the vessel and its lifting arrangements, and enable the fisherman to become familiar with the relationships between lifting, heel angle and residual freeboard.

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. To provide this level of accuracy, the heel angle should be at least 5 degrees and preferably about 10 degrees.

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 for Vessels with Stability Data**
Increased weight of fishing gear	Stability documentation – gear details and loading conditions
Longer derricks, or a higher lifting point	Stability documentation – derrick details Stability Notice – maximum recommended lifting loads
Reduced vessel stability	Conduct new inclining experiment Stability documentation – loading conditions Stability Notice – all data

20 GUIDANCE FREEBOARD MARK

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

A line could be placed at one of the guidance freeboards, but it is proposed that a mark be used such that its top and bottom edges indicate freeboards corresponding to the safety zone boundaries. See Figure 30. On undecked vessels, where only the amber/red boundary is presented on the Stability Notice, only the upper half of the mark might be used, and this will distinguish them from decked vessels. In both cases, to standardise the marks, a width of half the height is suggested. The marks then will appear as in the illustration. They should be in a colour that contrasts with the local colour of the topsides.

If the value of Hs_{IMO} is determined using Formula 3, the freeboards associated with the zone boundaries are determined as shown in Figure 30.

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

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

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

For vessels with stability data, which have been used to prepare the guidance information on the Stability Notice, it may be impractical to apply freeboard marks for a number of reasons, principally because there may be a number of different freeboards, each associated with a different loading or lifting case. At this stage it is considered preferable not to attempt to place freeboard marks on such vessels. The guidance on their Stability Notices is based on more accurate information, and in most cases will be defined by loads carried, loads lifted or heel angles. Familiarity with the recommended minimum freeboards therefore is less critical

21 .SUMMARY OF GUIDANCE AND ASSESSMENT PROCEDURE

21.1 Guidance and Assessment Flow Chart

Figure 31 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 560 for larger vessels.

21.2 Stability Assessment

Assessment is proposed for new vessels over 10 tons registered which are equipped for towing.

An inclining experiment should be conducted and stability curves prepared for the extreme loading conditions in the absence of lifting. The minimum requirements are:

Range of stability must be at least 50 degrees,
Maximum value of GZ must be at least (L+10)/125

21.3 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.

21.4 Guidance Information

The safety zone boundaries are defined as:

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

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

Where stability calculations are conducted, 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.

Where stability calculations are not conducted, the guidance freeboards to be presented on the Stability Notice are determined as:

For decked vessels
Green/amber boundary, Min Freeboard = $Hs_{IMO}B/LOA$
Amber / red boundary, Min Freeboard = $Hs_{IMO}B/2LOA$

For undecked vessels
Amber / red boundary, Min Freeboard = $2.6Hs_{IMO}B/2LOA$

21.5 Guidance Freeboard Marks

For those vessels without stability data, where guidance is based on freeboards alone, freeboard marks should be applied as described in Figure 30.

22 REFERENCES

1. Report on the Investigation of the capsize of the fishing vessel Charisma, MAIB, January 2002.

2. Code of Safe Practice for Registered Fishing Vessels less than 12 metres Length - Final Report of the Capsize Safety Specialist Sub-Group, Seafish Technology, June 1997.

3. 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.

4. 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.

5. MCA Research Project 509, HSC – Evaluation of Existing Criteria, Wolfson Unit MTIA report 1807, March 2005.

6. An Investigation into Simplified Stability Assessment Methods for Small Fishing Vessels. Report by Seaspeed Technology Ltd. For the MCA, September 1994.

7. Ocean Wave Statistics. N. Hogben & F.E. Lumb, HMSO, 1967.

Figure 1. Beam and length distribution of the UK fleet

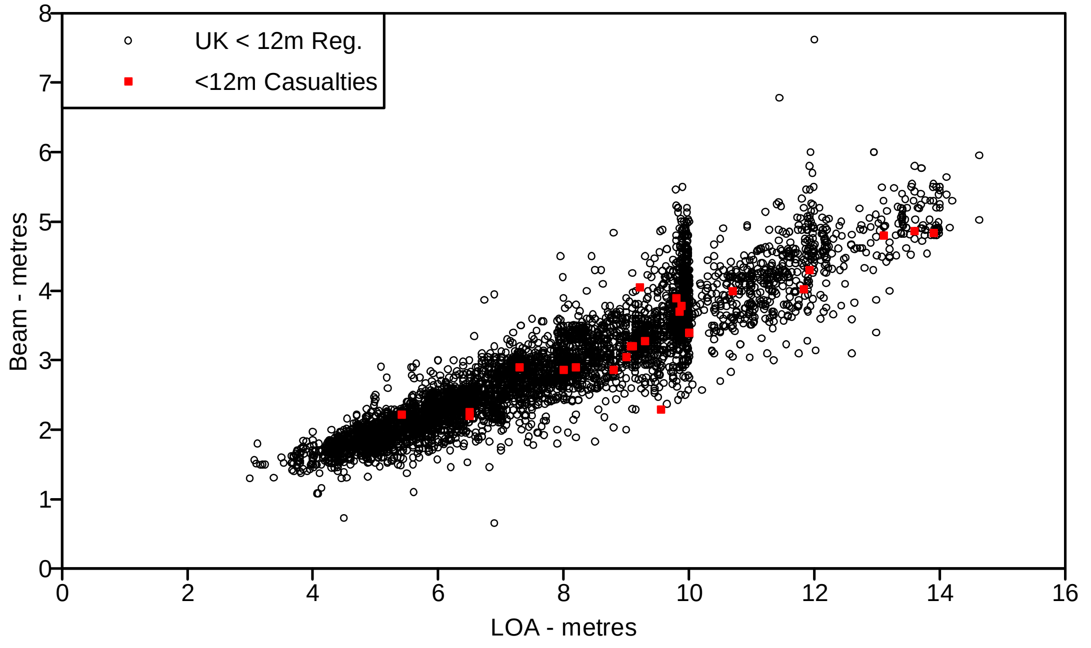


Figure 2. Distribution of fishing method with vessel size

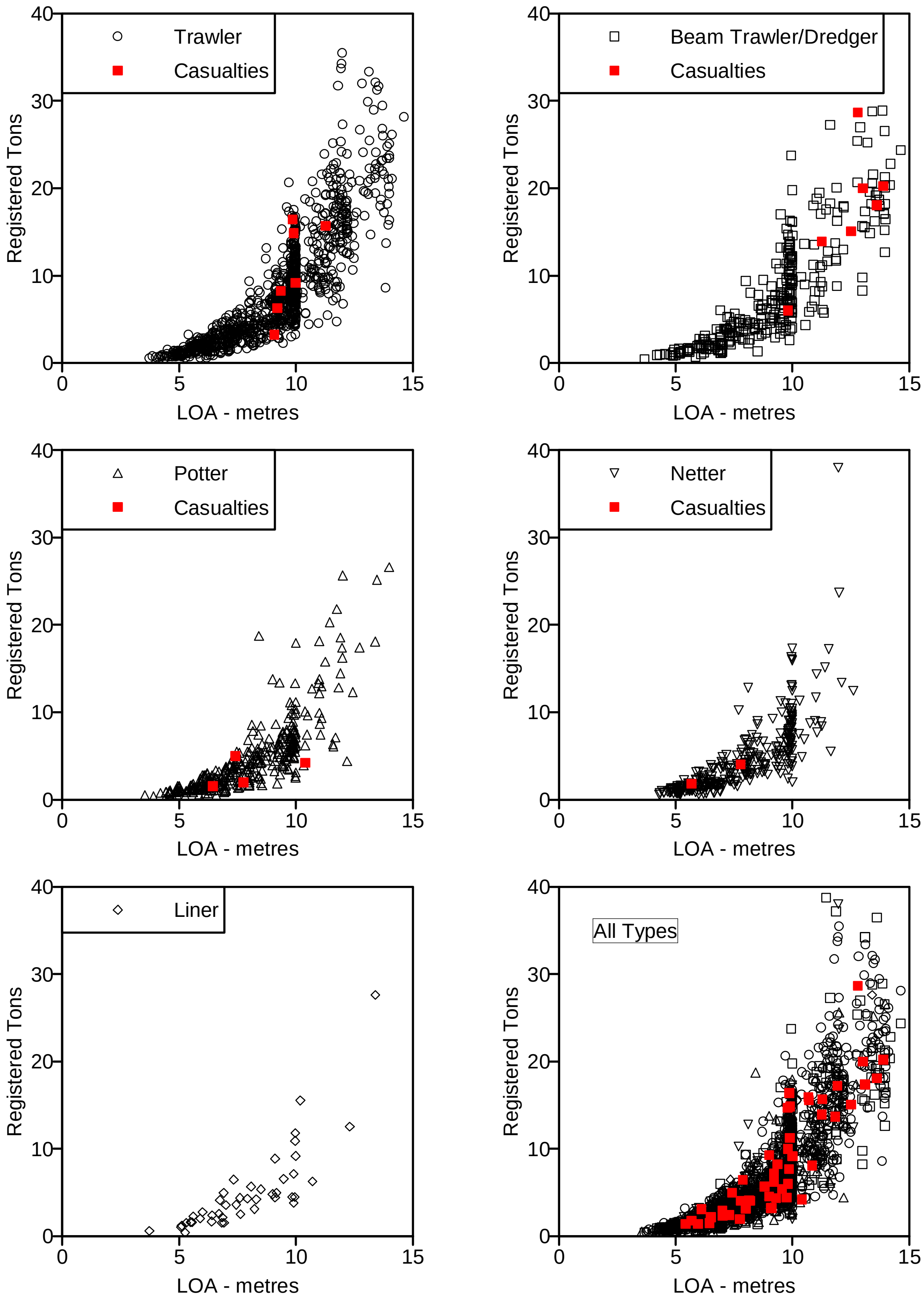


Figure 3. Stability characteristics of database vessels, and casualties

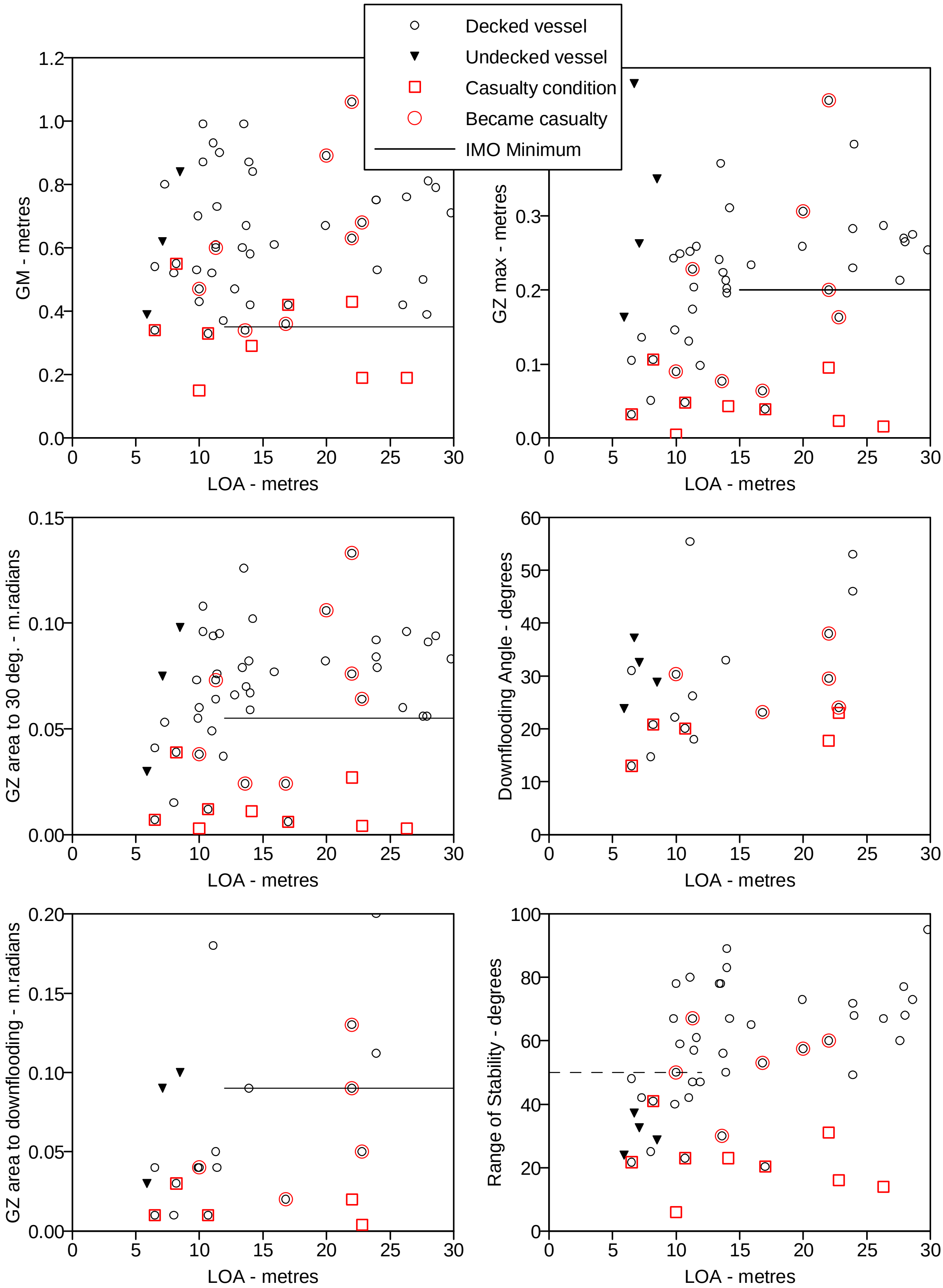


Figure 4. Results of model capsizing tests, relating wave height to stability

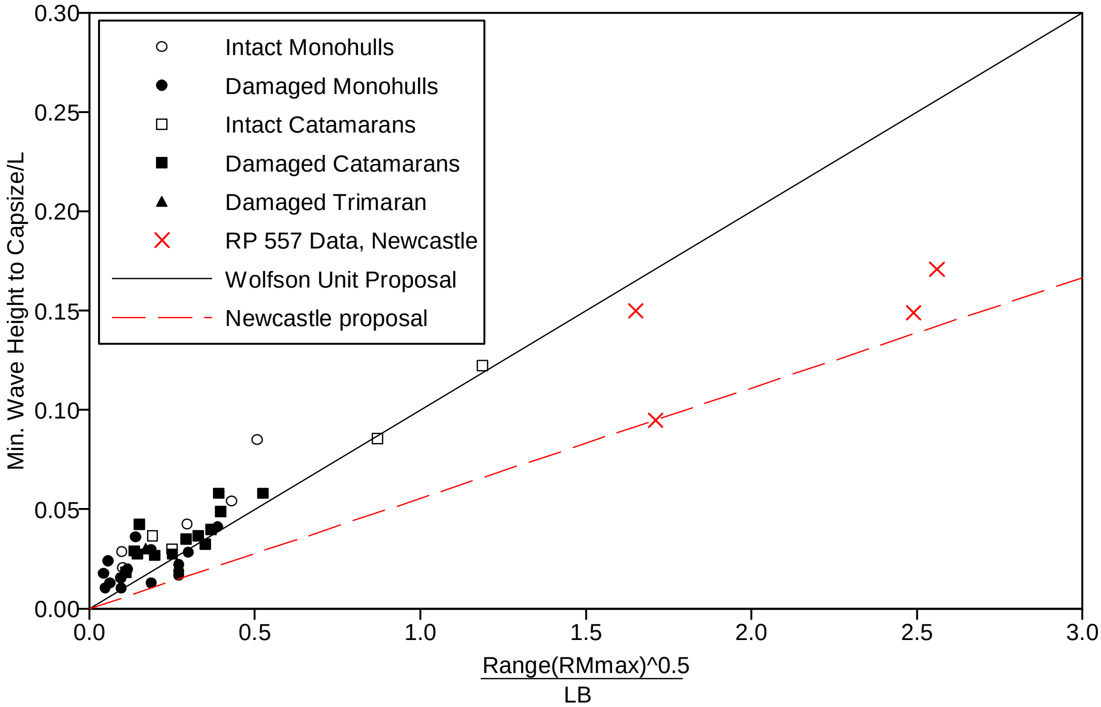


Figure 5. Critical wave height predicted for the stability database vessels and casualties

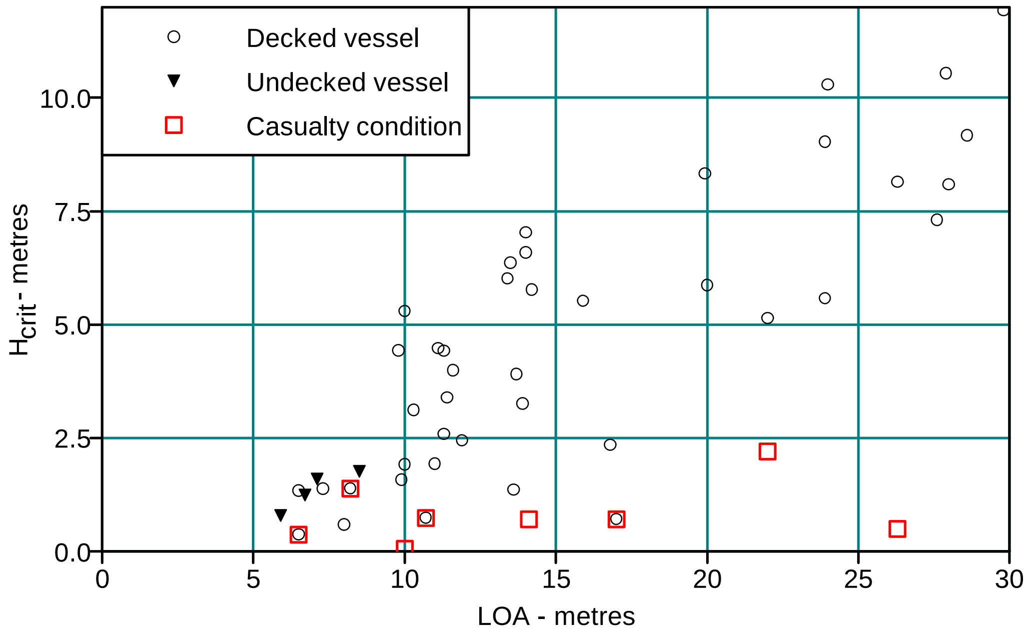


Figure 6. Critical seastate/length predicted for the stability database vessels and casualties

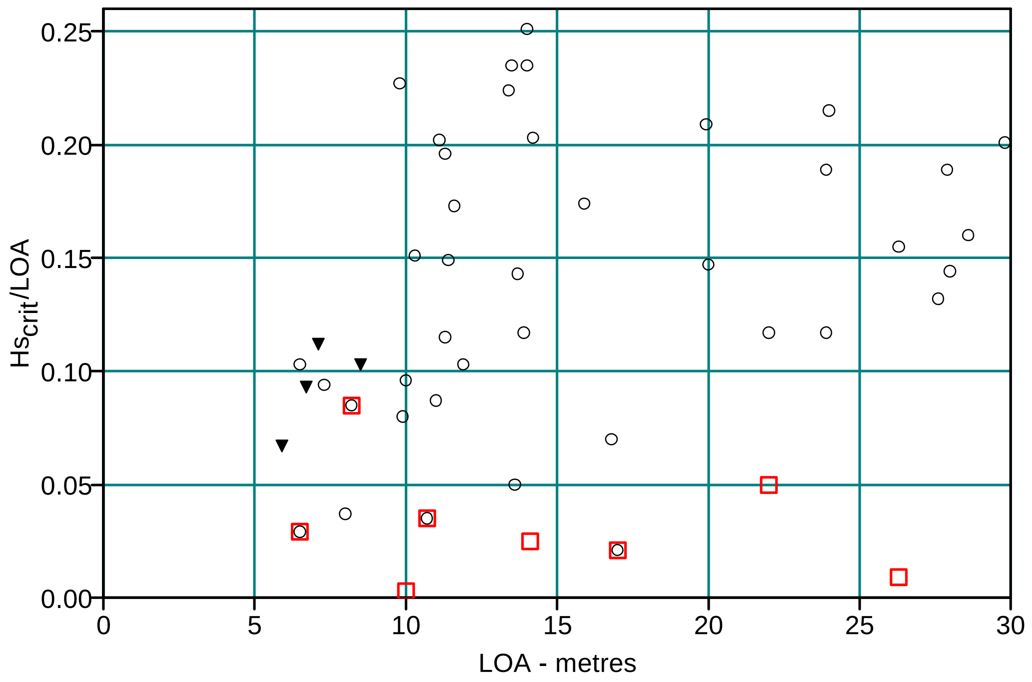


Figure 7. Variation of vertical centre of gravity within the database

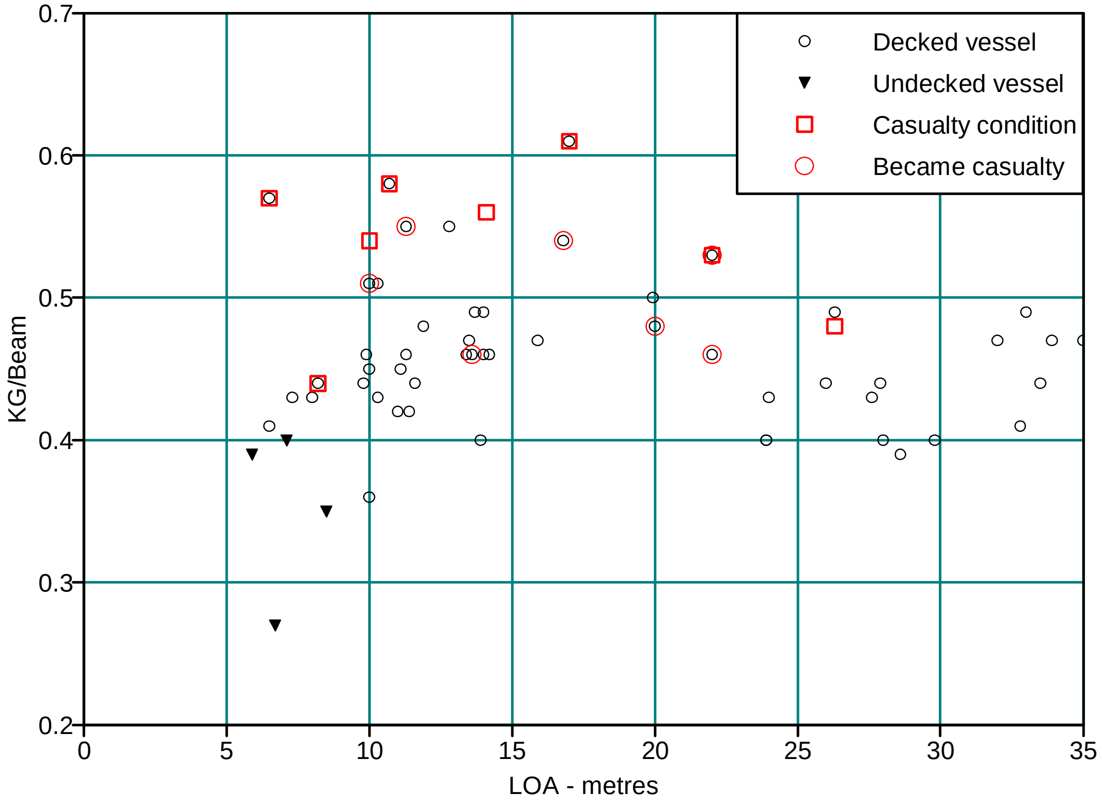


Figure 8. Variation of stability with freeboard

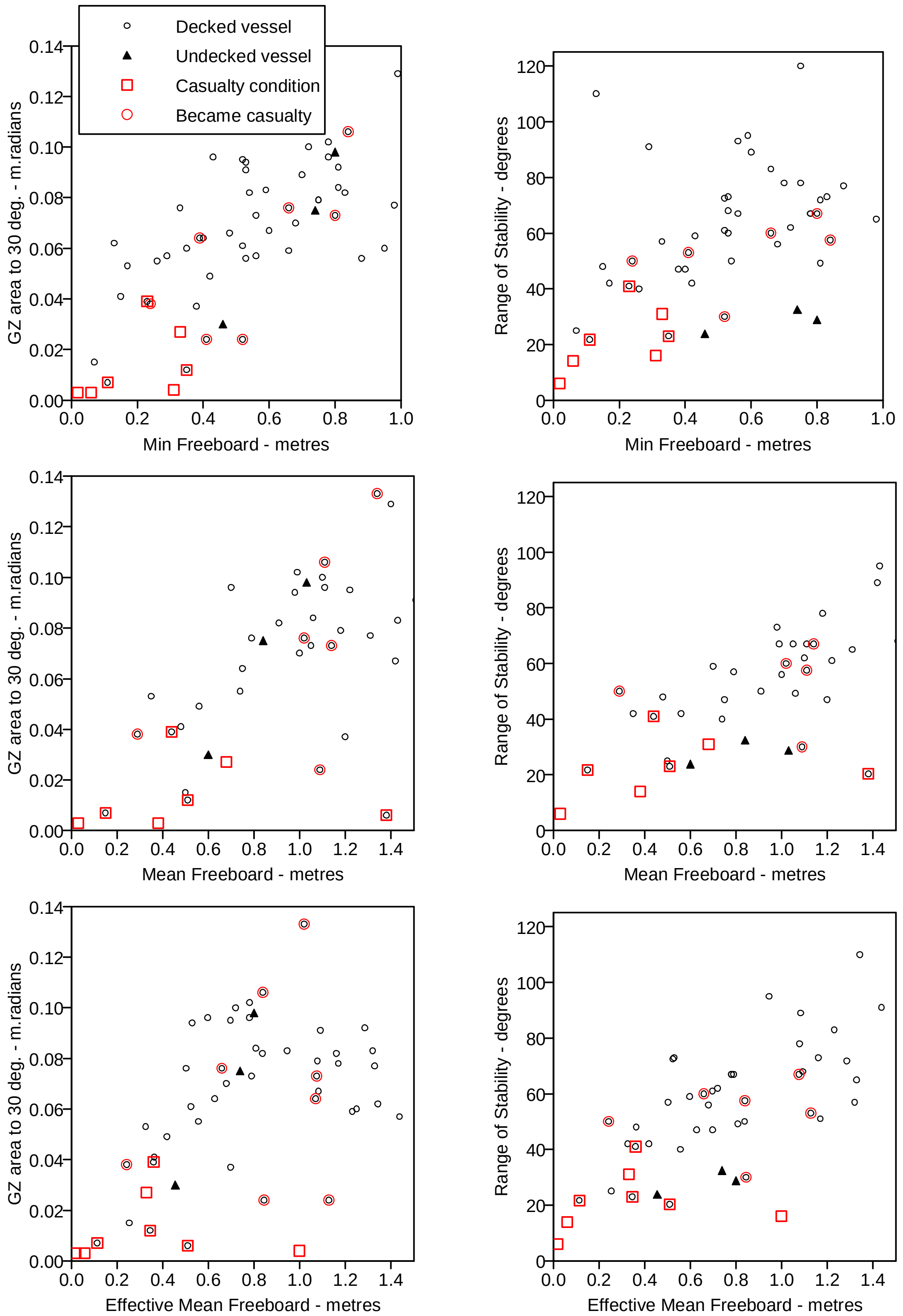


Figure 9. Variation of stability with freeboard/beam ratio

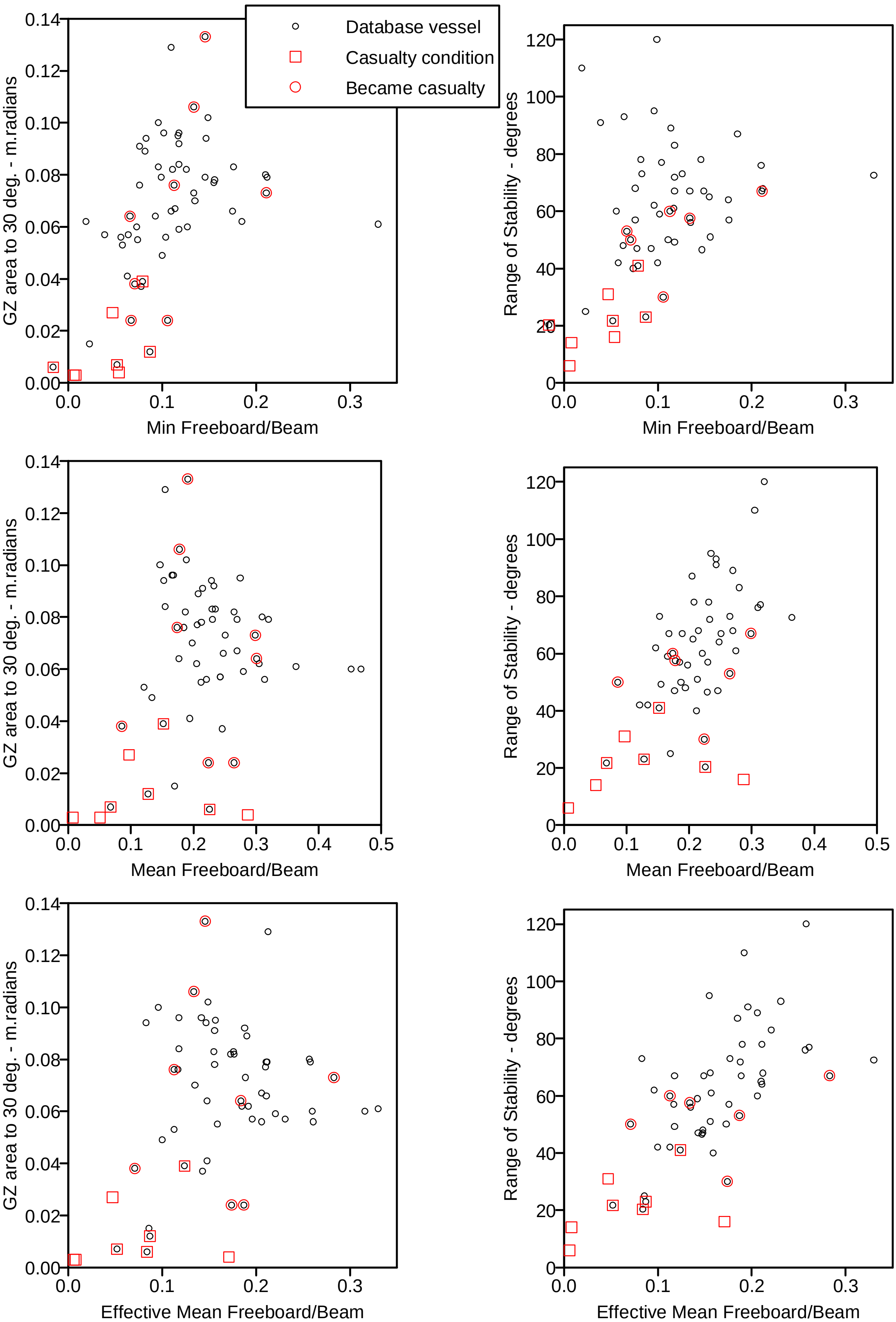


Figure 10. Variation of range of stability with freeboard for rectangular boxes

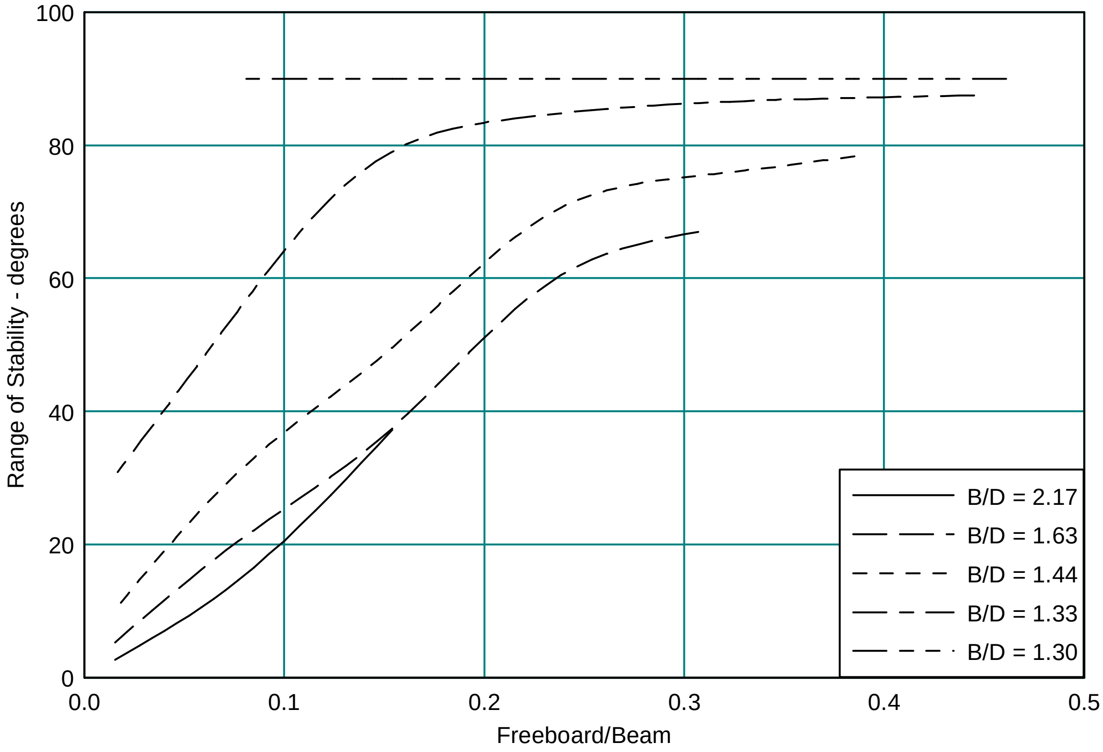


Figure 11. Variation of stability with freeboard for six trawlers

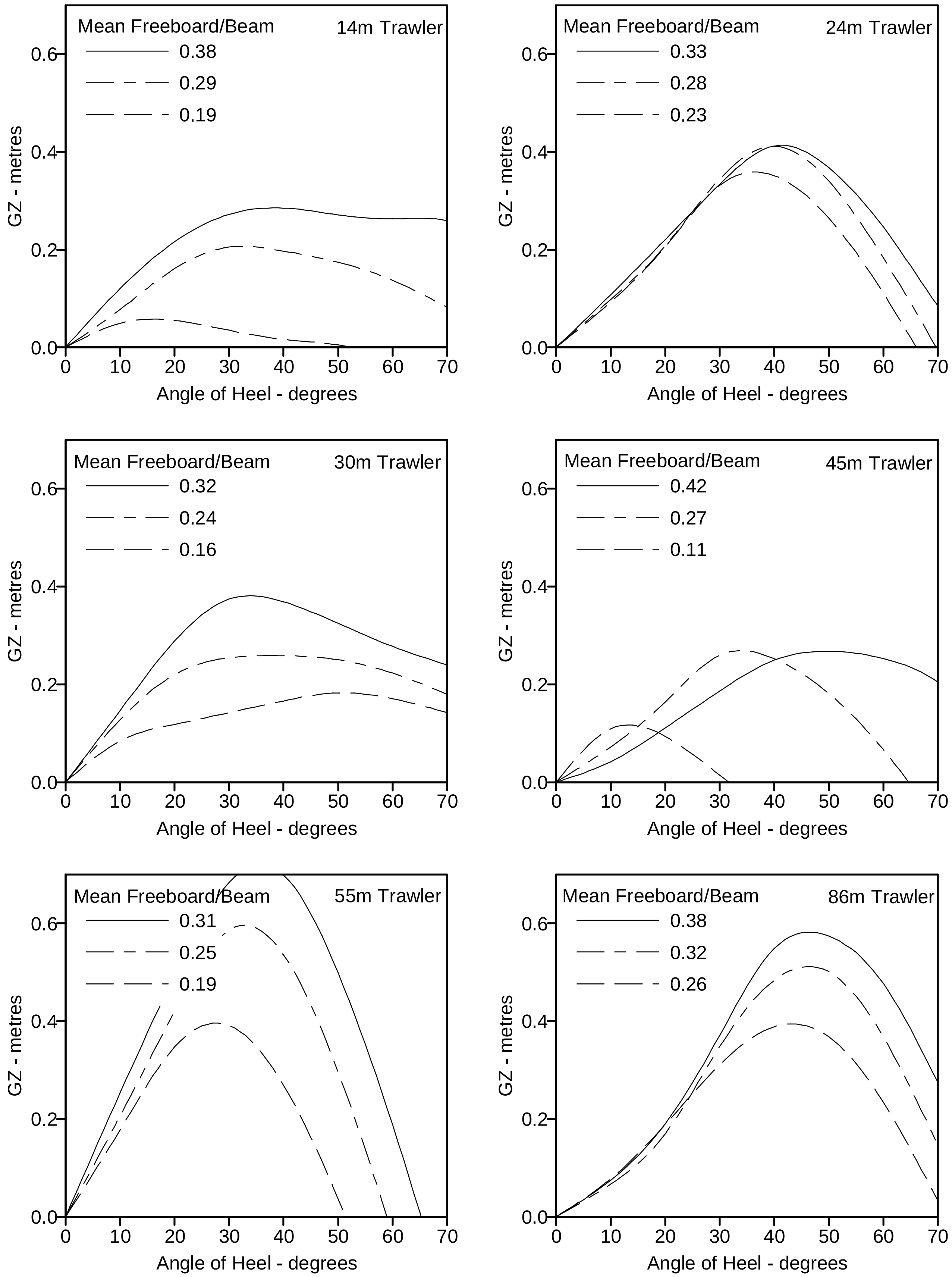


Figure 12. Variation of range of stability with mean freeboard/beam for ten trawlers

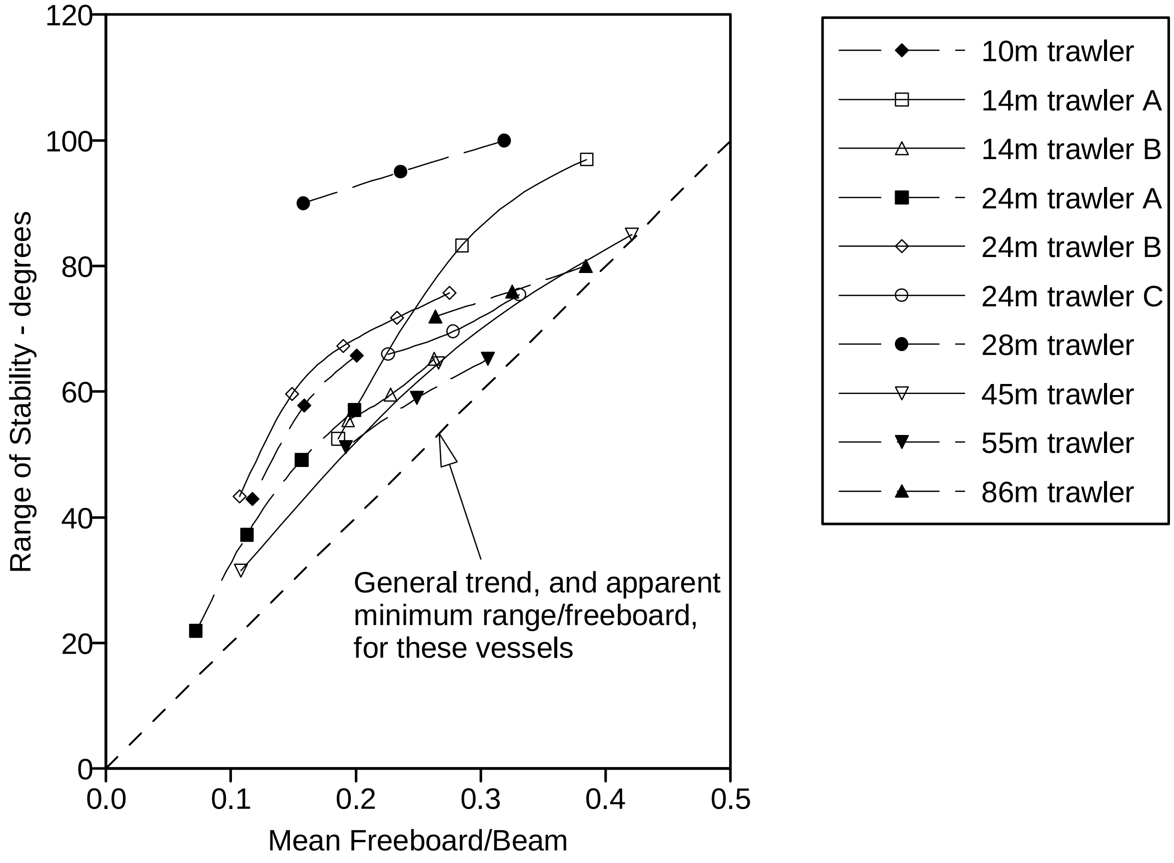


Figure 13. Variation of range of stability with freeboard for undecked vessels

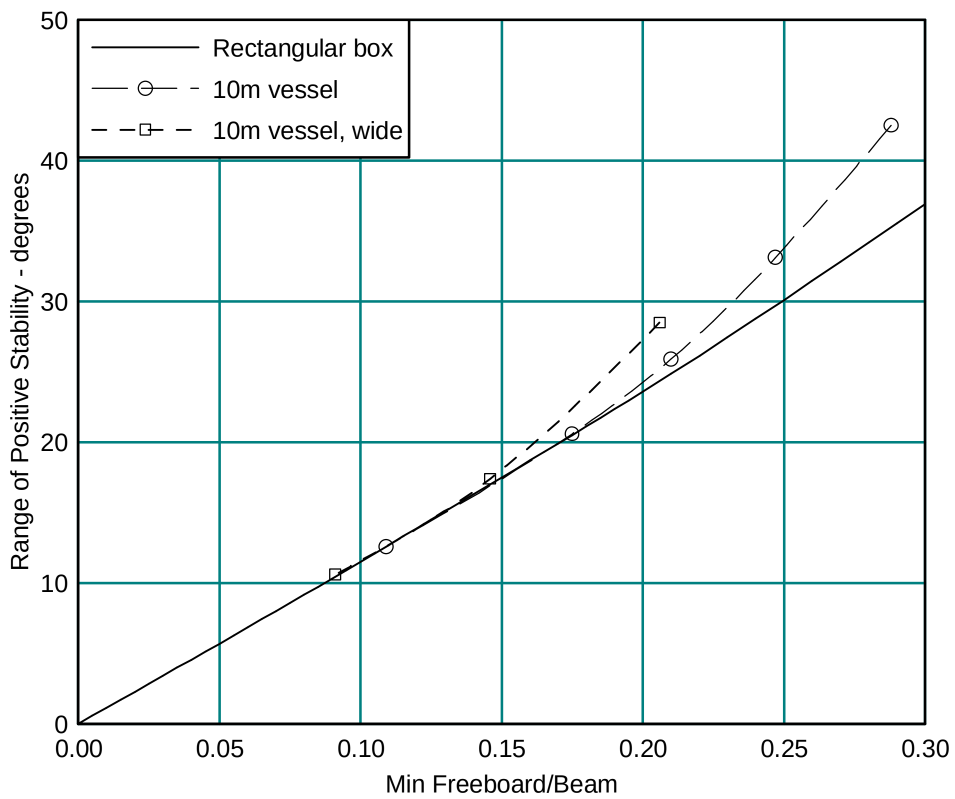


Figure 14. The effects of lifting on the stability of a small vessel

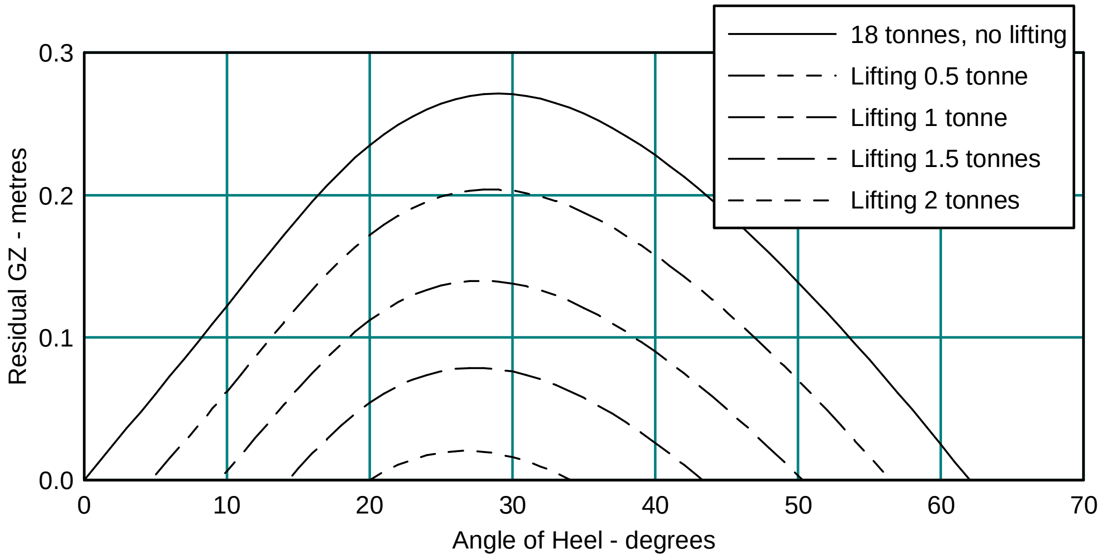


Figure 15. Variation of range of stability with residual freeboard for loading and lifting cases

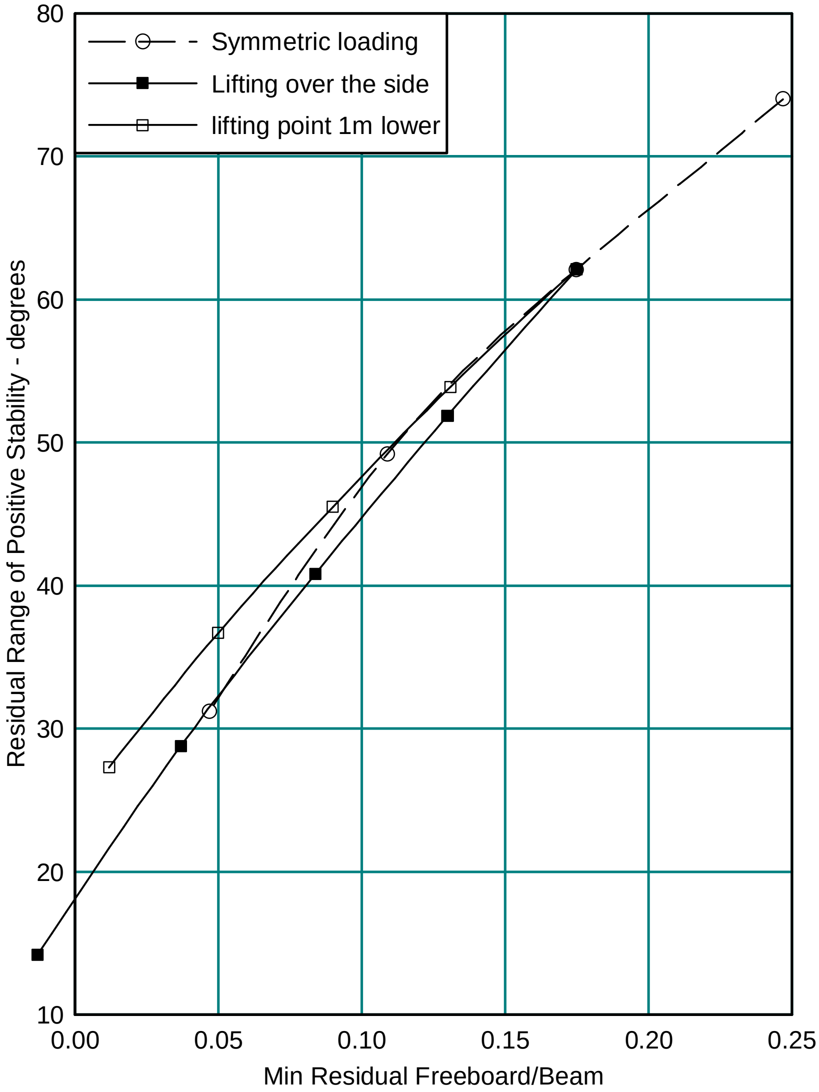


Figure 16. The effects of lifting over the side on a small twin rig trawler

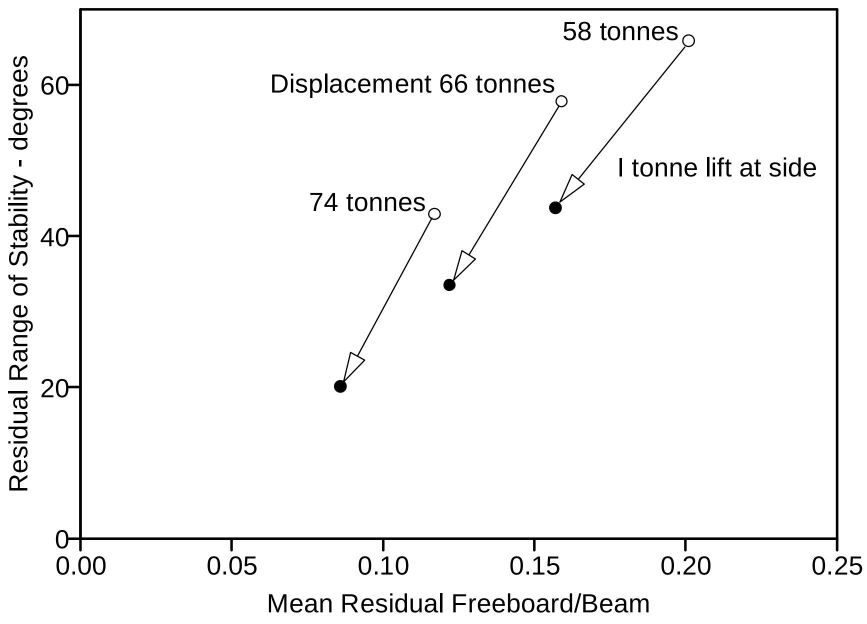


Figure 17. Minimum freeboard data compared with some freeboard regulations

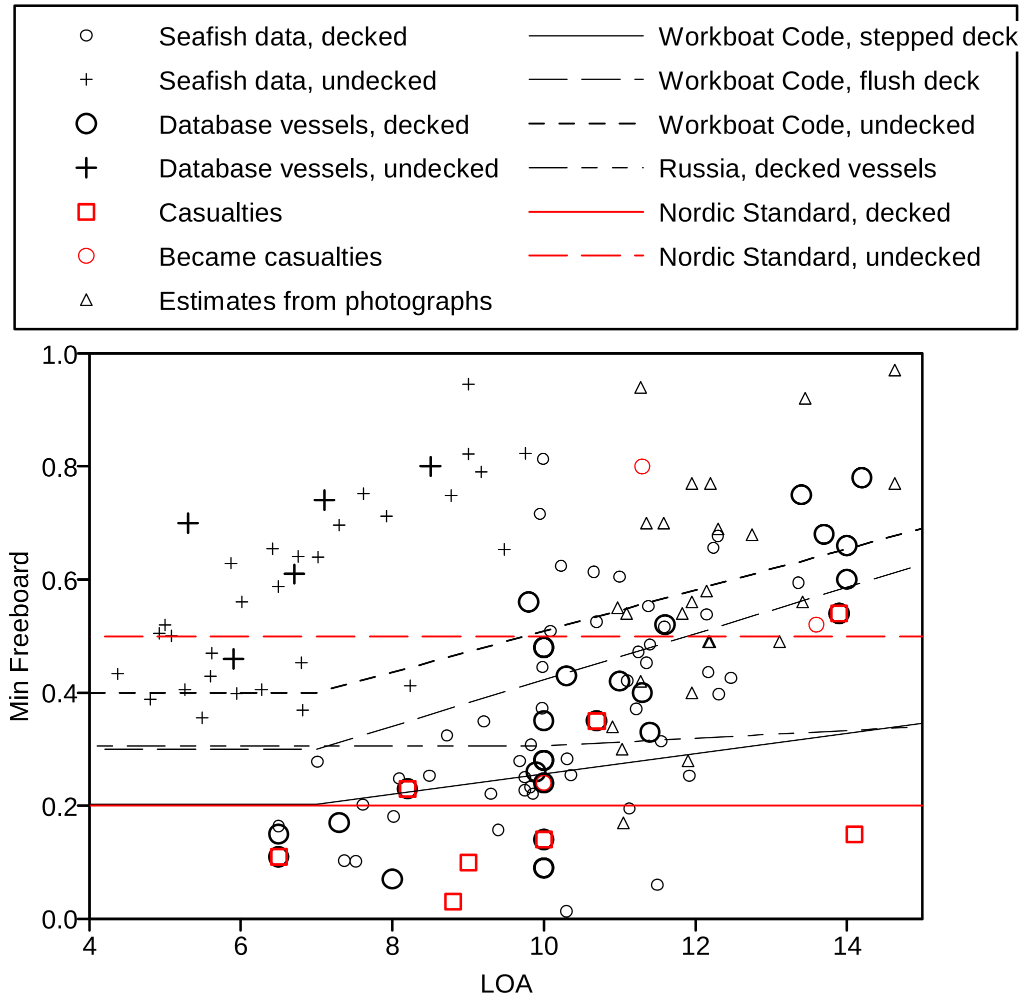


Figure 18. Possible method of guidance based on heel angle when lifting

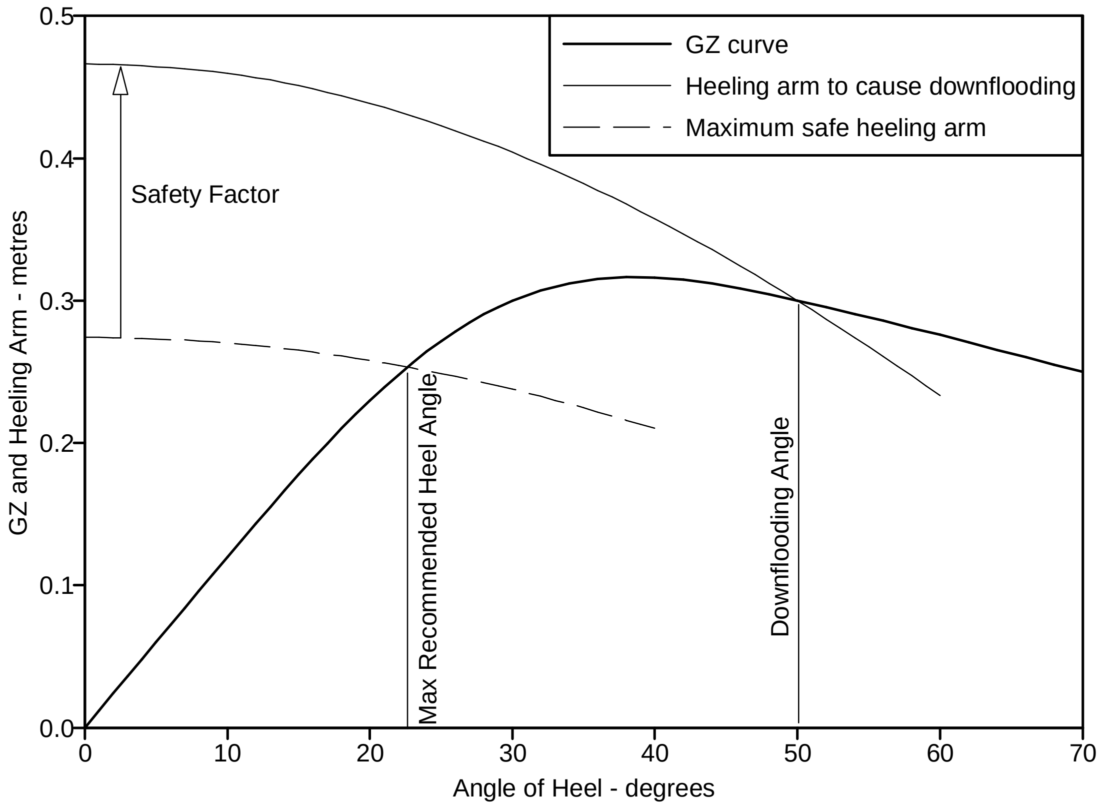


Figure 19. Variation of Hs with length, assuming stability equal to IMO minimum criteria

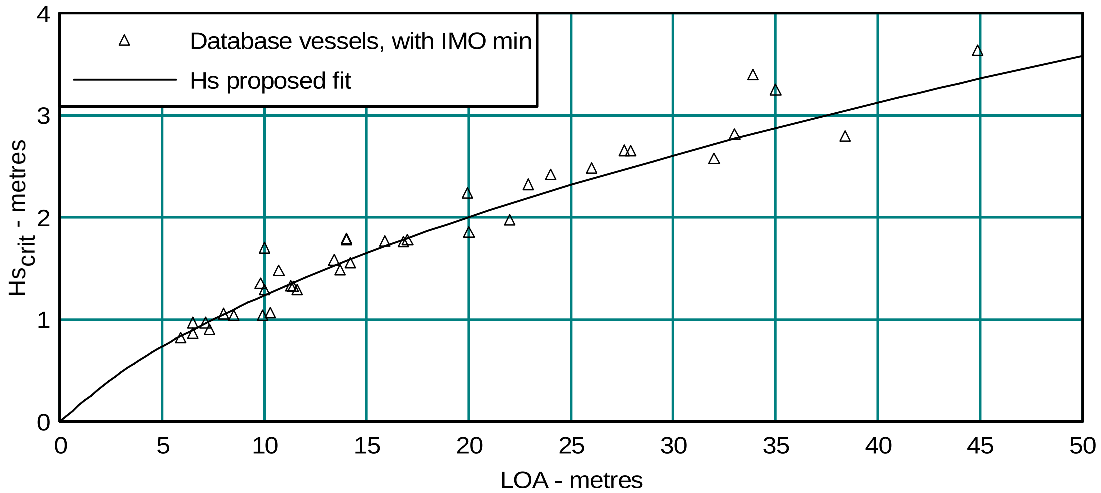


Figure 20. Relationship between the database vessels, the casualties and the proposed safety zones

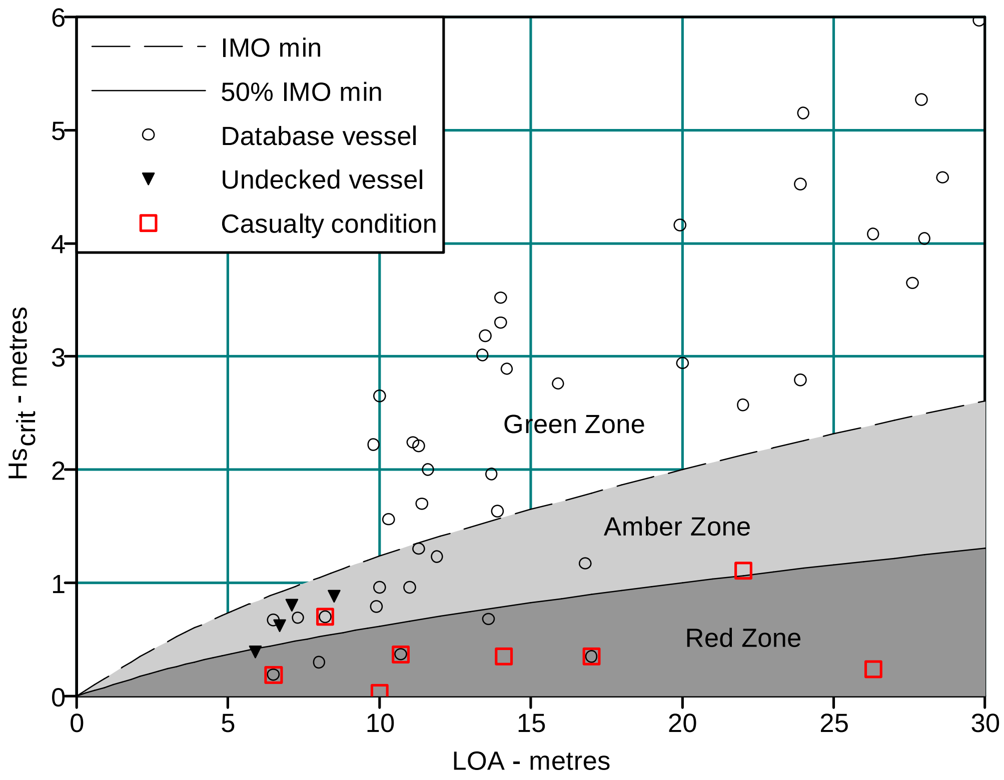


Figure 21. Comparison of predicted critical seastates and actual capsize wave heights for the casualties

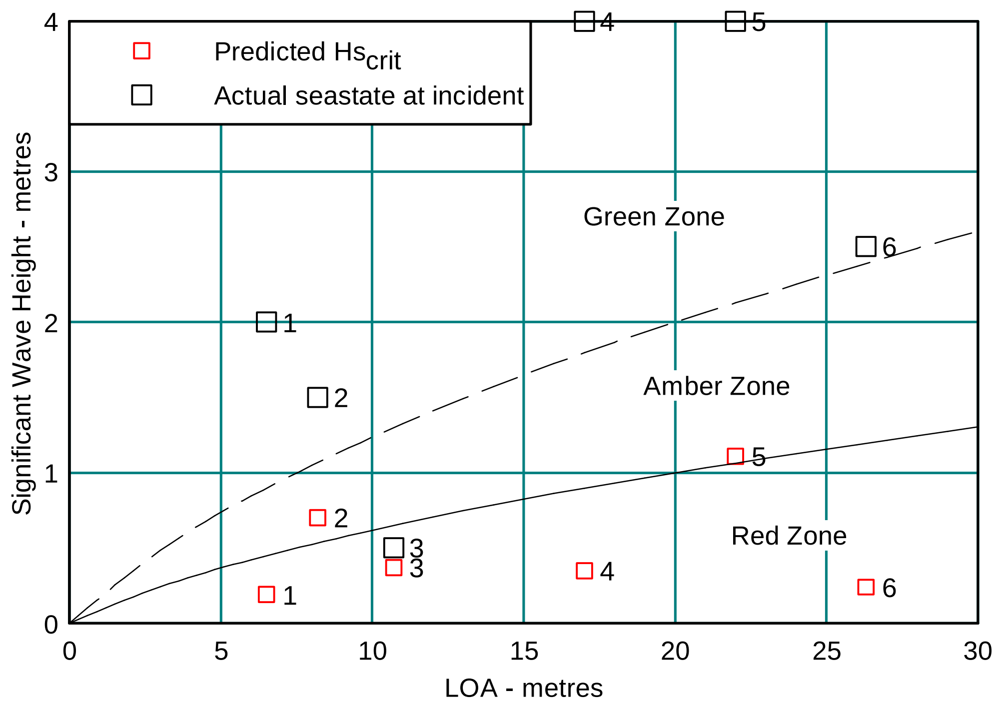
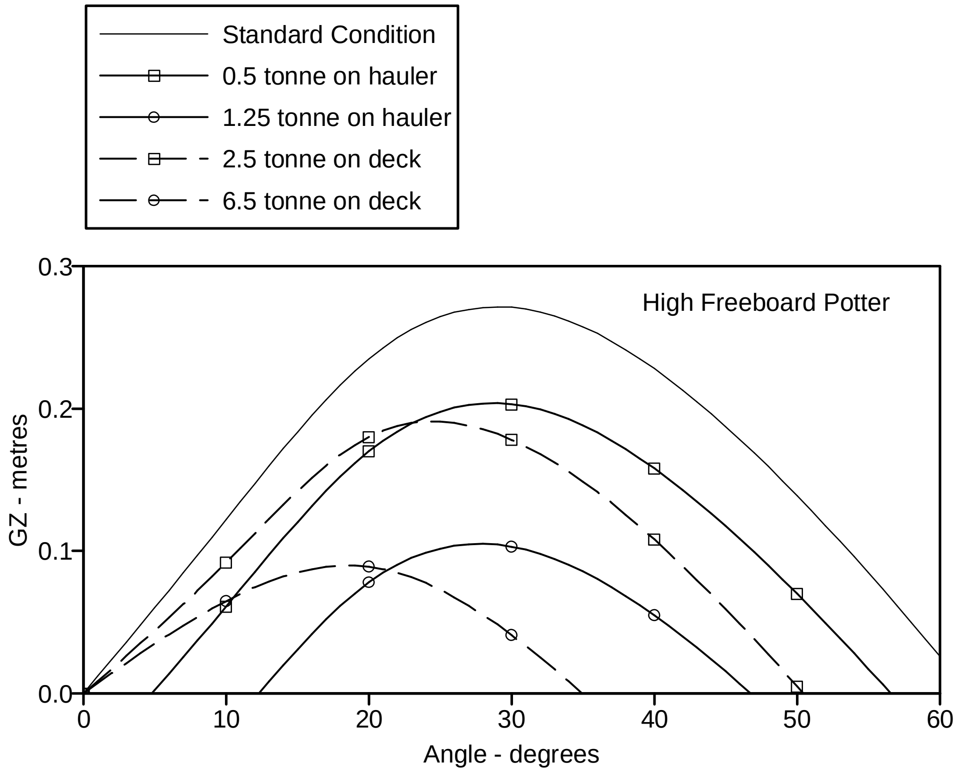


Figure 22. GZ curves defining the zone boundaries, for two potters with different freeboards



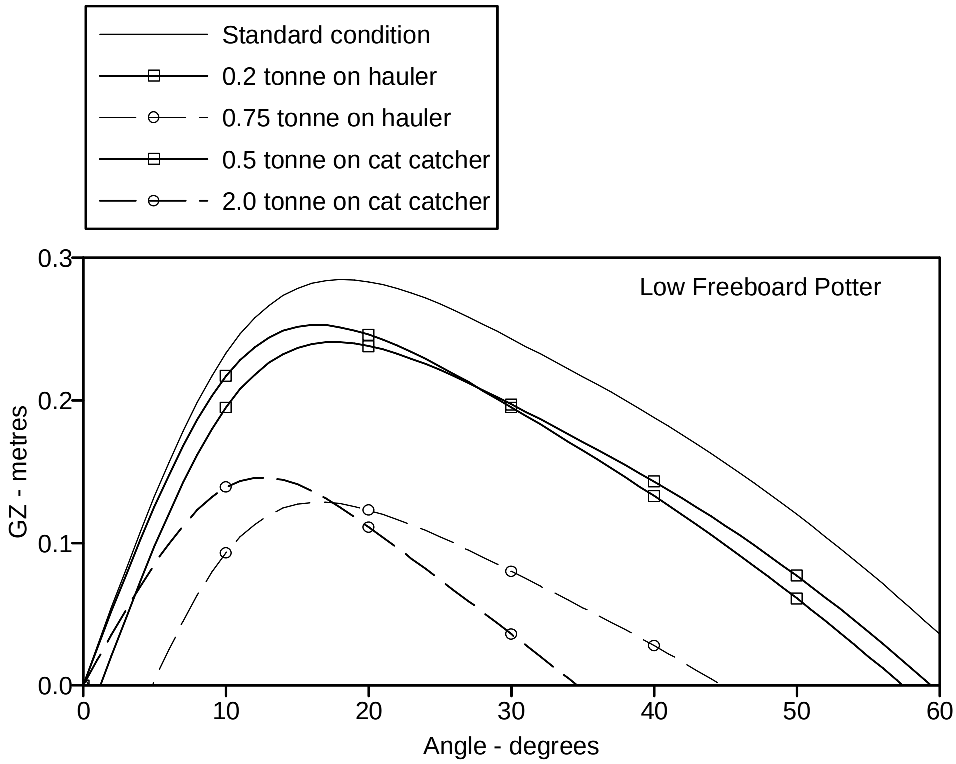
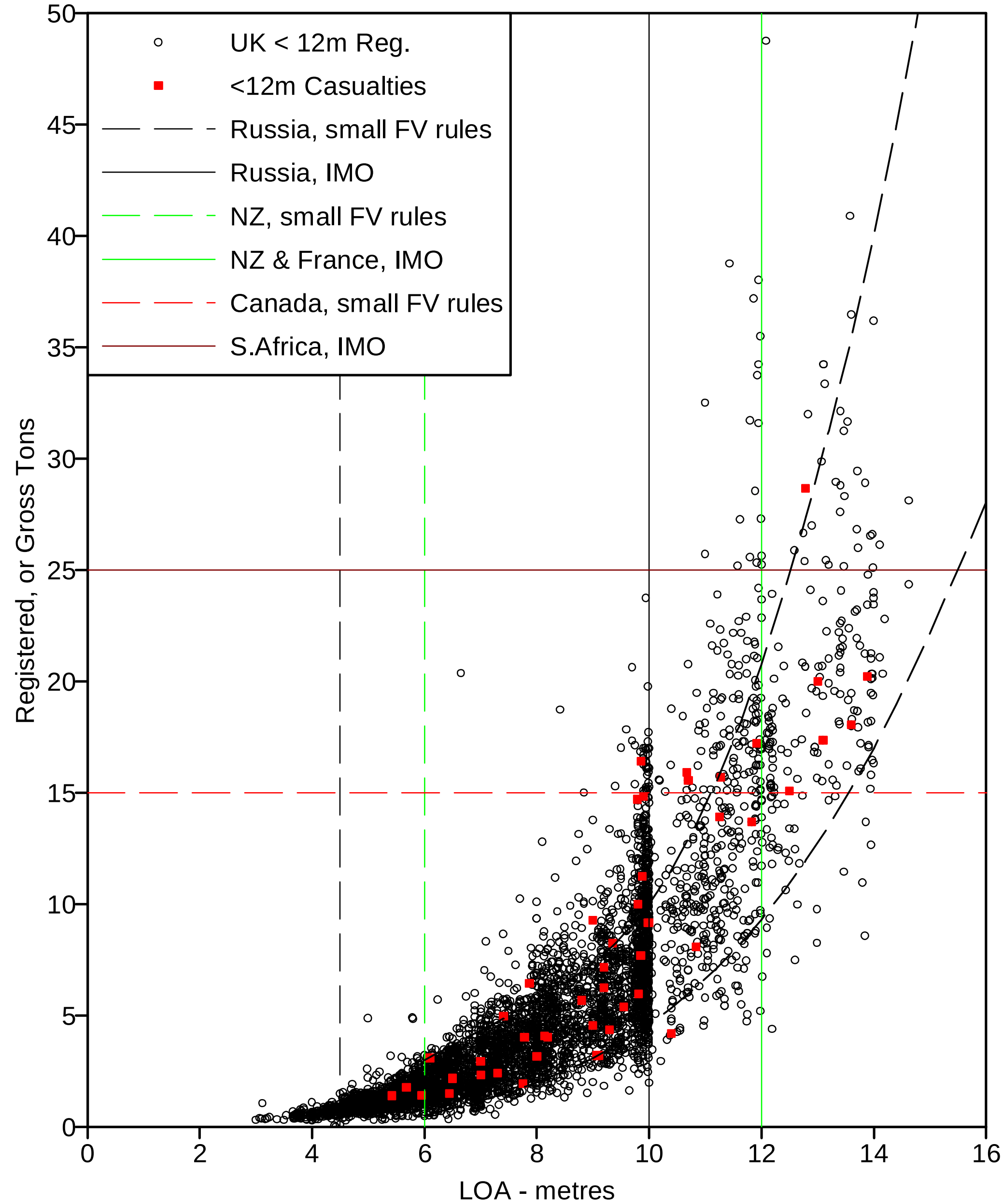


Figure 23. Application of IMO, and other requirements, in other countries



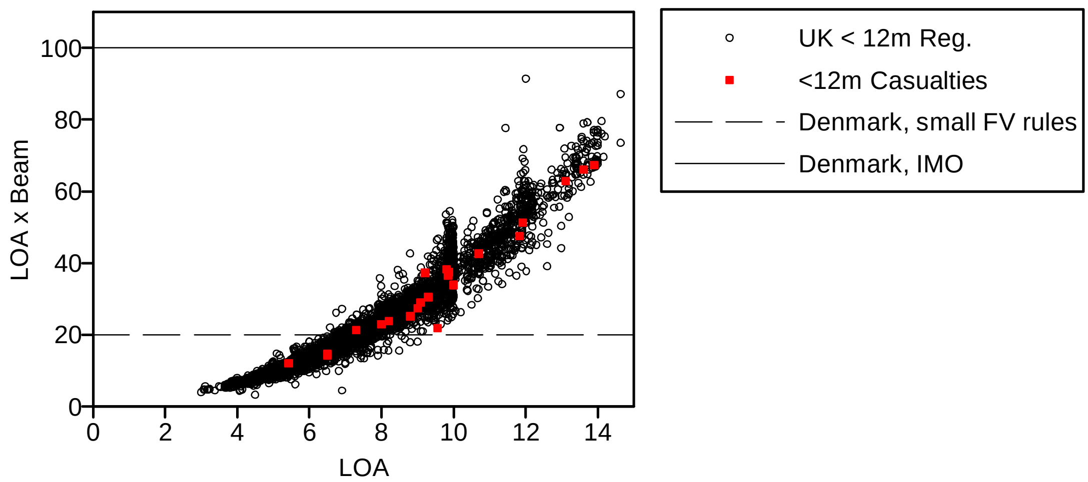


Figure 24. Proposed tonnage limit in relation to the existing fleet

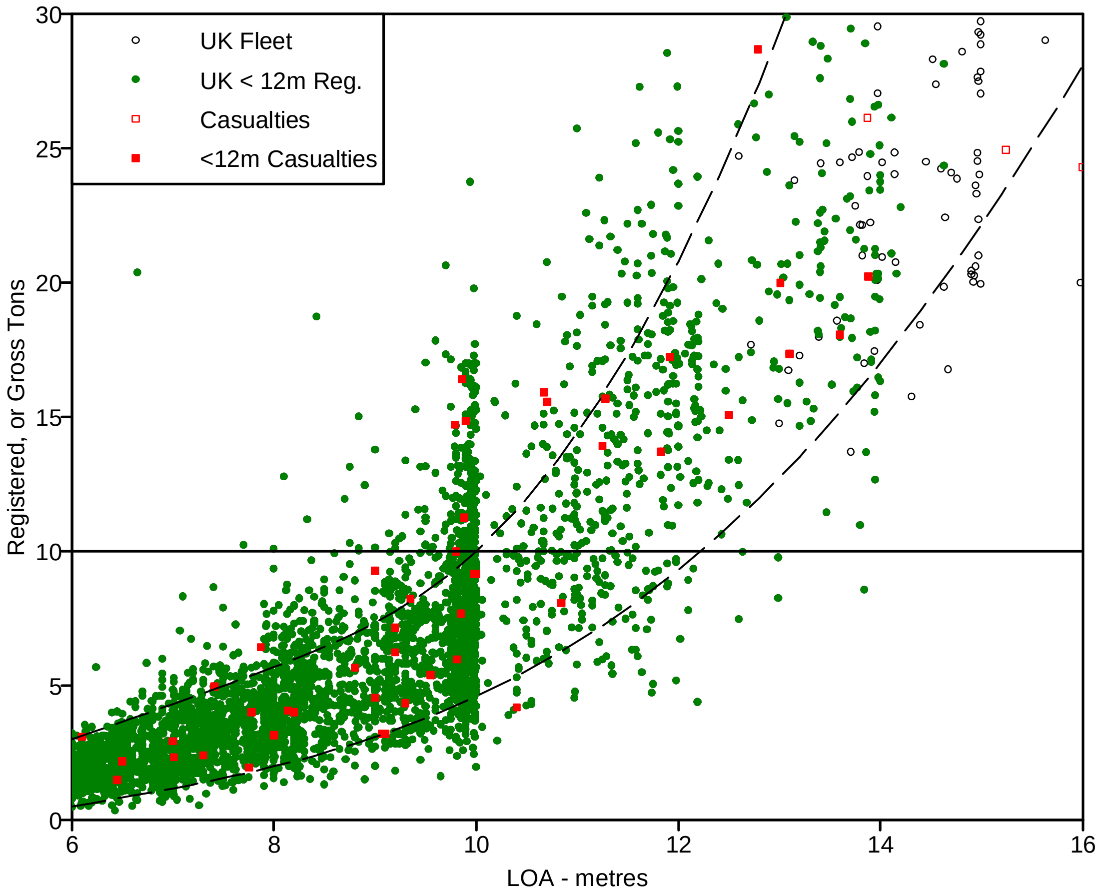


Figure 25. A GZ curve which just complies with the IMO minimum requirements

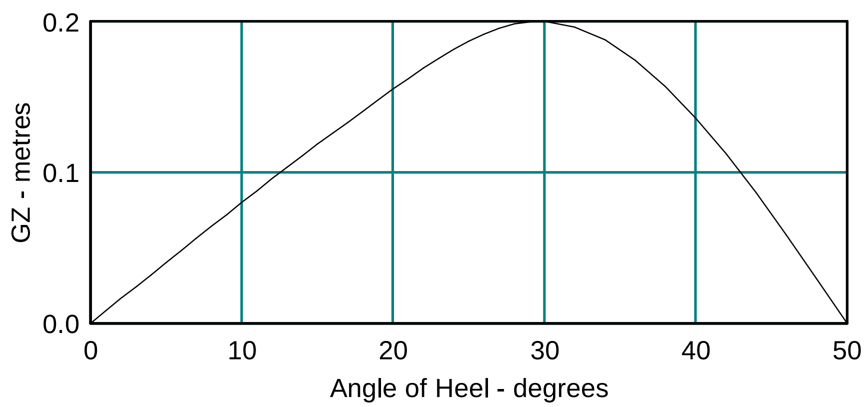


Figure 26. Proposed relaxed requirement for GZmax for small vessels

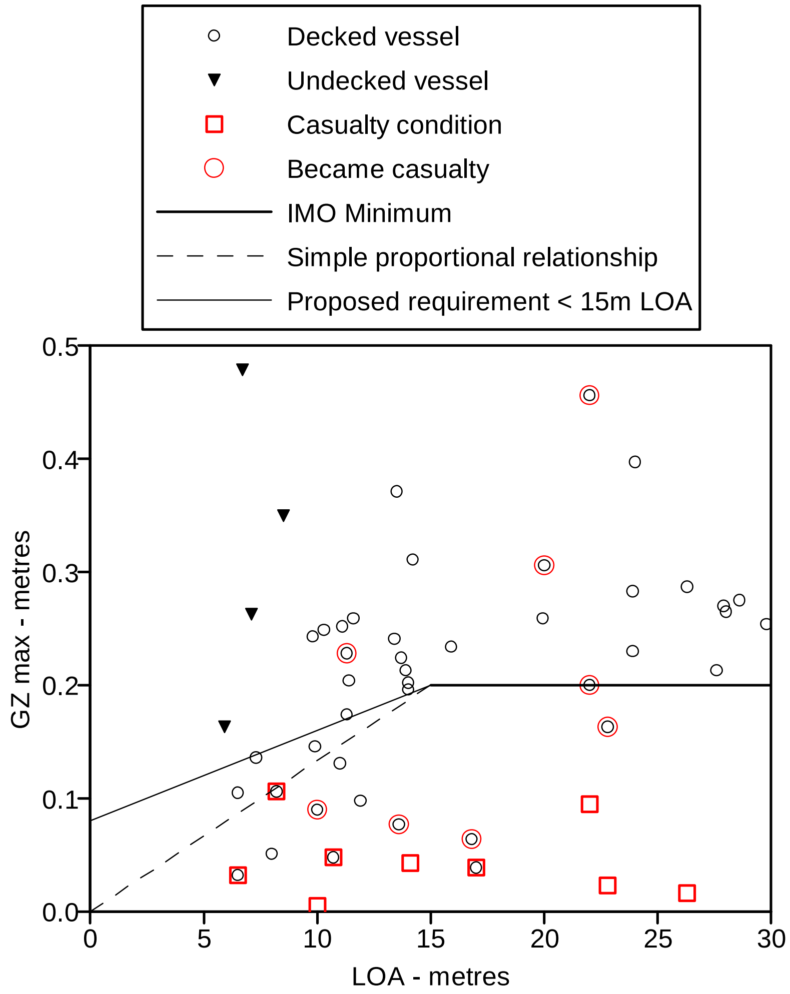


Figure 27. Relationship between Hs/length and minimum freeboard/beam

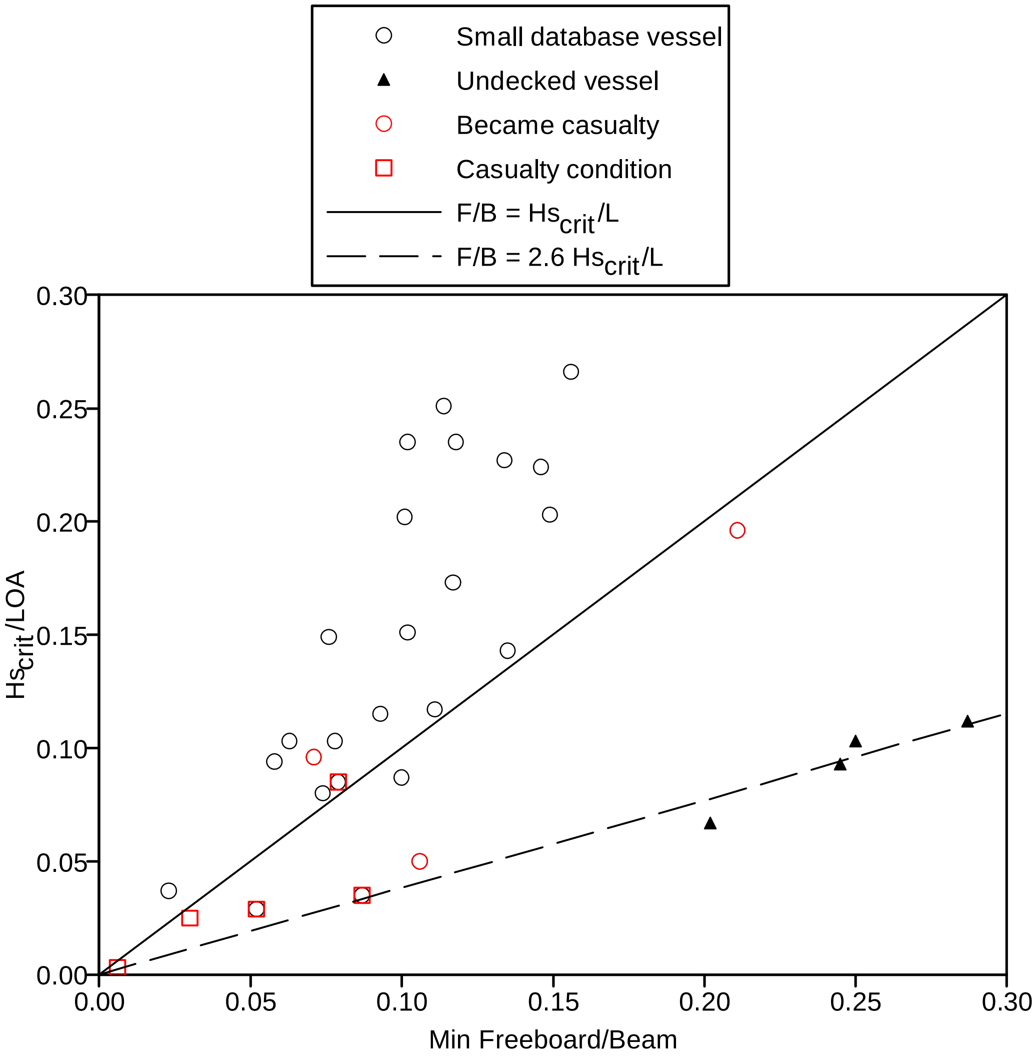


Figure 28. Proposals for freeboard guidance

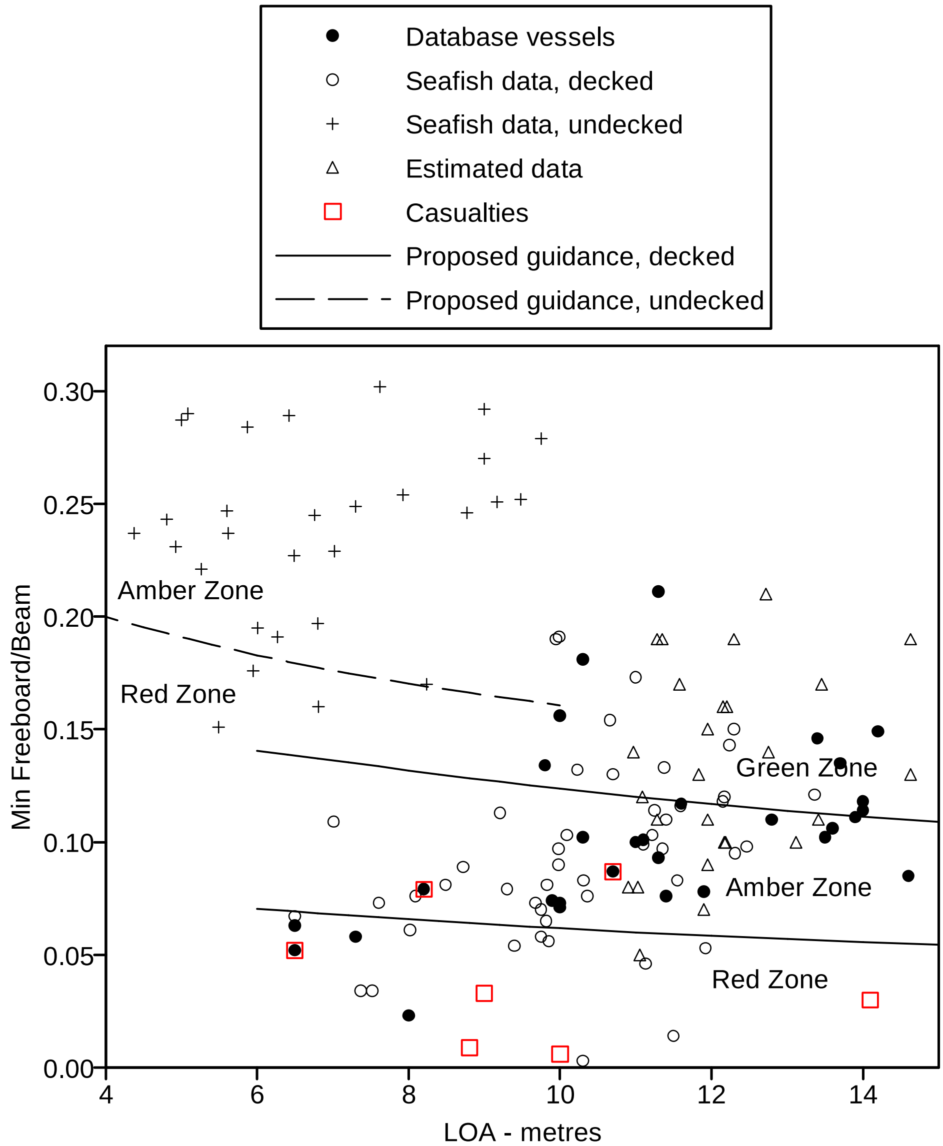


Figure 29. Relationship between range of stability and minimum freeboard/beam ratio

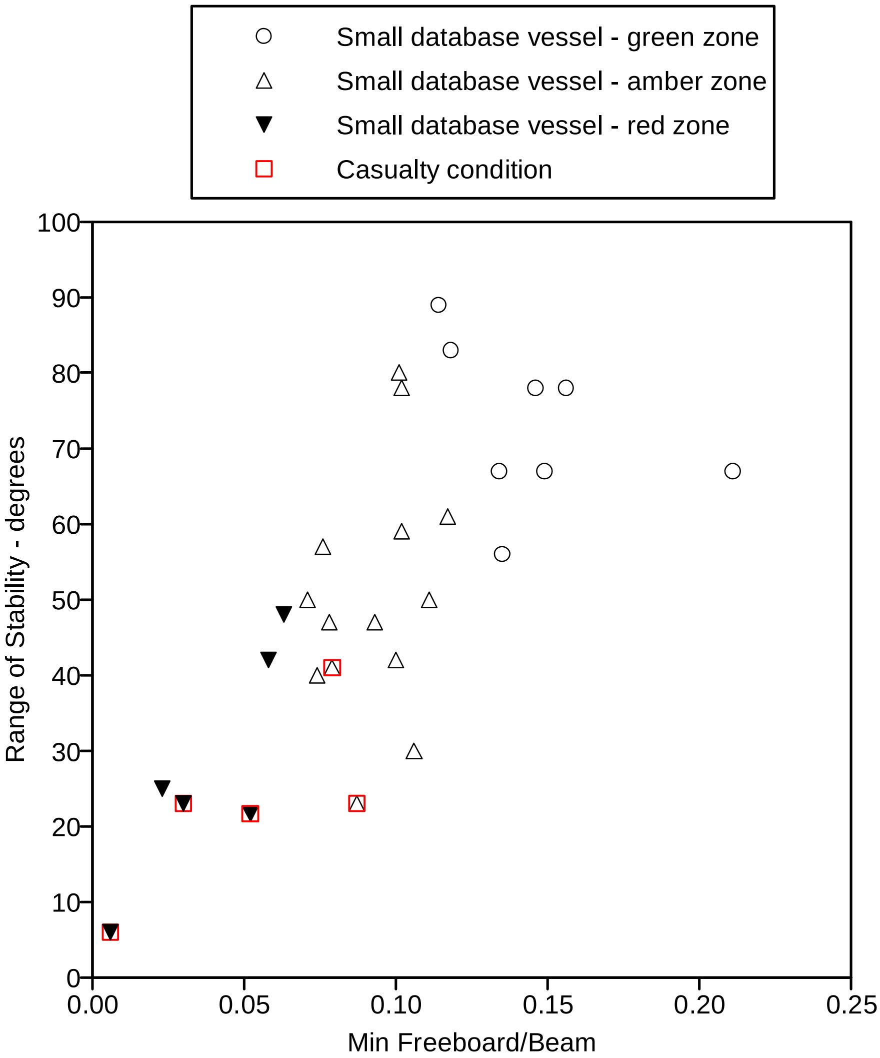


Figure 30. Proposed Guidance freeboard mark

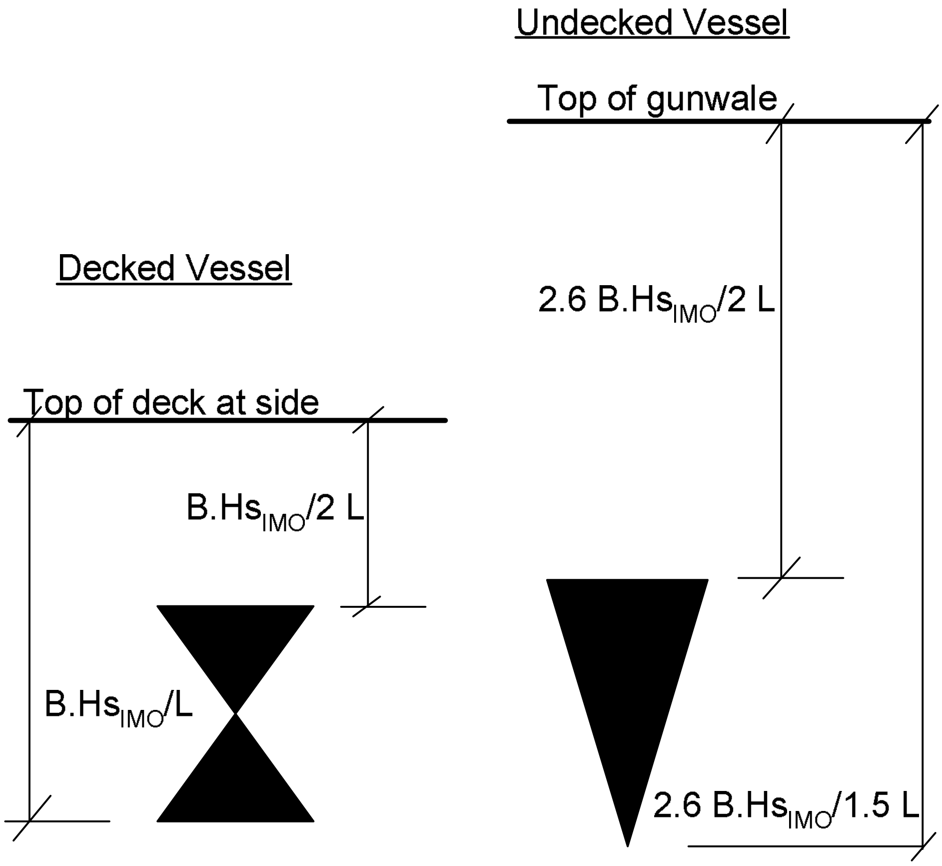


Figure 31. Flow chart of the proposed system of assessment and guidance for fishing vessels

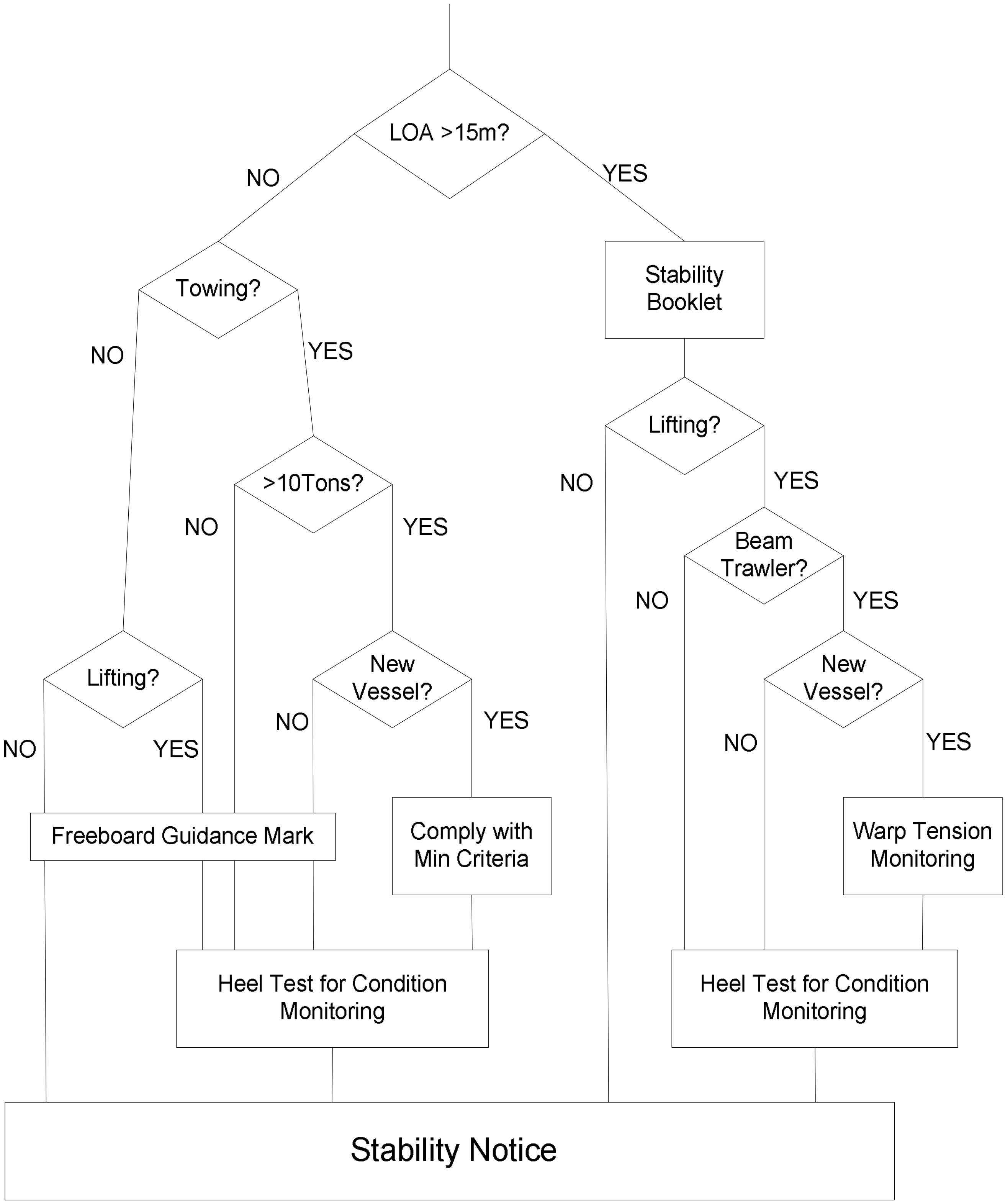
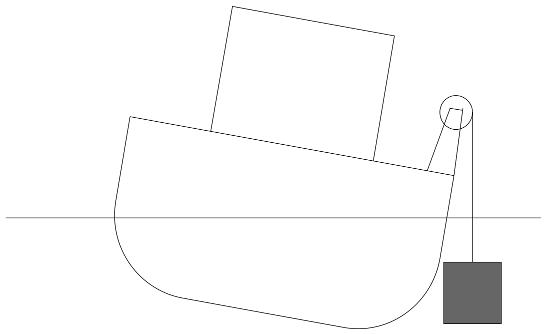
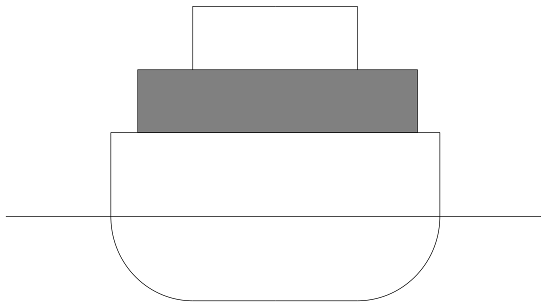


Figure 32. Example Stability Notice for the 10.6m high freeboard potter

STABILITY NOTICE

BONNIE LADD AB456 **LOA: 10.6m** **Owner: Mike Fisher**	**Loading and Lifting Guidance**		
	Good margin of safety	**Low level of safety** Max recommended seastate 1.3 metres	**Danger of capsize** Max recommended seastate 0.6 metres
 Lifting from hauler	Less than 0.5 tonnes Min freeboard at least 50cm	0.5 – 1.25 tonnes Min freeboard 20 - 50cm	More than 1.25 tonnes Min freeboard Less than 20cm
 Loading on deck	Less than 2.5 tonnes Min freeboard at least 50cm	2.5 – 6.5 tonnes Min freeboard 25 – 50cm	More than 6.5 tonnes Min freeboard less than 25cm

Simple efforts for maintaining stability:

- If maximum recommended lift from the hauler is exceeded the lift must be abandoned immediately. Position of gear should be marked and noted for retrieval by a larger vessel.
- Ensure scuppers are open and clear of obstructions to allow water to drain from the deck.
- Ensure all items stowed on deck are secured against movement in waves.

Heel Monitoring Test

This vessel heeled 6 degrees with 0.5 tonne lifted from the hauler, with 80 x 15 kg pots on deck.
The residual freeboard was 48cm. 5th February 2006.

Photograph of vessel profile

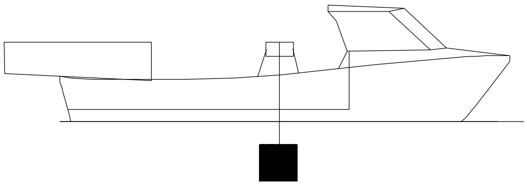
Dated 5th February 2006

Figure 33. Example Stability Notice for the 10.6m low freeboard potter

STABILITY NOTICE

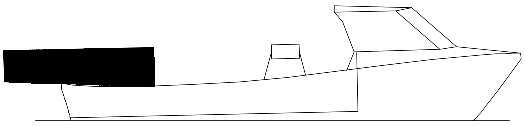
<table>
<tr><td rowspan="2">LOWLY LADD AB123
LOA: 10.6m
Owner: Graham Fisher</td><td colspan="3">Loading and Lifting Guidance</td></tr>
<tr><td>Good margin of safety</td><td>Low level of safety

Max recommended seastate 1.3 metres</td><td>Danger of capsize

Max recommended seastate 0.6 metres</td></tr>
<tr><td>
Lifting from hauler</td><td>Less than 0.2 tonnes

Min freeboard at least 24cm</td><td>0.2 – 0.75 tonnes

Min freeboard 10 - 24cm</td><td>More than 1.25 tonnes

Min freeboard Less than 10cm</td></tr>
<tr><td>
Pots on cat catcher</td><td>Less than 30 pots

Min freeboard at least 24cm</td><td>30 – 130 pots

Min freeboard 7 -24 cm</td><td>More than 130 pots

Min freeboard less than 7cm</td></tr>
</table>

Simple efforts for maintaining stability:

- If maximum recommended lift from the hauler is exceeded the lift must be abandoned immediately. Position of gear should be marked and noted for retrieval by a larger vessel.
- Ensure scuppers are open and clear of obstructions to allow water to drain from the deck.
- Ensure all items stowed on deck are secured against movement in waves.

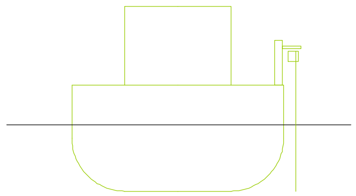
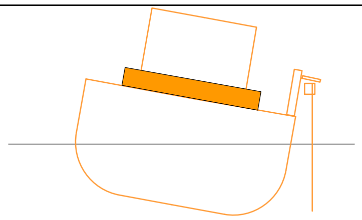
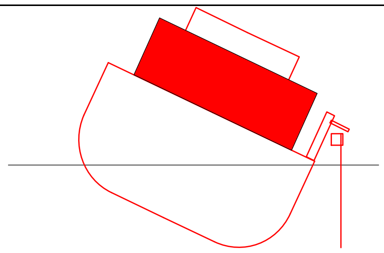
Heel Monitoring Test

This vessel heeled 6 degrees with 0.5 tonne lifted from the hauler, with 80 x 15 kg pots on cat catcher. The residual freeboard was 2cm. 5th February 2006.

Photograph of vessel profile Dated 5th February 2006

Figure 34. Example Stability Notice for a 10m potter with no stability data

STABILITY NOTICE

SIMPLE LADD AB987 LOA: 10.6m Beam: 3.85m Owner: David Fisher	**Loading & Lifting Guidance**	STABILITY		
		Safety Zone	Minimum Freeboard	Maximum recommended seastate
	Good margin of residual freeboard	Good margin of safety	At least 47cm	
	Loading or hauling reduces minimum freeboard to less than 47cm	Low level of safety	24cm to 47cm	1.3 metres
	Excessive loading or hauling reduces minimum freeboard to less than 24cm	Danger of capsize	Less than 24cm	0.6 metres

Simple efforts for maintaining stability:

- If lift from the hauler reduces the freeboard to less than the minimum recommended, the lift must be abandoned immediately. Position of gear should be marked and noted for retrieval by a larger vessel.
- Ensure scuppers are open and clear of obstructions to allow water to drain from the deck.
- Ensure all items stowed on deck are secured against movement in waves.

Heel Monitoring Test

This vessel heeled 6 degrees with 0.5 tonne lifted from the hauler, with 80 x 15 kg pots on deck.
The residual freeboard was 48cm. 5th February 2006.

Photograph of vessel profile

Dated 5th February 2006

23 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 560. 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
Existing Databases																	
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															
Created Databases																	
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 "An Investigation into Simplified Stability Assessment Methods for Small Fishing Vessels". Seaspeed Technology Ltd. For the MCA, September 1994.
MAIB casualty databases were supplied by MAIB.

24 APPENDIX 2, STABILITY DATABASE

Vessel Type	LOA	BOA	Depth	Draft	Min F	Mean F	Erection/L	Disp	KG	GM	List	θf	GZmax	GZarea30	GZareaf	GZarea	AVS	Range
Decked																		
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
Decked (contd.)																		
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
Undecked																		0.0
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
Casualties																		
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.