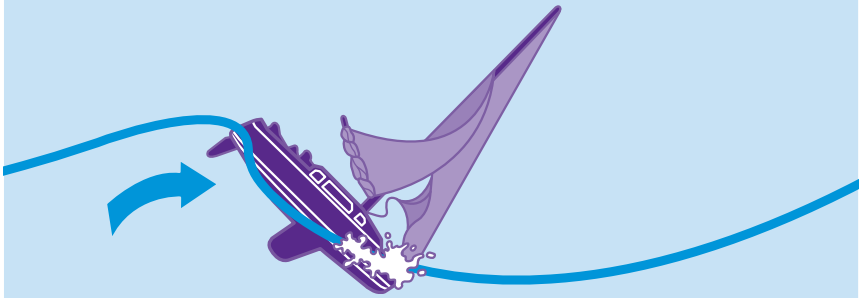
Stability Guidance Booklet

FOR MASTERS AND WATCH KEEPERS

for Sailing Vessels



Maritime and Coastguard Agency

Contents

This booklet was prepared by a working group comprising representatives from:

The Royal Institution of Naval Architects

The Royal Yachting Association

The Royal National Lifeboat Institution

The Jubilee Sailing Trust

The Multihull Offshore Cruising and Racing Association

The Wolfson Unit for Marine Technology and Industrial Aerodynamics

in consultation with a wide range of experienced seafarers.

Illustrations by Sarah Selman

Caution

It should be noted that, while every care has been taken in the preparation of this booklet, the advice and information given cannot take account of every exceptional circumstance. Final responsibility for the safety of the vessel rests with the Master.

Owners may find it helpful to display pages 1 to 5 in a prominent place for the information of the crew.

This page to be completed for the specific individual vessel

Information specific to the sailing vessel:

Type of vessel (design/class and length)	(eg: Smith-Jones 440 – 13.4m)	
Identification/registration number[1]		
Approved limit of operation according to stability assessment[1]	(eg: 2 = up to 60nm from a safe haven)	
ISO stability index[2]	(eg: 29)	
	Computed[3]	**Master's estimate**[4]
Recommended maximum steady heel angle under sail Vessels should not be sailed continuously at a greater angle of heel	(eg: 23º)[5]	
Angle of first deck-edge immersion	(eg: 29º)	
Angle of first immersion of coaming/bulwark	(eg: 34º)	
Angle of first downflooding (hatch and ventilators open)	(eg: 42º)	
Angle of vanishing stability (AVS)	(eg: 120º)	
Angle of heel at which propellers or rudder are estimated to become ineffective	(eg: 46º)	
Maximum apparent wind speed in smooth water without reducing sail area	(eg: 27 knots)[6]	
Openings labelled as required to be secured closed when at sea (eg: skylights, emergency escape hatches, foredeck hatch)		
This vessel is designed to float after sustaining localised damage to the hull or fittings, excluding bulkheads.[7]		
This vessel will continue to float when fully loaded, even if fully flooded or swamped.[7]		
A squall diagram for this vessel is available in the MCA stability information booklet.[7]		

1 Where this exists.
2 Where this is known.
3 Data to be supplied or verified by the Certifying Authority.
4 Data to be provided by the Master, especially when computed data is not available. These figures are not required to be checked by the Certifying Authority. Where both are provided, the Master's estimate should not exceed the computed value.
5 Calculated for Maximum Loaded Displacement.
6 Calculated for all sailing vessels mainly reliant on form stability, for the Minimum Operating Displacement.
7 Text to be deleted unless the appropriate requirements are fulfilled.

Master's standing orders

Recommended sequence for reducing sail area

Sail combination[8]	Maximum *apparent* wind speed (kts)[9]	
	Computed[10]	Master's instruction[11]
(eg: mainsail, mizzen, working genoa)		
(eg: mainsail, mizzen, 70% of working genoa)		
(eg: 1st reef in mainsail, 40% of working genoa)		
(eg: 2nd reef in mainsail, heavy weather jib)		
(eg: 3rd reef in mainsail, heavy weather jib)		
(eg: trysail, storm jib)		
(eg: storm jib)		

What to do if hit by a sudden gust[12]

What to do after a knockdown[12]

8 List to be tailored to individual vessel.

9 Caution – refer to explanatory note 18.

10 Calculations are required by MCA Code for all multihull and form-stable vessels. Data to be supplied or verified by the Certifying Authority.

11 Data to be provided by the Master, especially when computed data is not available. These figures are not required to be checked by the Certifying Authority. Where both are provided, the Master's instruction should not exceed the computed value.

12 To be completed by the Master. Not required to be checked by the Certifying Authority.

Master's standing orders

How to heave-to[12]

Certifying Authority approving the data
(computed and below)

Stability assessed assuming

Maximum permitted number of persons

Maximum permissible weight to be carried (kg)

Minimum operating displacement (tonnes)[13]

Maximum loaded displacement (tonnes)[13]

Outfit items included in the assessment[14]

Liferaft(s) (eg: 2 by 8 person liferafts in containers on coachroof)

Mast(s) (eg: alloy extrusions, main = 7.4kg/m, mizzen = 2.9kg/m)

Dinghy (eg: rigid dinghy in stern davits)

Radar (eg: radar antenna weighing 4kg on wheelhouse roof)

Furling (eg: in-mast furling mainsail, roller furling genoa)

Other topweight

[13] Where this is available.

[14] All items likely to significantly affect the vertical centre-of-gravity should be included. This list may not be necessary in very large vessels.

General cautions

Final responsibility for the safety of the vessel rests with the Master.

	see note
• Adding weight high up or moving weight higher in the vessel (including lifting from any high point) reduces the stability.	1
• Excessive list or trim adversely affects the stability and handling of the vessel.	2
• Breaking waves are capable of inverting most smaller vessels, and should therefore be avoided if possible.	3
• Form-stable and multihull vessels are capable of being capsized if excessive sail is carried. Most multihulls are designed to float should this occur.	4

Stability check lists

Before putting to sea

	see note
• Remove bilge water and check that bilge suctions are clear.	5
• Check that freeing ports and deck drains are clear.	6
• Ensure that openings labelled as required to be closed when at sea are secured shut.	7
• Locate all seacocks and close those not required to be open.	8
• Thoroughly secure all loose gear, on deck and below.	9
• Ensure that the vessel is not overloaded, if applicable by checking the freeboard mark is visible.	
• Check air tanks or flotation elements to ensure that they are effective.	10

At sea in normal conditions

• Breaking waves higher than the beam of your vessel, if taken beam-on, may cause capsize.	11
• Observe the recommended sequence for shortening sail.	12
• Do not exceed the maximum recommended steady heel angle when sailing monohulls.	13

Stability check lists

At sea in normal conditions (continued)

	see note
• If resonant rolling develops, alter heading and/or speed.	14
• Tight turns at speed may lead to capsize.	15
• Where possible avoid shallow water near to where fast ferries are operating.	16
• When altering course closer to the wind, be aware that the apparent wind will increase, and consider reducing sail beforehand.	17
• Before the onset of severe weather, be sure you know the Master's instructions for heaving-to.	18
• Watch out for squalls and reduce sail in good time.	19
• Be sure you know the Master's prior instructions in the event of a knockdown.	20
• Be aware of the risk of burying the bow at speed in following or quartering seas.	21

At sea in rough conditions

• Close all downflooding openings not essential for the working of the vessel.	22
• Keep weatherdeck hatchways and doors closed whenever possible.	23
• Take particular care to avoid areas where severe breaking waves are likely to occur as they can cause capsize.	24
• Actively steer the vessel to avoid the most hazardous waves.	25
• In following seas, be aware of the risk of broaching and pitchpoling.	26

Emergency conditions

• In reduced visibility, or after a collision, or if any compartment is being flooded, call the Master and close all watertight doors.	27

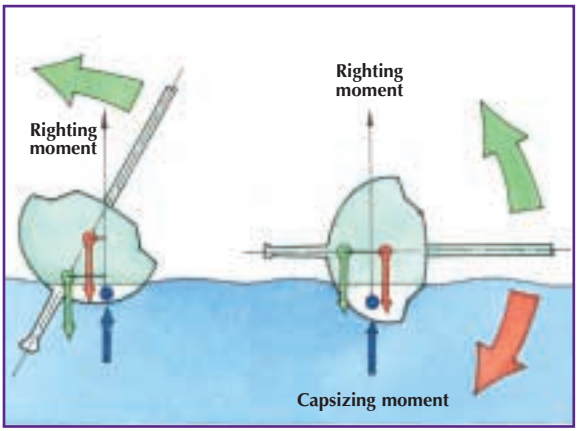
See explanatory notes for more information.

Explanatory notes

General cautions

1 Weight added above the centre-of-gravity of the vessel, or taken off below the centre-of-gravity reduces the stability. What may seem to be a small effect near the upright is greatly increased at 90° of heel.

The ability to recover from a knockdown or inversion may be drastically reduced by a seemingly small increase in centre-of-gravity height.



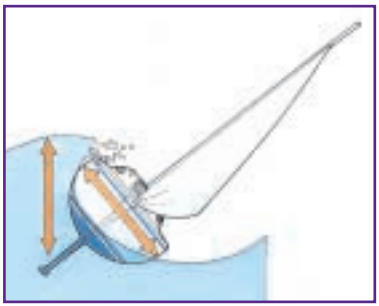
The effect of a suspended weight is as if it were located at the point of suspension. A vessel can be capsized even in perfectly calm water by lifting an excessive weight, or by raising the point of suspension too high. A very slow rolling motion is a sign that this condition may be being reached.

2 A list or permanent heel in one direction reduces the stability in that direction.

A trim down by the bow may reduce the directional stability, increasing the tendency to turn and increasing the possibility of broaching in following seas, or of shipping water over the bow.

A trim down by the stern may increase the directional stability, thus reducing the ability to manoeuvre, and increasing the possibility of shipping seas over the stern.

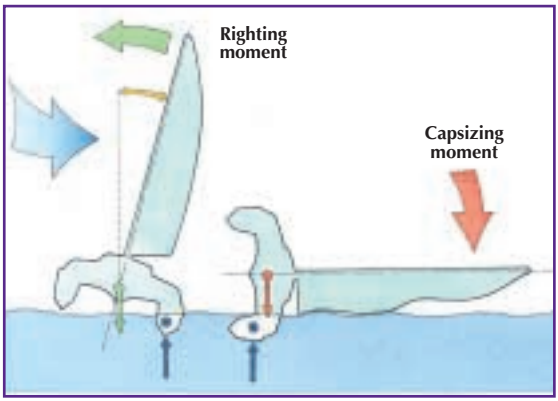
3 All monohull vessels under about 24m length are capable of being inverted by a breaking wave of sufficient size. To be dangerous in this respect, a breaking wave must have a height exceeding the beam of the vessel.



Carefully designed fore-and-aft rig monohull sailing vessels with a sufficiently high Angle of Vanishing Stability (eg: as required by the Code of Practice) can be expected to recover after a complete inversion within a short period of time.

4 Multihulls and form-stable monohulls reach maximum stability at a relatively small angle of heel (typically 10° to 15°) and very seldom have sufficient righting moment at 90° heel to overcome the wind forces on the bridge-deck structure. Virtually all multihulls and form-stable monohulls are therefore capable of being capsized by wind action alone if too much sail is carried.

As soon as the wind moment exceeds the maximum righting moment, a complete inversion is inevitable. Code vessels are designed to continue to float if this occurs, but clearly this is not a situation from which the crew can recover without outside assistance.



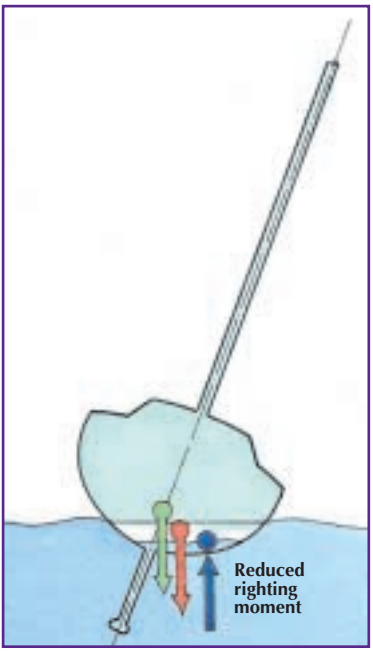
It is therefore vital that the amount of sail carried is not sufficient to cause capsize, even in a gust, which may cause a doubling of wind heeling moment.

Before putting to sea

5 Bilge water if present in any quantity reduces the effective stability of the vessel. As the vessel heels, loose water moves to the lower side, thus increasing the initial heel angle ('free-surface effect').

Many vessels make some bilge water in rough conditions, so regular bilge checks at sea are advisable.

Pump suctions are often prone to clogging with debris that has found its way to the bilges, so suction points should be checked and cleared before sailing.



6 Cockpits, or decks with bulwarks rely on drains and freeing ports to enable any water shipped to drain away quickly. It is important that such fittings are working properly, because trapped water reduces the stability in two ways:

Firstly water trapped on deck has the same 'free-surface effect' as loose bilge

water (see note 5 above). Secondly water trapped high in the vessel raises the centre-of-gravity (see note 1), and its weight also reduces freeboard so that more water is likely to be shipped.

Deck drains and freeing ports (especially those fitted with non-return flaps) must therefore be in proper working order.

7 Most vessels are fitted with various types of opening that may admit water if left open when at sea, namely: portlights, skylights, engine or deck hatches. The stability is assessed assuming that all openings marked 'to be kept shut at sea' have been closed.

If such openings are not closed before putting to sea, a progressive accumulation of bilge water is likely with consequent adverse effect on the stability – see note 5 above.

8 Some seacocks must be left open for the proper working of the vessel's systems, eg: engine cooling, drains and scuppers, fire pump suction. Some may cause inadvertent flooding if left open. Typically these include those relating to toilets and sinks fitted relatively low in the vessel and which may become submerged when the vessel is heeled to large angles.

9 Loose gear, if not properly secured, will fall to the low side of the vessel when it heels. Apart from the risk of injury or damage, this has a similar effect on stability as loose water – see note 5.

It is especially important that heavy items such as batteries or spare anchors are very well secured against movement, even at very large angles of heel, for example after being heeled to 90° or more.

10 If the vessel is fitted with air tanks or flotation spaces, survival after swamping or damage may be severely impaired if such spaces are not well maintained and regularly checked for water. Drain plugs on all such spaces should therefore be opened at regular intervals to ensure that leakage has not occurred.

At sea in normal conditions

11 The bigger the wave relative to your vessel, the greater the risk of being rolled by a beam sea. This risk can be significantly reduced by not taking such waves beam-on. See also note 24.

12 A recommended sequence for shortening sail is given in the front of this booklet. It is important to be familiar with this, especially on sailing multihulls and form-stable monohulls, which can be capsized if too much sail is carried.

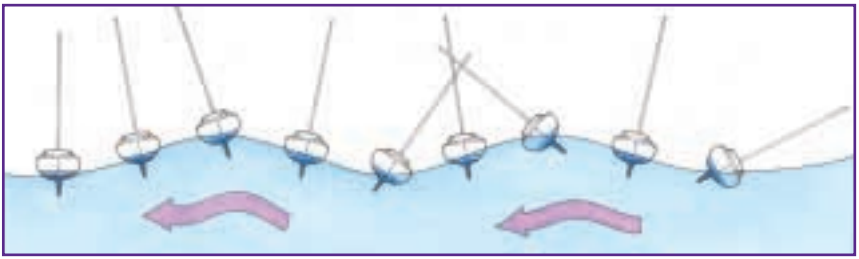
13 Monohull sailing vessels, if sailed at less than the recommended maximum steady heel angle (see front of booklet) are unlikely to experience significant downflooding even in a strong gust (ie: 40% higher than the average wind speed).

Rather than continuously referring to an inclinometer, check how this angle for your vessel compares to the angle at which the lowest point of the deck-

edge or bulwark becomes submerged – see the information in the front of this booklet. Keeping the side-deck dry is often a good indicator.

A full explanation of recommended maximum steady heel angle is given in the full *MCA Master's Stability Information Booklet* in the section called *Maximum Steady Heel Angle to Prevent Downflooding in Gusts.*

14 Resonant rolling occurs when an initial disturbance causes a rolling motion that progressively grows due to the action of the wind or waves.



Vessels may experience resonant rolling if encountering a series of fairly regular beam waves. The waves do not have to be especially large, but may just have a period similar to the natural rolling period of the boat. Due to the damping effect of wind in the sails, this is generally of less concern to vessels under full sail.

A change of heading and/or speed reduces resonant rolling motions.

Fore-and-aft rigged monohull sailing boats running dead before the wind, even in smooth water, can develop a rolling action that can magnify so much that control is lost and the boat broaches violently.

Sheeting in the mainsail, or fitting a gybe preventer and running by the lee may solve the problem.

15 Tight turns at speed generate substantial centrifugal forces that can increase the risk of capsize.

16 A fast ferry develops a different kind of wash from a conventional ship, a wash that may only reach your vessel some 15 to 20 minutes after it has passed. Such wash comprises a few very short and steep waves that are normally not dangerous.

However, when such waves encounter relatively shallow water they can become dangerously high and steep, sufficient to swamp smaller boats. It is therefore wise to avoid shallow water in the vicinity of routes where such ferries operate at high speed.

17 The apparent wind speed is dependent on the vessel's speed and the apparent wind direction. Altering course closer to the wind will increase the apparent wind speed, particularly in faster vessels.

Therefore be aware that conditions can seem to get significantly rougher after altering course closer to or into sea and wind, and consider reducing sail before such an alteration of course.

18 To be prepared for the eventuality, make sure that you know the best technique for heaving-to or laying a-hull for your specific vessel. This may require some experiment in suitably fresh conditions, especially for square-rigged sailing vessels.

The Master's instructions are given at the front of this booklet.

19 Squalls (localised dramatic increases in wind strength) can often be anticipated by carefully observing the behaviour of other sailing vessels to windward, and are often detectable on radar. Squalls are also often accompanied by marked changes in cloud type and wind direction.

If possible, reduce sail before encountering a squall. A good lookout is therefore necessary.

An explanation of how to restrict the steady heel angle to minimise problems in squalls is given in the full *MCA Master's Stability Information Booklet* in the section called *Maximum Steady Heel Angle to Prevent Downflooding in Squalls*.

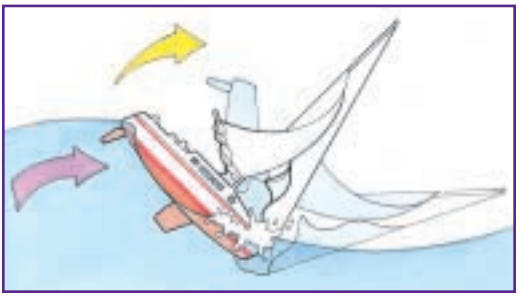
In unsettled weather, especially with rain squalls about, be aware that white squalls (or 'microbursts') can occur with no visible warning.

20 If a sudden gust of wind is unusually strong, threatening to heel a sailing vessel beyond 60°, rapid action should be taken to reduce the effect on the boat. Action with the helm is quickest to perform, but any navigational hazards in the area should be considered. Freeing all sheets is an alternative course of action if a change of course is not possible.

Because vessels differ in their behaviour, it is not possible to give generalised advice. The Master's specific instructions should therefore be followed if such gusts are encountered – see the front of this booklet.

21 All vessels, if driven too hard in following or quartering seas, can bury their bows into the sea, resulting in a sudden increase in apparent wind speed.

This behaviour may lead to 'pitchpoling' due to the bows digging into the



trough of the wave while the stern is being lifted by wind and sea. The stern is then lifted OVER the bows!

Sailing multihulls, if pressed too hard in beam or quartering winds may 'cartwheel', ie: when the lee-bow becomes submerged, causing tremendous drag, so that the boat pivots about this point in both pitch and yaw.

The solution is to reduce speed, and perhaps deploy a drogue.

At sea in rough conditions

22 In rough weather, small amounts of water regularly finding their way into the vessel over a lengthy period can accumulate alarmingly. One litre every ten seconds becomes 1080 litres or over a tonne every three hours!

Before the going gets rough, all potential downflooding openings should be closed unless they really need to be open. On smaller vessels the only ventilators that should be left open are those fitted with water traps.

Special care should be taken with any hatches or ventilators fitted well off the centreline of the vessel, as these will be the first to become immersed when the vessel heels.

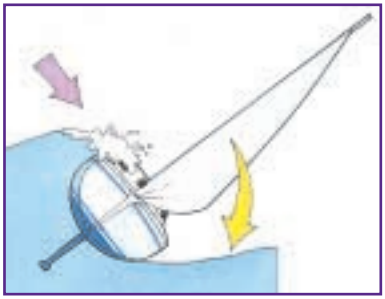
23 The main hatchway opening should be kept as small as practicably possible by keeping the sliding top closed, and one or more washboards in position.

If hatches or doors need to be opened in a rough sea, close and secure them as soon as possible afterwards.

24 The broken crest of a breaking wave contains a massive amount of energy that can exert a powerful heeling effect on any vessel, especially those under about 24m length. Such waves are one of the most likely causes of capsize, so it is prudent to avoid areas where they are likely to occur.

Breaking waves are especially likely when wind is against tide, when the wind is rapidly increasing in strength, or after a sudden wind shift when waves are coming from different directions.

The most dangerous breaking waves are likely to occur where:



- there are tide races or overfalls marked on the chart
- the wind is contrary to the current direction
- the sea bed shoals rapidly, even if the least depth seems to be very generous
- near lee shores, especially those that shoal steeply
- in areas such as headlands where the current is strongest.

25 It is often possible, by alert helmsmanship, to steer the vessel away from threatening waves, but this is a tiring task and requires frequent changes of helmsman. However, avoiding such waves is much more important than keeping a steady course.

26 Broaching in following seas occurs when a wave crest picks up the stern, causing the bow to dig in and the boat to slew rapidly through 90°.

In large waves, the violence of this uncontrolled manoeuvre can result in the boat being thrown onto its side, sometimes being completely inverted.

If the tendency to broach is persistent, consult the Master and slow the vessel down, in extreme cases by towing long bights of heavy warps or a strong drogue.

Emergency conditions

27 If any compartment is being flooded, whether through holing, failure of a fitting or downflooding, any watertight doors should be closed immediately, only being opened temporarily for access.

Similar action should be taken as a precaution when navigating in reduced visibility, or crossing shipping lanes, as the risk of collision damage is greatest. Some vessels do not slow down sufficiently when visibility is poor, so that a collision may occur within seconds of the other vessel being sighted.

Some definitions

Angle of Vanishing Stability (AVS)	The angle of heel at which, in calm water, a vessel continues to an inversion rather than returning to the upright.
Area of Operation	One of seven categories assigned under the *MCA Small Commercial Vessel and Pilot Boat Code,* based on distance from refuge.
Broaching	A violent turning and heeling effect created in following or quartering seas.
Buoyancy	The upward force produced when a vessel is immersed in water.
Capsize	When a vessel is heeled to any angle from which it cannot recover without assistance.
Design Category	One of four categories defined in the *EU Recreational Craft Directive* based on sea and wind conditions.
Downflooding	Flooding through openings that are normally above the calm water level.
Flooding	When a vessel fills with water relatively slowly, eg: through submerged downflooding openings, or through leaks of fittings below the waterline.
Flotation	Means of providing buoyancy in a vessel after swamping or flooding, eg: air tanks, air bags or foam material.
Form-Stable	Stability derived from the shape of the hull rather than ballast. Applies to vessels such as barges or multihulls.
Inversion	When a vessel becomes completely upside down in the water.
Knockdown	When a sailing vessel is heeled to about 90°.
Pitchpole	When the vessel inverts end-for-end, eg: stern over bow.
Righting Moment	The moment tending to return a vessel to the upright, being the product of vessel weight and righting lever.
Swamping	When a vessel is suddenly filled with water from above, eg: by waves.

Additional guidance for masters

Stability check lists

Explanatory notes

Stability check lists

General cautions

see note

- Be aware of the implied weather limitations of the Area of Operation assigned to your vessel. **28**

In rough conditions

- Raising an unballasted centreboard or leeward dagger-board generally reduces the risk of capsize. Ballasted 'drop keels' should generally be left lowered and locked into position if possible. **29**
- Heave to if the vessel is labouring.
- If heaving-to ceases to be practical, the usual options are to:
  - lay to a sea anchor, or
  - run before the waves towing a drogue or warps.
- Laying a-hull is a possible option for large multihulls and a few monohull vessels.

Emergency conditions

- After a collision with another vessel, do not disengage until any need to evacuate has been established. **30**
- If aground on a falling tide, ensure that the vessel lists away from deep water by moving onboard weights.
- If aground on rock or a sharp obstruction, check the extent of damage before attempting to free your vessel, as it may sink quickly.
- Even if partially swamped many craft will stay afloat and should not automatically be abandoned.

Explanatory notes

28 Areas of operation are defined in the *MCA Small Commercial Vessel and Pilot Boat Code* in terms of geographical limitations. These designations contain implicit assumptions regarding the severity of the conditions that may be experienced.

Explanatory notes

A vessel assigned to **Area 0** is not restricted and therefore may be assumed to at times experience storms (force 10) with accompanying very high sea states, significant wave heights exceeding five metres.

A vessel assigned to **Area 1** may experience severe gale (force 9) winds and associated sea states, significant wave heights exceeding four metres.

A vessel assigned to **Area 2** may experience gale (force 8) winds and associated sea states, but is expected to seek sheltered waters before severe gale force conditions are met. Significant wave heights up to four metres may be encountered.

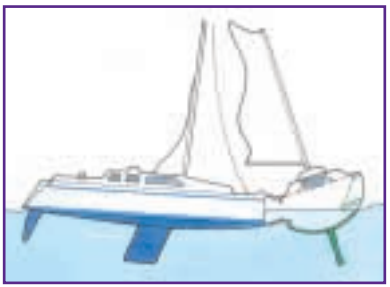
A vessel assigned to **Area 3** may experience near-gale (force 7) winds and associated sea states, but is expected to seek sheltered waters before gale conditions are met. Significant wave heights up to three metres may be encountered.

Vessels assigned to **Areas 4 to 6** may experience force 6 winds and associated sea states, but are expected to seek sheltered waters before force 6 conditions are exceeded. Significant wave heights up to two metres may be encountered.

29 Sailing vessels can reduce the heeling effect of breaking waves by raising the centreboard or daggerboard, because this reduces the tendency of the underwater hull to resist the waves. Boats fitted with twin daggerboards should only raise the leeward one.

Because righting moments would be reduced if a ballasted 'drop keel' were to be raised, this is not recommended. Indeed it is preferable for them to be locked down, so as to avoid movement in the event of an inversion.

Emergency conditions



30 In the event of a collision, if locked together the two vessels should not be separated immediately. This is for two reasons:

Firstly, the withdrawal of one vessel will increase the flow of water into the other, potentially resulting in rapid sinking.

A properly designed vessel will usually survive bow damage without immediate difficulty.

Secondly, evacuation of the more badly damaged vessel is much easier if the two remain in contact with one another.

Therefore carefully assess the condition of both vessels before attempting to separate them.

Stability Guidance Booklet for Masters and Watch Keepers **for Sailing Vessels**

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