A guide to

FISHING VESSEL STABILITY

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MARITIME NEWZEALAND

New Zealand Government

2011

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Published by
Maritime New Zealand
Level 10, Optimation House
1 Grey Street
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Wellington 6141
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Please note
The information in this document is intended for explaining stability issues and to provide guidance on stability hazards. It should not be relied upon for stability compliance. Please refer to the relevant maritime rules and seek technical advice on any issues that arise. You can also seek guidance from MNZ staff.

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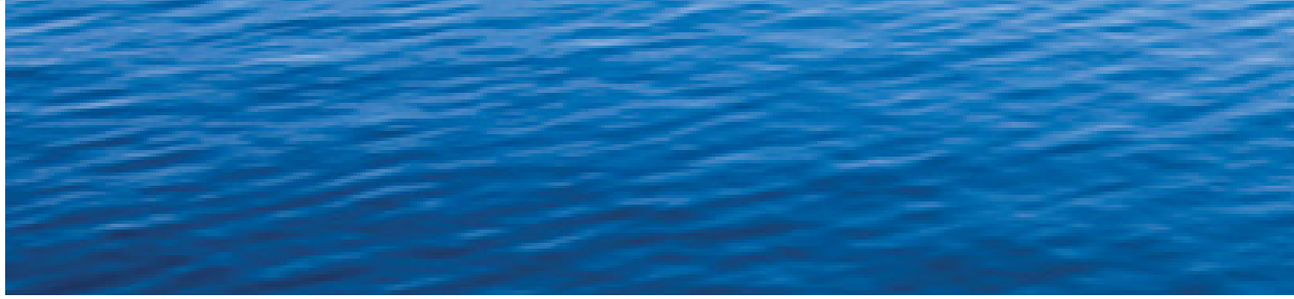
Notes



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PART 1

The importance of stability

The stability of your fishing vessel is something you depend on, for both your livelihood and your life.

It is your actions and your decisions that will keep your vessel safe. Even if your vessel is a safe one that complies with all the rules, poor operational decisions can cause it to capsize.

This guide will help you understand the key elements that influence vessel stability and the critical hazards that fishing vessels are exposed to.

Understanding each of the factors that reduce stability will help you make the right decisions and take the right actions to keep your vessel safe.

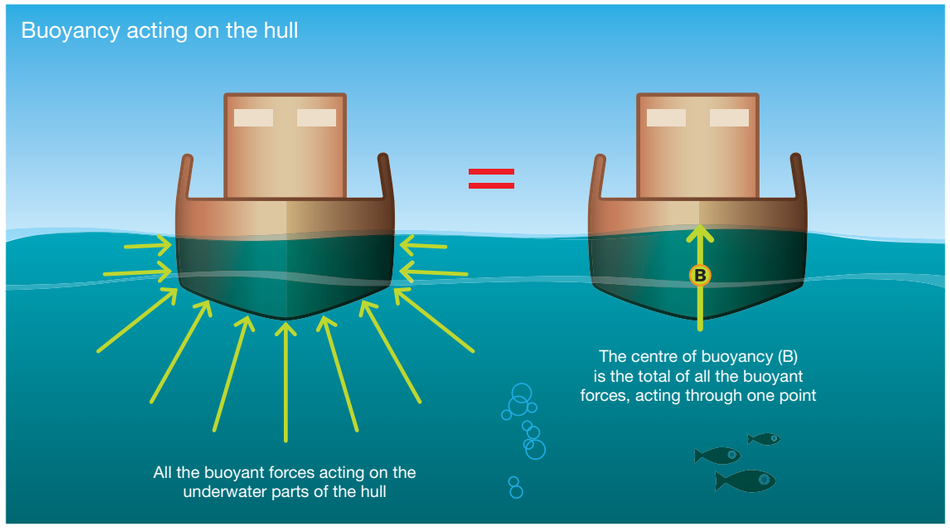
Notes

Notes

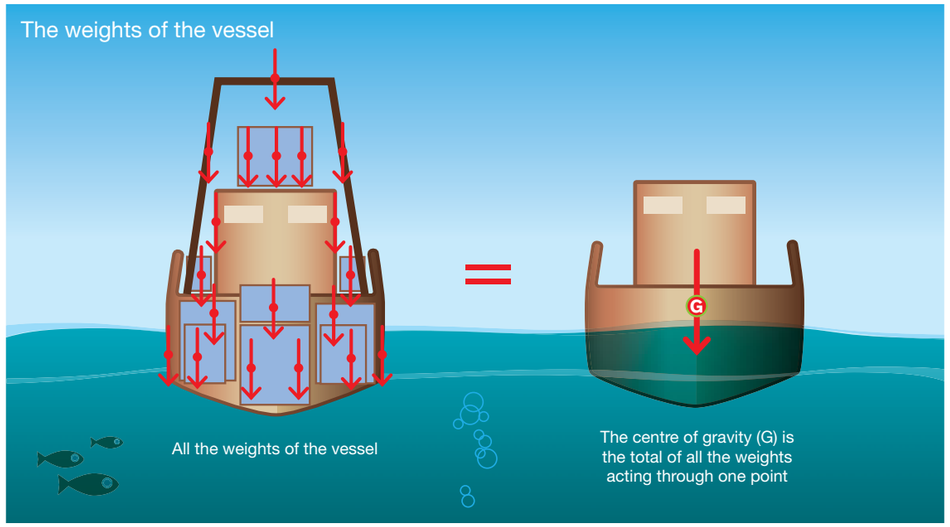
The basics of stability: buoyancy and gravity

The buoyancy provided by the underwater parts of your vessel, coupled with the combined weight of its hull, equipment, fuel, stores and catch, determines the stability of your vessel.

How the forces of buoyancy and weight are simplified

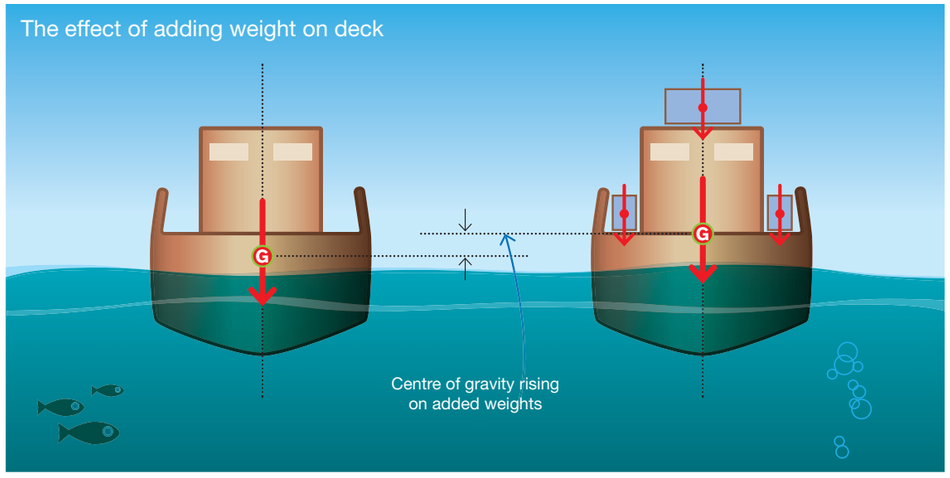


Buoyancy acts on all the underwater parts of the hull. The total of this buoyant upward force can be represented as acting through one point, the centre of buoyancy (B).



The total weight of the vessel, including all the stores, fuel, equipment and fishing gear, can be represented as acting through one point, the centre of gravity (G).

How the centre of gravity moves

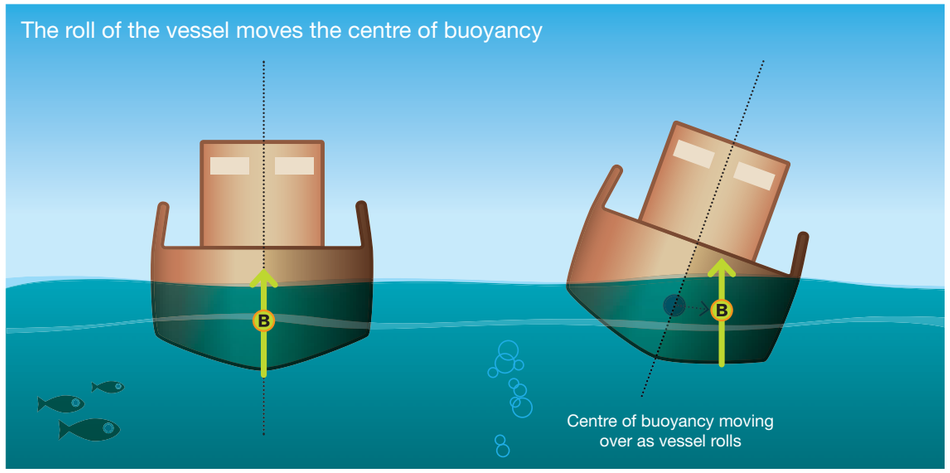


As a simple rule of thumb, the centre of gravity tends to move towards any added weights and away from any weights that are removed. If you add weight higher up on the vessel, the centre of gravity will rise and promote a top-heavy or 'soft' feeling. For example, if you add extra weight on deck or lift an object with a high derrick (crane), the centre of gravity moves up.

Similarly, if you reduce weight from low in the vessel (such as using fuel from low down in the fuel tanks), the vessel will become more top heavy.

To summarise, your vessel's centre of gravity moves in response to the weights you add and those you remove (or use).

How the centre of buoyancy moves



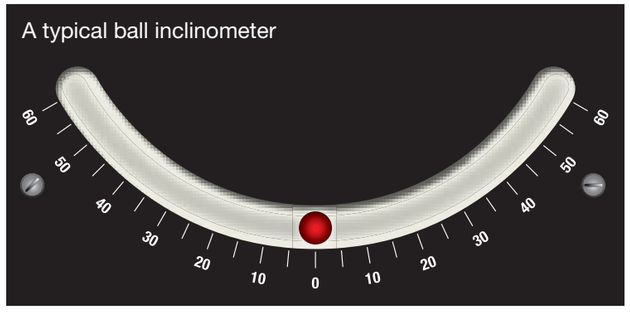
The buoyancy force, acting through the centre of buoyancy (B), moves away from the centreline of the vessel as it rolls over on an angle. The parts of the hull entering the water add buoyant forces on one side, as those parts of the hull on the other side come out of the water. The centre of buoyancy moves to a new position towards one side of the vessel. This is where the buoyancy force will now act.

Inclinometers and how they help

Bubble and ball inclinometers are like spirit levels on a curve that tell you the angle the vessel rolls to, port and starboard. Regularly noting extremes in the logbook can help build an accurate picture of the vessel's motions in different conditions or when lifting.

Maritime New Zealand strongly recommends each vessel is fitted with an inclinometer, mounted athwartships (at right angles to the keel) in a position visible from the helm. In this way, the angle of the vessel's roll can be monitored during fishing or loading operations, bad weather or adverse sea-states.

Inclinometers are not expensive and help raise awareness of stability issues for all people on board.



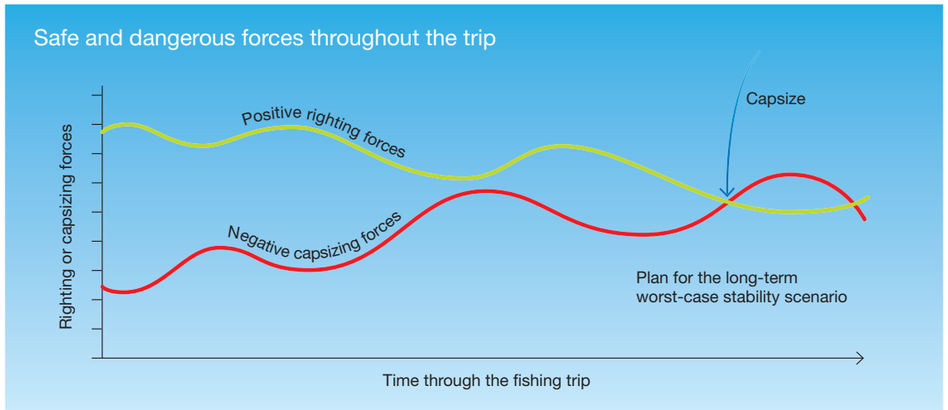
Planning your stability for the whole trip

The stability of your ship is not something that is set once and remains the same – it changes constantly throughout your trip.

The factors that provide good positive stability forces, such as full fuel tanks normally being low down in a vessel, are initially present and then reduce during a trip as fuel is burnt. Having some catch loaded in your hold can also help your positive stability forces.

The conditions that have a negative impact on stability safety are not constant either. Fuel reductions and fishing operations steal margins of safety from the vessel's stability. The weather and sea-state can also negatively affect your stability safety.

The following representation of a vessel's stability safety throughout its trip shows how the good and bad parameters are constantly changing and why a skipper needs to plan ahead for the worst-case scenario.



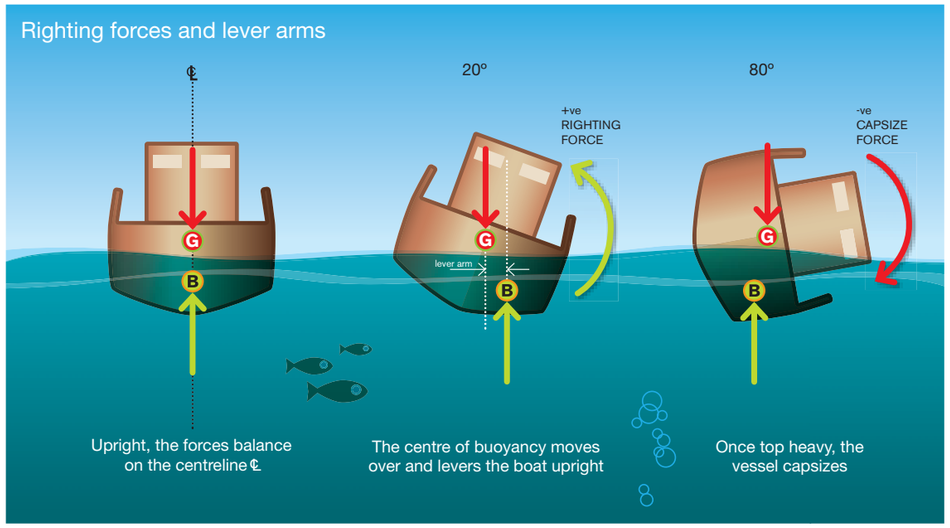
If you have one, your stability book can help with this planning. It helps you prepare for and check loading conditions at certain stages of your trip. These loading conditions can be considered by the skipper while planning a trip, and used as a set of parameters to check against and stay within.

The different stages include:

- leaving port with full fuel and stores but no fish
- being at the fishing field with a full catch
- coming home with a full catch and not much fuel and stores
- coming home with a small catch and not much fuel and stores
- any other actual operating conditions (such as fishing operation).

The loading conditions are useful descriptions of the boundaries for a vessel's stability safety. If you want them explained, please contact the naval architect who calculated them for your vessel.

How stability changes as a vessel rolls over



Upright in flat water, the forces at G and B balance each other on the centreline of the vessel.

When wind or a wave rolls the vessel over, the centre of buoyancy moves to one side and levers the vessel back upright. This horizontal distance, between the forces at G and B, is called the 'righting lever' (or GZ).

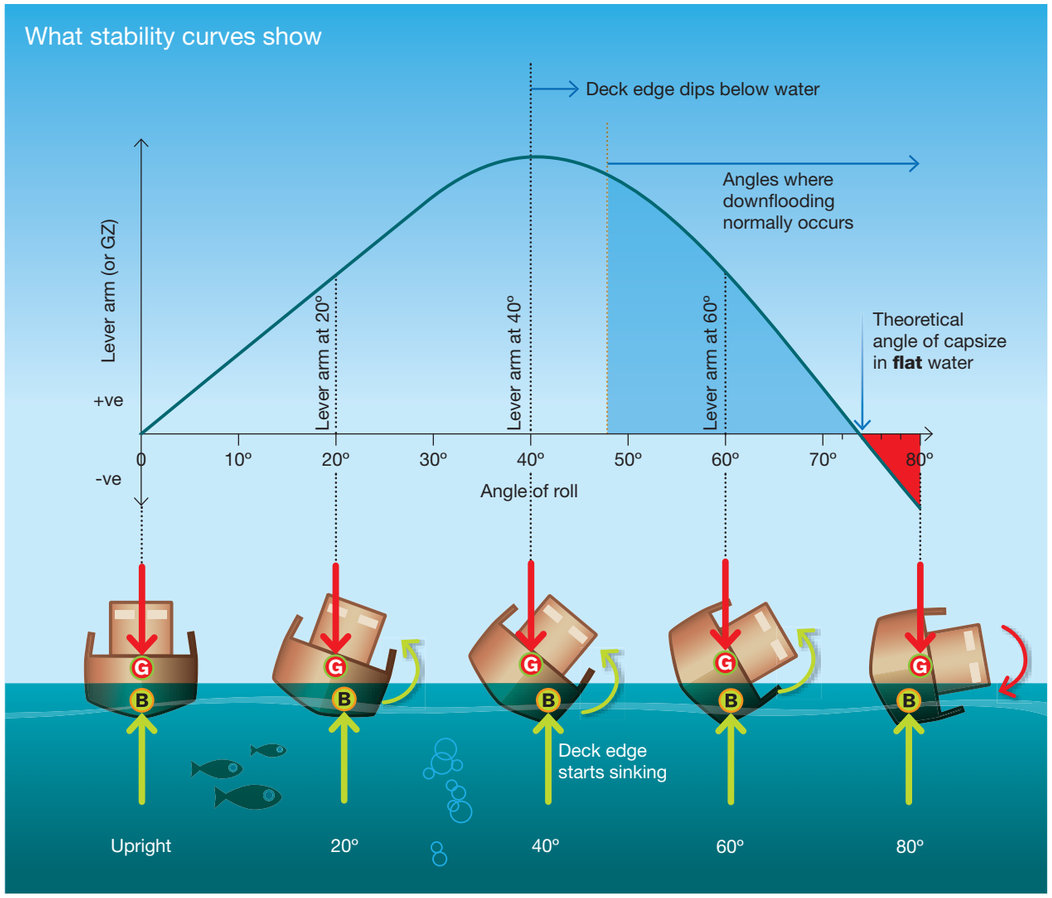
If the vessel rolls too far, the centre of buoyancy can't move over any more and the vessel becomes too top heavy and capsizes.

This tendency to capsize happens much sooner if the centre of gravity is moved higher.

As a vessel rolls, the shape of its hull limits how far the centre of buoyancy can move. The beam of the vessel's hull and the height of the deck's edge above the water determine how much buoyant force is available and how large the righting lever can be.

Normally, when the edge of the deck rolls below the water, the angle of roll with the largest possible righting lever has passed.

If the vessel gets lower in the water, from loading too much weight or catch, the freeboard (the distance from the water to the deck edge) is reduced. In this condition, when the vessel then rolls, the deck edge goes underwater sooner and reduces the righting lever more quickly. The effect is to reduce the range of stability safety (meaning the vessel capsizes sooner at a smaller angle of roll).



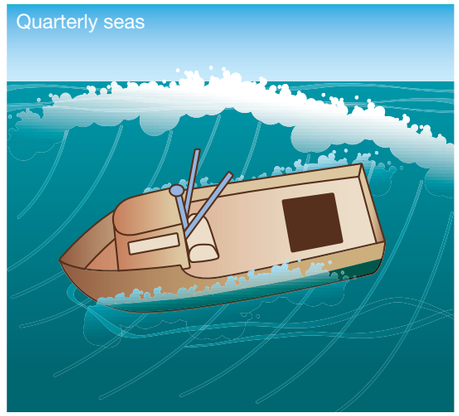
The graph shown above is a stability curve, sometimes called a righting lever curve or, technically, a GZ curve. You will find some of these for your vessel in your stability book if you have one. The small boats that sit underneath the graph illustrate the corresponding angles of roll and how the forces acting on the vessel move.

The graph shows the righting lever arm for a stationary vessel in flat water, at increasing angles of roll. This righting lever curve will be different depending on how the ship is loaded with fuel, stores and catch.

For each angle of roll, the position of the centre of gravity and the changing position of the centre of buoyancy determine how big the righting lever (or distance GZ) is. This is what the curved line of the graph shows. As the boat's roll increases, the righting lever gets larger and then, beyond a certain angle, it starts reducing. Eventually the lever reduces to zero, and beyond that angle it starts working to capsize the vessel.

Quarterly seas – an extreme hazard

Quarterly seas are even more prone to broaches, wave attack and swamping than following seas. On every wave, the vessel is partially broached on the wave face, increasing the chances of a full broach. The aft quarter is exposed to breaking waves and the deck exposed to swamping.



On the back side of the wave, the vessel often rolls back to windward with a corkscrew motion that rolls through to an even more dynamic motion to leeward with the next wave. This progression can often lead to a loss of steerage and broaching, especially if the vessel starts surfing on the wave face.

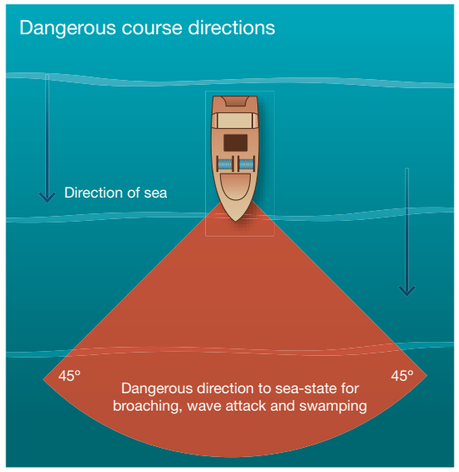
On this course, the underside of the stern is exposed to being picked up by a following breaking wave, causing the vessel to turn hard and roll on the leading slope of the wave. This is highly dangerous. Breaking waves can only safely be taken square on the transom, or head on with the bow into the sea.

This course direction in a large sea-state with breaking waves is very dangerous, even if the vessel has good reserves of stability. Any decision to take a course of this nature in such a sea-state should only be taken with a sound understanding of the vessel's stability reserves and experience of its handling.

The hazards that are generated by both quarterly and following seas are particularly relevant to safety when returning to port over a river or harbour sand bar.

Direction of chosen course

A skipper normally has a choice about the course to steer while at sea. Running at angles between 45 degrees either side of the sea-state direction are the most dangerous for surfing, broaching and wave attack.

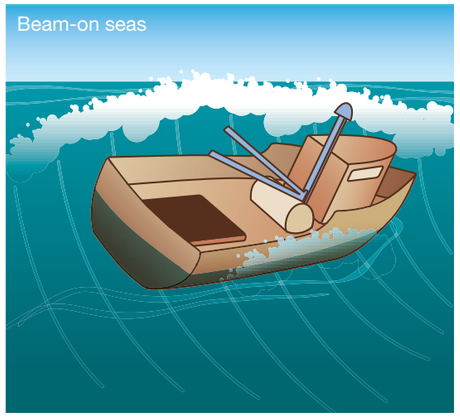


In severe conditions, it may not be possible to continue in the direction of the waves and avoid the serious risk of capsize. It may then become necessary for the skipper to wait for an opportunity to turn the bow into the seas and head slowly upwind until conditions improve.

Risks from heavy seas, breaking waves and broaching

Beam-on seas – a hazard

In beam-on seas, there is a high risk of a vessel taking large rolls. If the vessel is also overloaded or subject to another stability hazard, large rolls can lead to capsize.



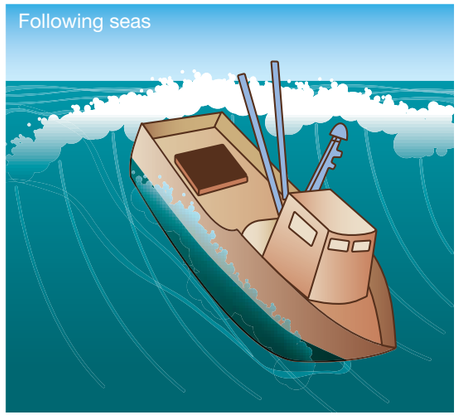
The rolling caused by a beam-on sea may be quite violent, and crew members may have difficulty just staying on their feet, let alone being able to work effectively.

The large forces within breaking seas are highly dangerous for fishing vessels, especially if they are already overloaded or taking water. There is also danger of the vessel being swamped and the working deck filling with water, exaggerating the rolling and further lowering stability levels.

As with all bad weather, the risk of shifting gear and catch is high, and all items need to be safely secured.

Following seas – a significant hazard

When steering a course with a following sea, great care is needed to avoid broaching. Running in the same direction as large waves makes steering extremely difficult, and the danger of yawing into a broach is always present.



The passing of a wave slows and then significantly accelerates the vessel, with the effects of surfing giving the vessel extra speed on the wave face. The burying of the nose and deceleration that follows, as the wave crest passes, throws the dynamic forces forward and often combines with the curvature of the hull trying to turn the vessel. At the same time, the rudder often has a loss of control due to the motion of the following wave and through being raised near the surface as the stern lifts.

The combination of the next surge of the vessel, being off course due to the broaching forces, and the vessel rolling on the next wave face makes a safe course very hard to steer.

In addition to the threat of broaching, the danger from being swamped is extreme in this direction. The extra weight and loss of stability from the deck being filled with water is frequently the cause of a full broach and potential capsize.

The area under the curve can be thought of as the 'stability safety envelope' for the vessel. The larger the area under the curve, the more stability is available. Maritime rules that apply to some commercial fishing vessels[1] specify how much area there must be under the different parts of the curve.

The curve has a maximum, at the top, after which the righting lever starts reducing. For fishing vessels, this is usually the angle of roll just before the edge of the deck goes underwater.

As the vessel continues to roll, taking on water or downflooding becomes likely. Once downflooding starts, through openings and hatches, stability is lost very quickly.

It is important to note that these curves are calculated for a stationary vessel in completely flat water. This millpond snapshot of static stability does not fully represent the vessel's real dynamic stability in waves, wind and while working. The real-life situation is a lot less stable than the stability curve suggests. Many naval architects ignore the area beyond the maximum of the curve because, in real life, the stability it suggests often does not exist. Stability curves are a tool and a guide, and the upper angles of stability should never be relied on, especially beyond the angle of downflooding.

1 Maritime Rule Part 40D

PART 2

Stability hazards to look out for

Fishing vessel owners, operators, skippers and crew should become familiar with each of the stability hazards outlined in this section, and understand how they are caused.

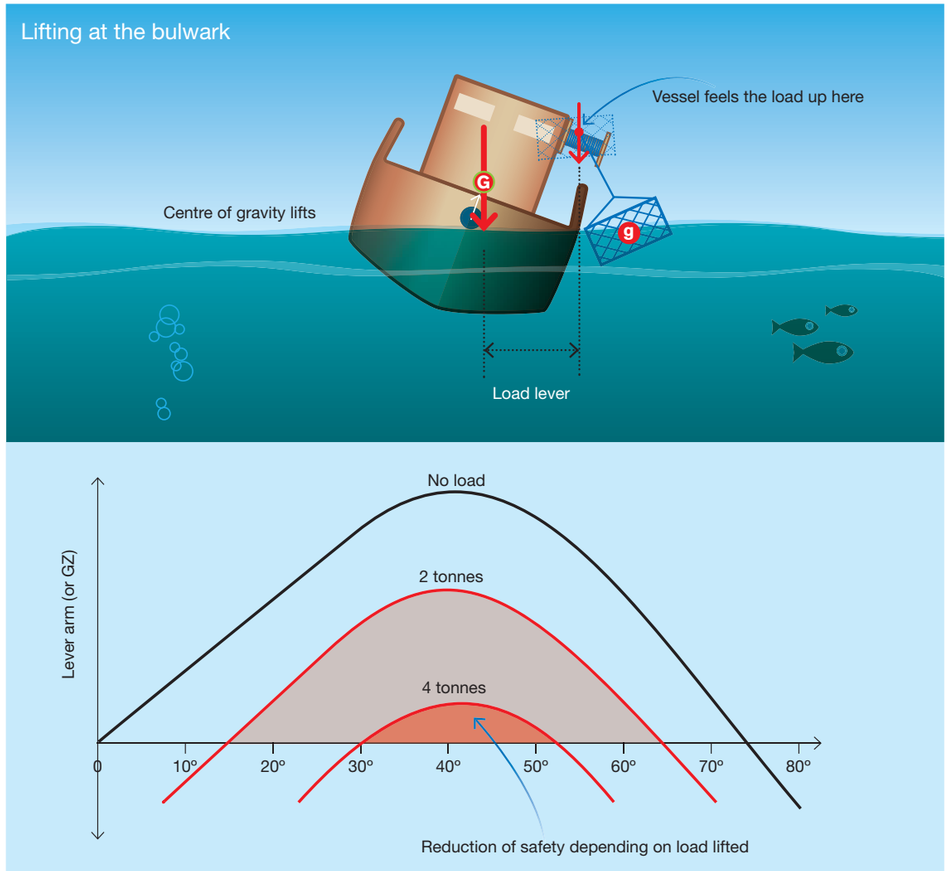
Any significant hazard should be formally identified in the vessel's onboard safety system. Measures should be in place to avoid or reduce their risk to the vessel and your crew.

For advice, contact your surveyor, the authorised person if you have a safe operational plan (SOP), or the naval architect who prepared your stability book.

Lifting or winching at the side

Lifting is also an issue for vessels lifting catch at the side. Any dredger, cod potter, crayboat, side loader or seiner lifting loads at the side is taking large chunks of safety out of its stability curve every time it lifts.

Again, the weight acts at the point of lifting. On a cod potter or crayboat, this point is the top of the winch.



How much the stability safety is reduced depends on the load lifted and whether a derrick is being used.

A lift at the side of the bulwark is safer than using a derrick (which is normally higher and reaches out further).

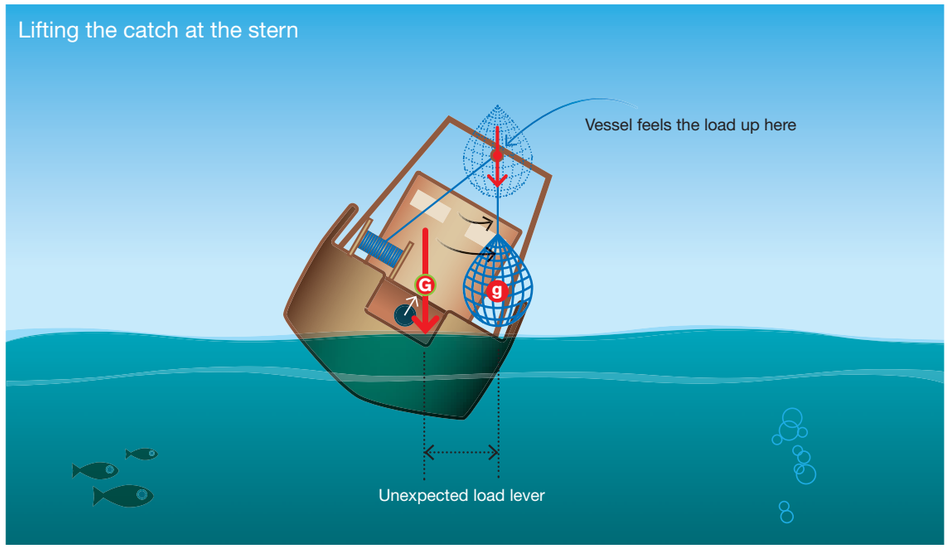
The example above, of a fishing vessel lifting at the side, illustrates how much each of the loads reduces the stability safety while working (shown as the area under the curve). Every lift is only as safe as the load lifted, the condition of the vessel at that time, and the sea-state size and direction.

Lifting the catch at the stern with an A-frame

This shifting of the centre of gravity due to the weight of the catch applies to stern lifters, too.

Any winch, block, wheel or lifting point used on an A-frame at the stern of the vessel will transfer some or all of the weight of the catch to that point. Any lifting or dragging of the gear or catch will have this effect.

The weight of the catch at the height of the deck has a big enough impact, but when it is lifted by blocks the centre of gravity of the catch shifts, partly or fully up to that height.



Visualise the gear and full catch at that height – that is how it feels to the vessel.

The effect on the vessel's stability reserves and the reduction in the range of roll before capsize is significant.

Before you lift, think about the condition of the boat, the sea-state, and how much you are going to lift.

Modifying a vessel or installing new fishing gear

If you add new equipment higher up on your vessel, or heavier equipment in the same location as the old gear, the centre of gravity will get higher and reduce the boat's stability.

This means the vessel will feel 'softer' and will capsize earlier, at a lower angle of roll. It will also mean that you can safely load less catch, and that the size of wave that can capsize the vessel will be smaller. Keeping weights as low down as possible is really important.

Any changes to a vessel's load-carrying capacity are critical to your vessel's stability safety and the reserves of buoyancy it will have at larger angles of roll. If you modify the vessel to make the fish hold bigger, the weight of a larger catch will reduce the distance from sea level to the deck edge (the vessel's freeboard). This, in turn, is likely to reduce the 'stability range' of the vessel (the boat will capsize at a smaller angle of roll).

If you wish to install new fishing gear that is heavier (or in a higher position), or want to install a new structure on your vessel, you need to contact your surveyor, your authorised person if in SOP, or the naval architect who prepared your stability book. They will advise how much this will affect your stability and whether adjustments need to be made or new stability calculations undertaken.

Keep an eye on how much extra weight you put on board your vessel as stores and equipment. Increases in weight take your vessel lower in the water, limiting both its range of stability and the catch you can safely carry. The slow accumulation of stores and equipment over the years can end up making a big difference to how stable your vessel is. Think about having a clean-out, and always consider carefully where you are storing heavy items.

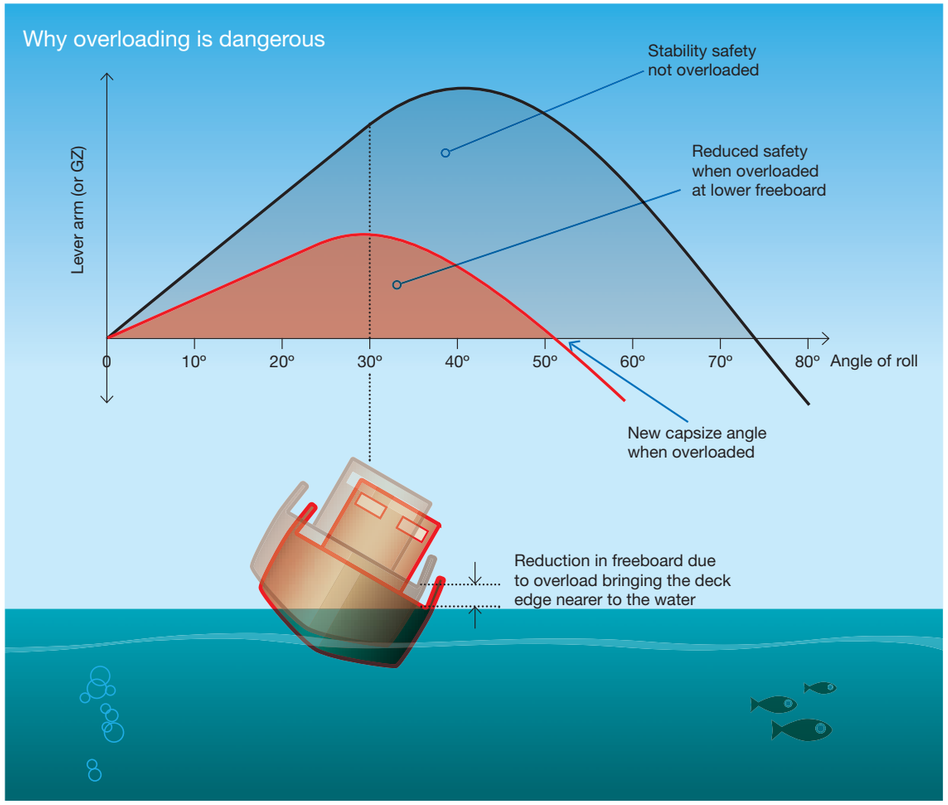
Overloading leading to capsize

Fishing vessels are normally overloaded by loading too much fish in the hold, or loading extra fish on deck.

Overloading causes two dangerous stability hazards:

- The heavier the load in the hold, the lower the freeboard of the vessel; the nearer the water level is to the deck edge, the more limited the range of stability becomes.
- Loading extra fish higher up on deck lowers the freeboard, but it also lifts the centre of gravity dangerously. This limits the range of stability and brings the boat much closer to a capsize condition.

When you load too much catch in the hold, the vessel gets lower in the water and the extra weight eats into the buoyancy reserves. This means that when the boat rolls, the deck edge is nearer to water, the stability safety is reduced and the strong righting forces are lost earlier. The vessel will capsize sooner at lower angles of roll.

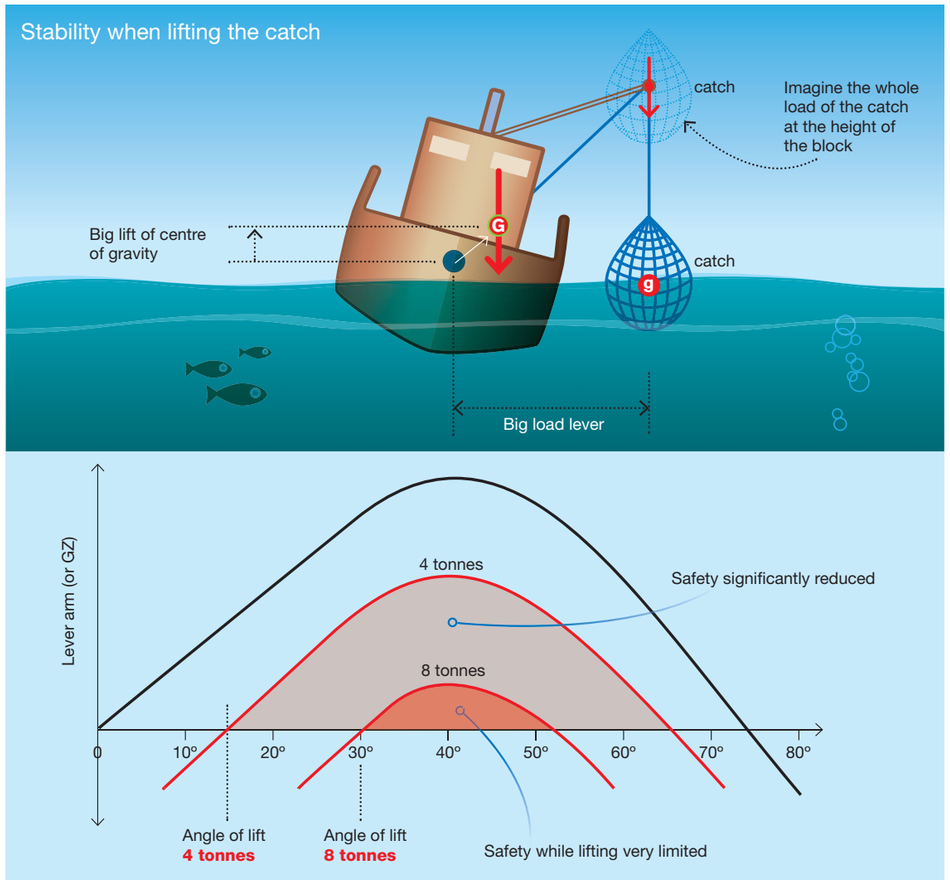


Loading too much catch on the deck has two significant negative effects. Firstly, it overloads the boat as described and reduces the freeboard (and range of stability). Secondly, it lifts the average of all the weight on board (lifts the centre of gravity) and makes the vessel more top heavy. This combined effect is important to remember, as it can be dangerous and needs to be guarded against.

Lifting, pulling on board or splitting the catch

People do not always realise that the centre of gravity and weight of any lifted object acts through the highest point of the blocks, pulley or winch line holding the weight.

What this means is that if you are lifting a catch, its weight is acting not where the object is, but at the top of the lifting point, block or winch that is lifting it. If you imagine the object up-high at this point, then this is where the vessel feels the weight.



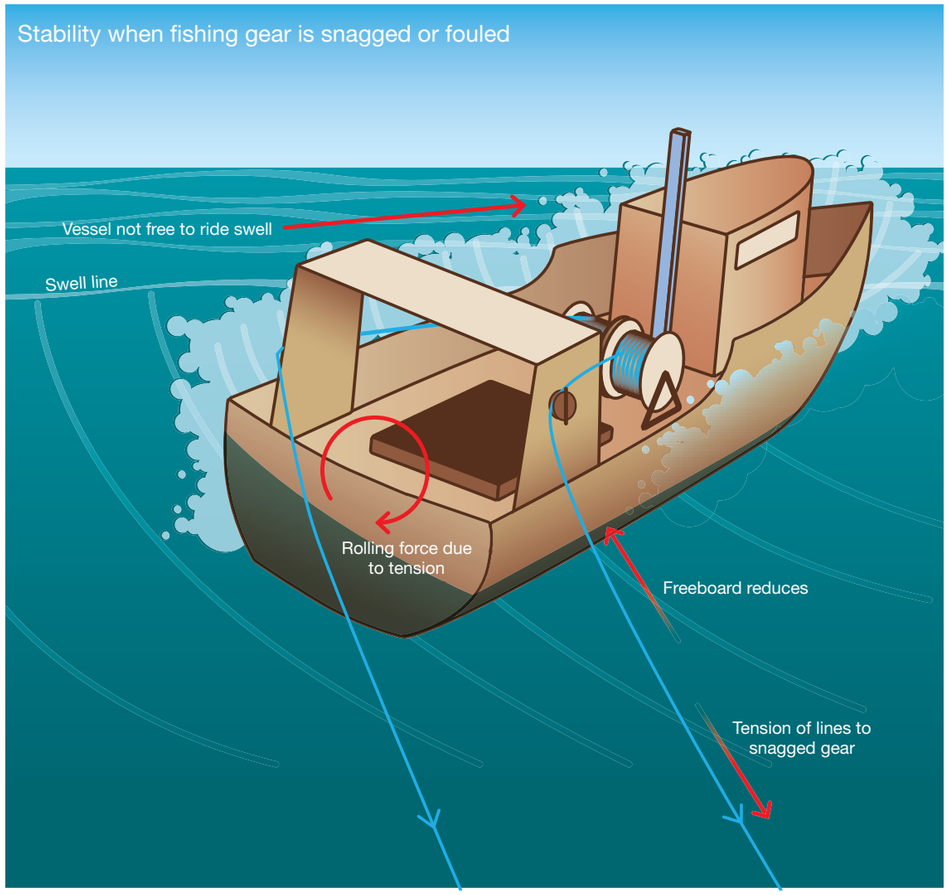
Lifting fishing gear or a catch out of the sea into the air shifts the full weight to the highest point of the wire, usually just above the blocks on a derrick or A-frame. This sudden jump in the vessel's centre of gravity is very dangerous. By the time you notice the vessel feels 'soft', it may be too late!

If the object then starts swinging in the swell, you may be in serious trouble. **Before you lift**, think about the condition of the boat, the sea-state and how much you are going to lift.

In the above example of a trawler lifting with a derrick, you can see that even the 4 tonne lift is dangerously reducing the stability safety, and with an 8 tonne lift the vessel is very close to capsize. Remember that these graphs only show the stability in completely flat water – and, as you know, the sea is seldom flat.

Fouling or snagging of fishing gear

For all fishing vessels, fouling or snagging their fishing gear is not just an inconvenience, it is a very dangerous and significant stability hazard.



With any gear stuck on the seabed, the vessel is extremely vulnerable:

- The sea condition, direction of the vessel and angle of the lines are all critical.
- The vessel may stop riding the swell (and waves will hit the vessel harder as a result).
- The more load there is on the lines, the more the freeboard is reduced.
- Any sideways tension on the line will roll the vessel.
- The tension on the lines will increase as waves pass, in time with the rolling forces on the vessel.
- Progressive 'grabs' at slack line on any roll of the vessel can introduce very large loads, which can be very dangerous to stability.
- Steep angles on the lines will worsen the stability hazard.

Operations to free the gear must only be undertaken with close attention to the effects of any actions on the vessel's stability, given the extra loads that will be needed to free the gear.

Overloading a vessel when you still need to motor home, using fuel as you go, is highly dangerous in a rough sea. Work out how much catch you can safely carry and leave plenty of safety margin for the bad weather, decreasing fuel levels and, if applicable, the need to cross the bar to get back into port. Plan your stability and don't overload the vessel so that you can make it home safely.

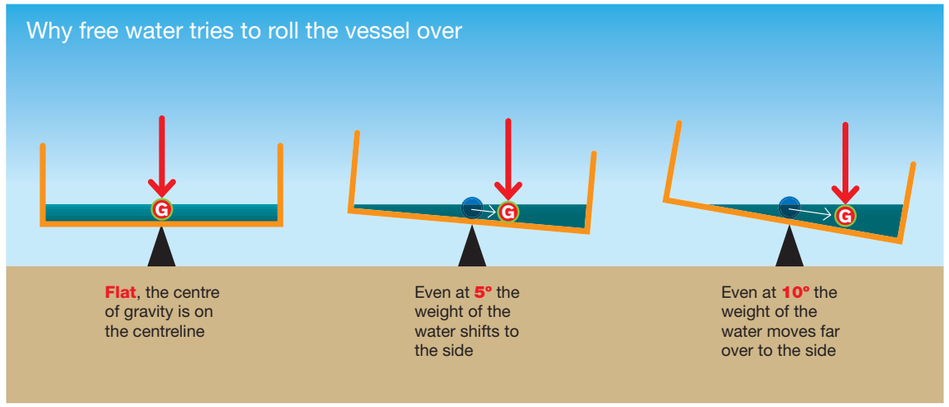
If you have a stability book, look at the 'loading conditions' prepared for your vessel. Loading conditions have been calculated for your vessel for specific amounts of fuel, stores and catch. Each scenario is designed to help you plan your trip and to highlight when the quantities of catch and/or fuel become a hazard. They should be thought of as useful guides to help you operate your vessel safely.

If your stability book is no longer current because you have installed new equipment or made modifications to your vessel, get your naval architect to prepare an update and ask them to explain each of the loading conditions to you.

Swamping of the deck and 'free-surface effects'

Water on deck is a serious stability hazard. A wave on deck can introduce many tonnes of water-weight and then add a strong rolling force from what are known as 'free-surface effects'. This combined effect is alarming from a stability point of view, because the extra weight drastically lowers your freeboard, the boat's centre of gravity is raised, and then the water shifts and tries to roll the vessel over.

This is why it is critical to move water off the deck as quickly as possible. Freeing ports in the bulwark must be big enough for the task and should never be closed or blocked, especially during critical fishing operations and bad weather.



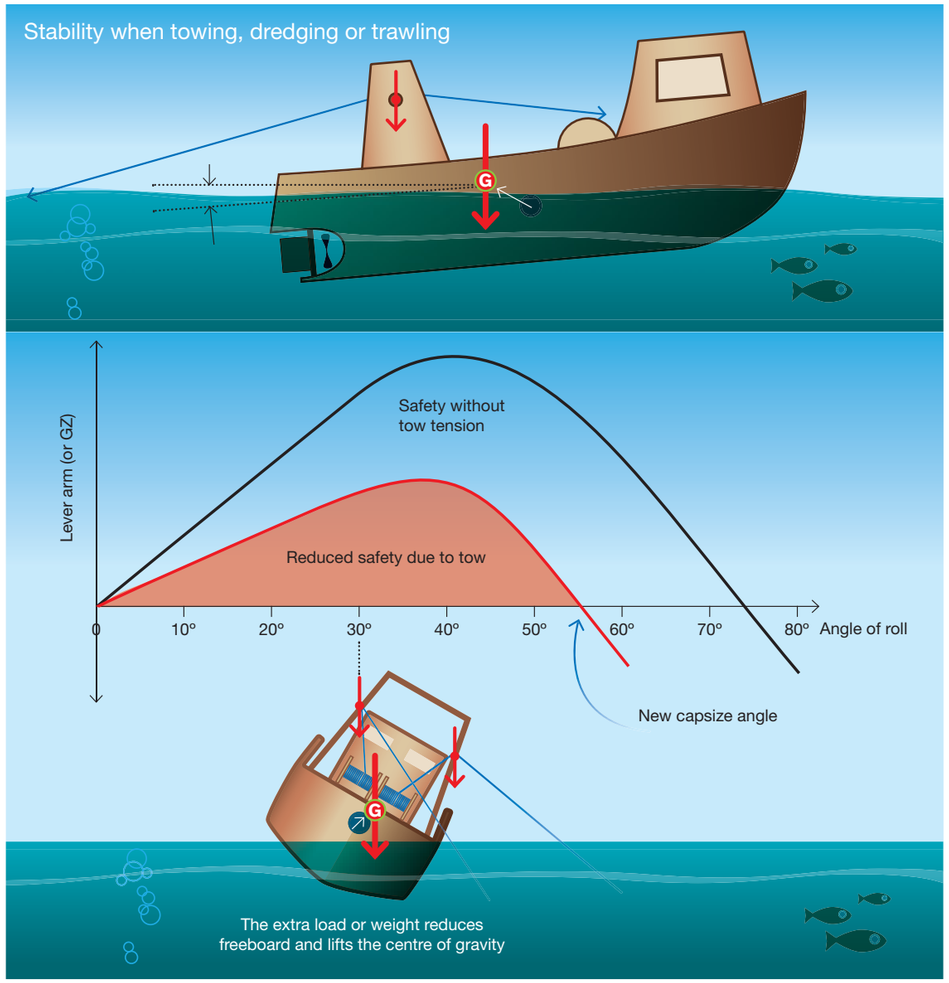
The diagram shows how the free-surface effect tries to roll the boat over. It applies to water on deck, fuel and ballast in tanks, bilge water and melted ice in the fish holds.

- Avoid conditions where breaking waves or following seas could cause the decks to be swamped. A deck full of water is often the first stage in a capsize.
- Always keep freeing ports open while at sea and ensure they are clear of obstructions.
- Keep all bilges and melted ice to a minimum.
- Keep fuel and ballast tanks either full or empty, to minimise the free-surface effect on board.

Trawling, dredging and towing

People often forget that the tension of the lines while trawling has a significant negative impact on the vessel's stability:

- the tow lines' tension pulls the stern lower in the water, reducing the freeboard aft
- the downward weight of the load brings the vessel lower in the water
- the tension of the lines, transferred through the towing point or blocks, dramatically raises the vessel's centre of gravity.



All these factors reduce the stability of the vessel. If the sea-state is rough, or if the vessel is already heavily loaded, the combined effect may be dangerous.

A heavy roll when towing may also cause the vessel to turn and roll to the tension of the lines. The direction of the swell and the overall stability of the vessel is critical to safety during this operation.

Before starting each tow, consider the available reserves of stability safety and the sea-state size and swell direction.

Stabilisers

Stabilisers are structures that swing out or lower down from the side of a vessel and deploy plates or lifting surfaces (often called 'birds') into the water to dampen the vessel's roll response. This damping effect is common with bilge keels and other surfaces deployed at the bulwark to slow the vessel's rolling.

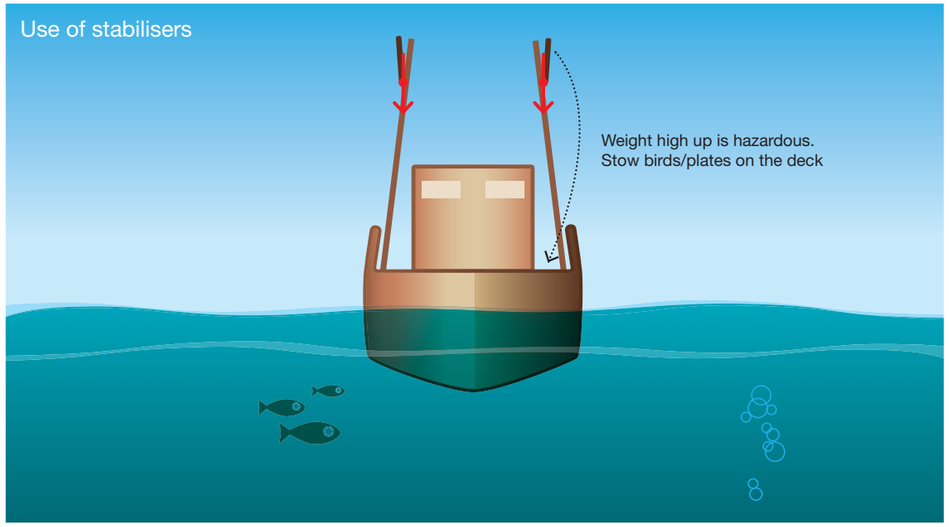
These structures make the vessel feel more stable because, when they are deployed, the vessel's roll accelerations are significantly reduced. However, stabilisers do not provide stability – they only slow the rolling motion of the vessel.

Stabilisers pose significant hazards when:

- lowering the arms, or swinging them into position, and recovering them afterwards
- deploying and recovering the plate, lifting surface or 'bird'
- the arms and plates are lifted, which raises the vessel's centre of gravity
- the vessel is caught with the stabilisers deployed in a bad and worsening sea-state – where recovering them will compromise the vessel's stability.

Each of these hazards should be considered and planned for in the vessel's safety manual.

Raising the stabiliser arms (with the weight of the plates) at the end of fishing operations can be critical to a vessel's stability. This operation must be planned for, to ensure sufficient stability is kept in reserve to allow for the negative effect that raising the arms will have.



The plates, lifting surfaces or 'birds' must always be stowed on deck while they are not in use. They can weigh more than 100kg, and leaving them at the top of the arms will significantly reduce a vessel's stability.

Maintaining the shackles, hanging eyes, pins, chains and all connectors is essential for safe operation with stabilisers. The failure of any of these during adverse weather could put the vessel in a critical situation. The vessel's maintenance plan should detail the required intervals for checks and replacements for these items of equipment.

Water ingress and downflooding

Accidental flooding of the vessel, through valves and leaks in the engine space or downflooding through hatches, doors and vents, can introduce a hazard that no-one notices.

When taking bilges or downflooding, the vessel sinks lower in the water, which eats into its buoyancy reserves. The loose water then introduces a free-surface effect that tries to roll the vessel over.

A heavy roll or a breaking wave that results in downflooding will make the vessel less stable and multiply the problems the vessel experiences next.

Take these measures to avoid this hazard:

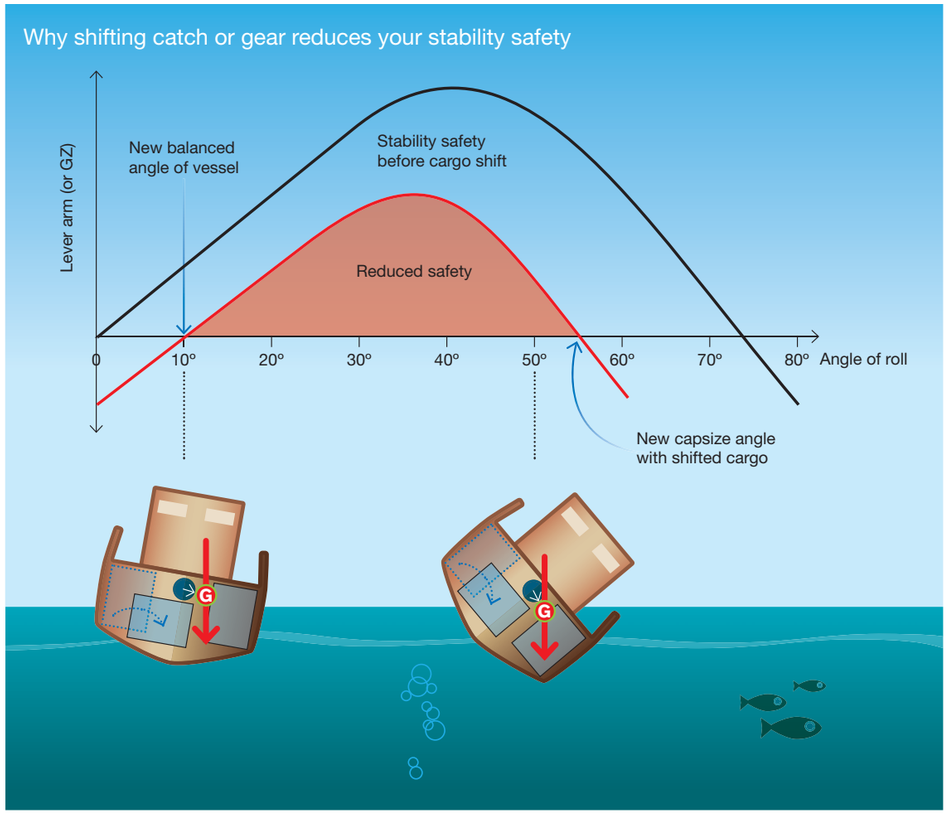
- Ensure your bilge alarms and bilge pump are working.
- Test them every trip.
- Never silence a bilge alarm without fixing the problem.
- During fishing operations, keep closed any doors and hatches that do not need to be open.
- Keep all doors and hatches free of lines, wires and obstructions.
- Ensure all hatches are fully secured and dog'd down when they need to be.

Shifting catch or fishing gear

Shifting catch

When your catch shifts – whether it is bulk, boxed or while it is being loaded on board – it can significantly reduce your stability. It must be kept on the centreline, or balanced port and starboard. Fish in bulk can also act like water and slide with the roll to produce a free-surface effect. Secured pound boards are essential to keep the catch adequately stowed.

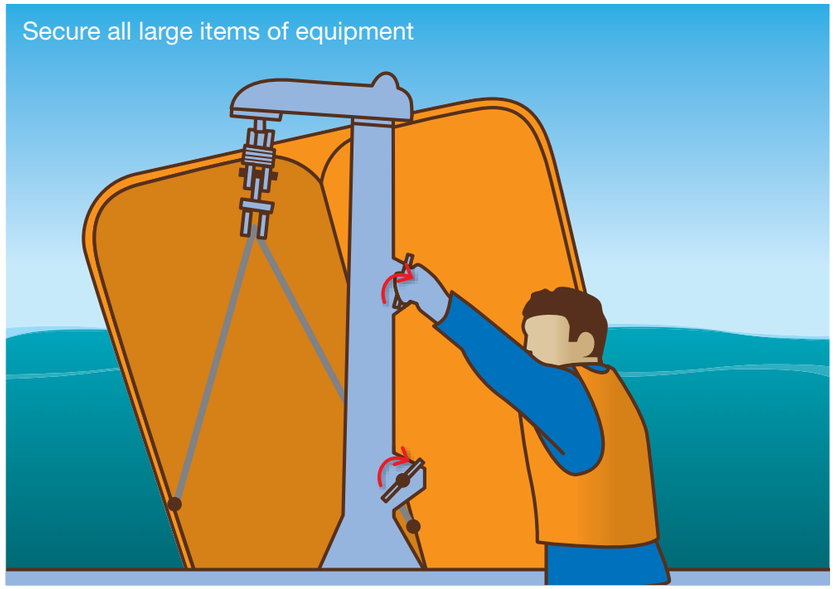
A shift to one side or another of boxed catch (or a stack of pots or cages) can also cause a list to port or starboard, which will reduce the vessel's stability safety and the angle of roll it can survive. In all weather conditions, you must ensure the catch is safely secured. Sorting it out in bad weather or while crossing a bar is dangerous, and most likely impossible.



Shifting fishing gear

Fishing gear must also be well secured. Any loose gear will be dangerous on deck and dangerous to the stability of the boat.

Cages, pots and other gear stored on deck must be kept as low as possible and secured to withstand wave impact, rolling and wind loading. Any shifting gear is a major hazard for the crew and the safety of the vessel.

Trawl doors, spare equipment and other heavy items stored in exposed high positions must be securely made fast. Keep the stowed positions as low as possible and avoid the weight of heavy items being transferred by lines to higher blocks and pulleys.

Ensure heavy items are secured with fastenings that are strong enough to withstand the loads they are exposed to in heavy weather. Swinging derricks and stabiliser boom arms must all be made fast to prevent movement.