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Acknowledgements

"They that go down to the sea in ships, that do business in great waters…."
Psalm 107:23

From my perspective, the FISH SAFE Stability Education Program has been 30 years in the making. Back in March 1975, it was the loss of 10 vessels in one herring season, including my father's fishing vessel the Bravado off the BC coast, that raised many questions about what contributes to a capsizing. Are they operational issues?\ Structural issues? Both? That same year, a special enquiry into vessel capsizings identified vessel stability as a key contributing factor and recommended a national program for stability education.

The Fish Safe Stability Education program is designed for fishermen and their unique operating conditions and we hope it will provide answers and practical knowledge on stability. This handbook is only one component of this long-awaited education program developed to answer questions, limit the number of capsizings and save lives at sea.

We would like to thank all those who assisted in developing this program by providing funding and their expertise.

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Stability is a vessel's ability to return to the upright when heeled by external forces such as wind and waves. Regulatory agencies like Transport Canada determine stability criteria based on what has been shown to work. Naval architects use that criteria to design vessels that will have adequate stability throughout all anticipated fishing conditions.

Your business is to understand the basic principles of stability and make them central to your every day reality when making any decision that affects your vessel's operations. Stable vessels don't capsize.

When a fishing vessel capsizes the Transportation Safety Board investigates and writes a report that includes causes, findings and recommendations. A report from 2001 indicates many investigations have revealed that fishing vessel operators do not have an appreciation for the factors affecting the stability of their vessels, particularly those factors which can be significantly influenced by their operating practices.
(TSB Report No. M01W0253)

A recent TSB Report also suggests that a "true **safety culture**" in the fishing industry can reduce the number of vessel incidents. Developing a safety culture includes stability education, risk awareness and understanding that with every incident there is a lesson to be learned. Transport Canada, educators, fishing associations, fishermen and their families need to coordinate, cooperate and converge in the effort to promote a safety culture.

Fishing Vessel Stability – Make it Your Bussiness presents fundamental principles of stability that will inform your fishing operations and ensure that your vessel always has adequate stability. Lessons learned speak throughout The Stability Handbook. If we listen, unnecessary loss and tragedy can be prevented.

"Unsafe practices are not carried out with the intention of jeopardizing the safety of the vessel and crew. Rather they are carried out by individuals who mean to operate their vessels in a safe manner but who, for a number of reasons, do not fully appreciate the risks associated with such practices." (TSB Report No. M02W0147)

Stability: *a vessel's ability to return to the upright when heeled by external forces.*

Culture: *the predominating attitudes, shared beliefs and behaviour that characterize the functioning of a group or organization.*

Questions *for discussion*

1. Write down one question you have about fishing vessel stability.

2. What do you think a **safety culture** means? Do you think that commercial fishing can achieve a safety culture with shared beliefs about safety?

3. If you have ever had a “near miss” involving vessel stability, what were the events that occurred?

4. Do you think vessel stability is a shared responsibility between the owner, skipper and crew? Why?

5. Do you believe a serious marine incident will never happen to you? Why or why not?

6. What do you think the most important thing is that fishermen need to know about stability?

7. Do you fully understand the stability characteristics of your fishing vessel? Explain your answer.

8. If you were to give another fisherman some advice about stability, what would you offer?

9. Would you feel comfortable giving your crew a stability briefing? Or, if you are a crew member, are you comfortable asking your skipper questions about stability?

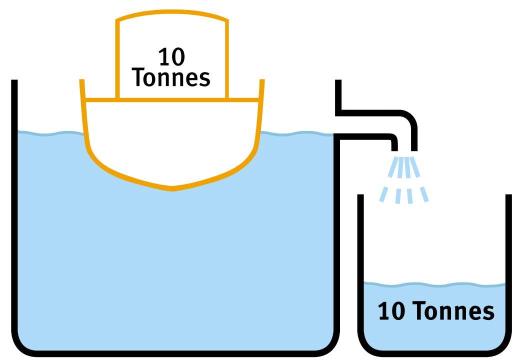
10. With regard to stability, what do you think is more important, the stability principles and the vessel, or the operating practices during fishing and traveling?

WHY FISHING VESSELS FLOAT... *why the goldsmith was beheaded*

The easy answer to "why do fishing vessels float?" is "because they don't leak or have a hole in them". Although this is true, Archimedes – the guy who while taking a bath exclaimed *eureka* - gave us a more detailed explanation known as **Archimedes' Principle**.

If you take a solid piece of metal and drop it into water, it will sink to the bottom. However, take the same piece of metal, flatten it and form it into the shape of a ship so that the volume it occupies is sufficiently increased, it will float. The same weight of metal when formed into a ship shape will put aside or displace a greater volume of water. This is called **volume of displacement.**

Lower a fishing vessel that weighs ten tonnes into a tank of water as shown in the picture below. If an open valve is arranged as illustrated, the water displaced can be collected in a container and weighed. It will weigh ten tonnes which is the weight of the fishing vessel. This what the term **displacement** means – a vessel will displace a weight of the liquid it is floating in equal to its own weight.

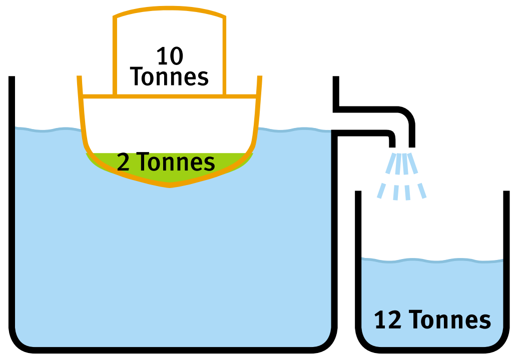


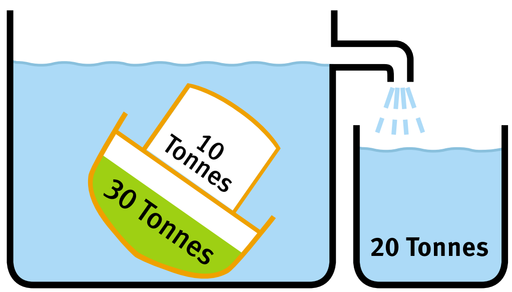
The volume of the liquid displaced will be equal to the vessel's underwater volume.

TALK THE TALK

Gross tonnage
Net tonnage
Lightship displacement
Deadweight
Displacement
Freeboard
Draft
Draft marks
Mean draft
Reserve buoyancy
Density
Archimedes' Principle
Beheaded

Note: Stability books can include metric or imperial units.
You will find both used in this handbook.





Add two tonnes of fish to the vessel. Then exactly two tonnes more water would be displaced for a total of 12 tonnes. When weight is loaded onto a vessel both the volume of displacement and the displacement weight are increased.

Add 30 tonnes of fish. The vessel will sink deeper trying to displace 40 tonnes of water. However the entire volume of the vessel cannot match a volume displacing 40 tonnes of water, and will sink – the vessel's own weight and catch included cannot exceed 20 tonnes.

Why Was the Goldsmith Beheaded?

Archimedes was on retainer by King Heiro of Syracuse (around 250 BC). Heiro had given the goldsmith the exact amount of gold he wanted in a new crown. After the crown was made the king suspected that it might not have as much gold in it as it was supposed to. So the king summoned Archimedes to verify his suspicions. Archimedes figured that a gold crown should displace a certain amount of water.

Archimedes plopped the king's new crown into water and determined that the crown displaced less water than the same weight of gold should have displaced. It displaced less water because the gold had been mixed with silver which is less dense revealing that the crown was not pure gold and the goldsmith was perhaps trying to fiddle the deal with the king to advance his own pocket.

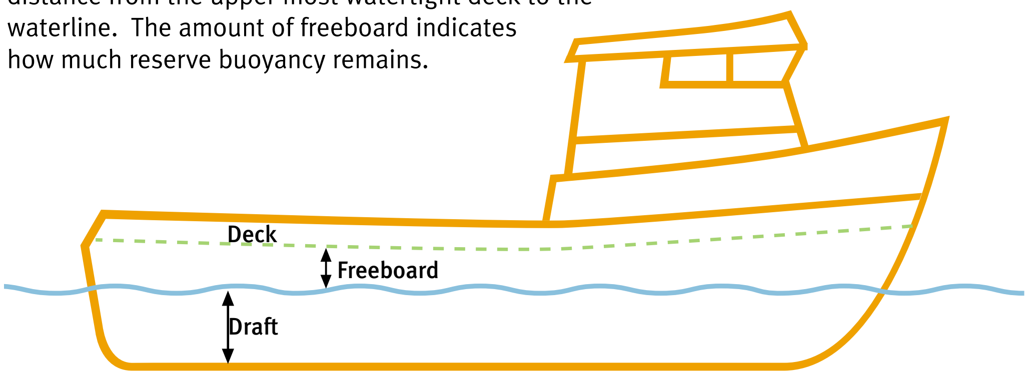
The goldsmith was immediately beheaded.

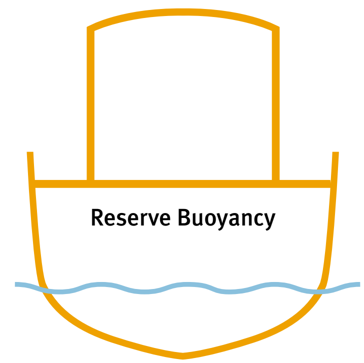
To Summarize Archimedes' Principle:

- A vessel displaces a volume of liquid equal to its underwater volume.
- A vessel displaces its own weight of the water it is floating in.
- If a vessel displaces its own weight before displacing its underwater volume, it will float.

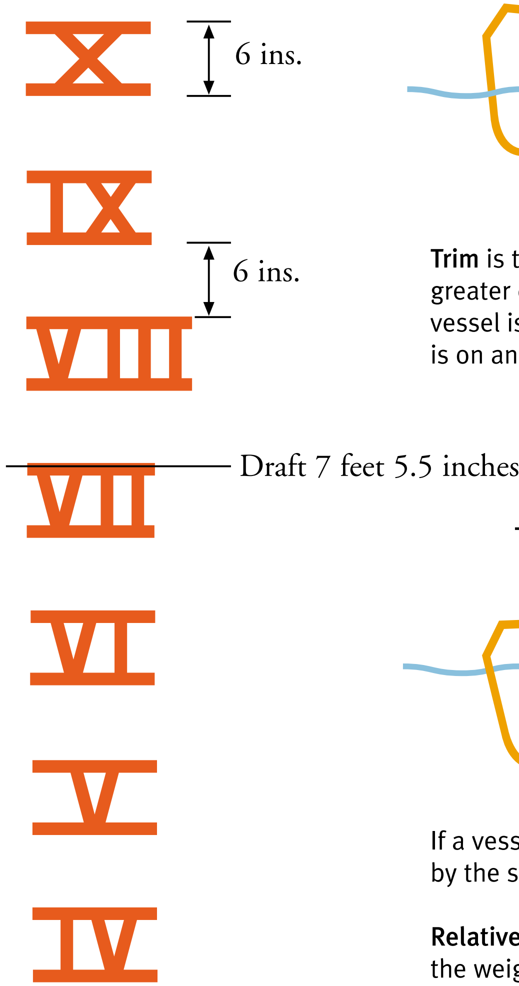
The volume of a fishing vessel up to the waterline is the buoyant volume. **Reserve buoyancy** is the volume of the vessel's hull above the waterline to the upper most watertight deck. The **freeboard** of a fishing vessel is the distance from the upper most watertight deck to the waterline. The amount of freeboard indicates how much reserve buoyancy remains.

A vessel's **draft** is the distance from the keel up to the waterline in any condition of load. Some larger fishing vessels have draft marks on the hull, forward and aft. Draft marks are read from the bottom of the numeral, and the numerals are 6 inches high (10 centimetres if metric drafts are given). **Mean draft** is the total of the draft forward and draft aft divided by two.

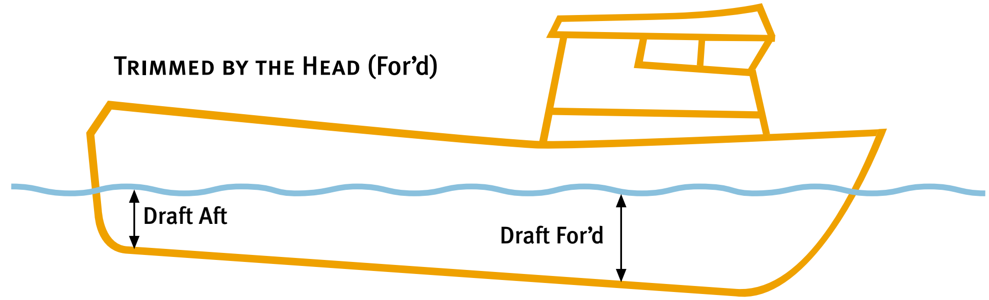




Draft Marks

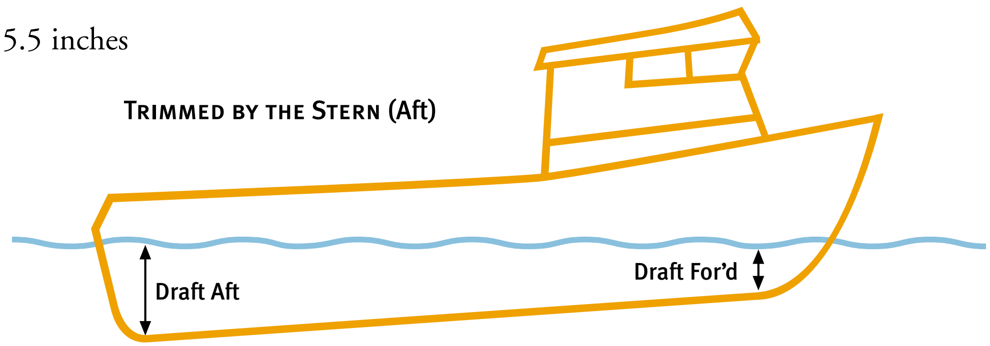


Trimmed by the Head (For'd)



Trim is the difference between the forward draft and the aft draft. If the vessel has a greater draft forward it is trimmed by the head. If the greater draft is at the stern the vessel is trimmed by the stern. If the drafts are the same forward and aft the vessel is on an even keel.

Trimmed by the Stern (Aft)



If a vessel has a forward draft of 4 feet and the draft aft is 6 feet it is trimmed 2 feet by the stern.

Relative density is defined as mass per unit volume. It is the comparative ratio of the weight of a substance shown against the weight of fresh water when both weights occupy the same volume.

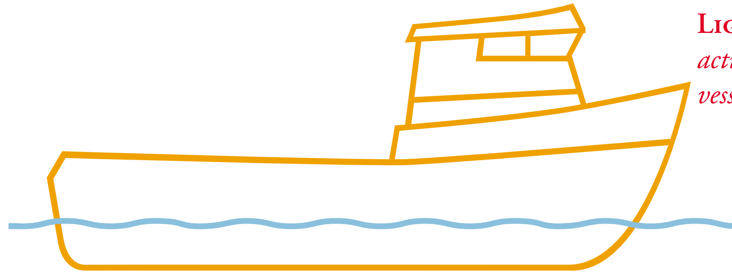
For example, the density of fresh water is 1.000. This means that one cubic metre of fresh water weighs one metric tonne. The density of salt water is 1.025, so one cubic metre of salt water will weigh 1.025 metric tonnes.

Three other terms that you need to know are: **lightship weight, deadweight,** and **load displacement.**

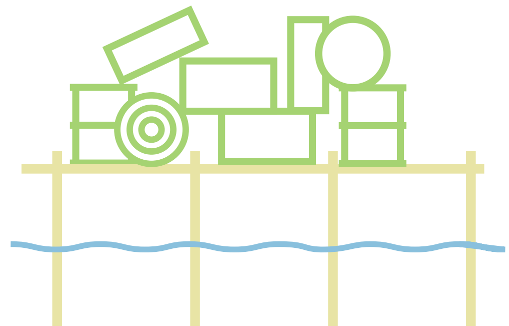
The term **gross ton** is a measurement of space not weight. One gross ton is equal to 100 cubic feet. Spaces that cannot carry cargo (for example crew accommodation space) may be "deducted" from the gross tonnage to get what is called **net tonnage.** A vessel's net tonnage is generally considered to be the space that can carry cargo and thus is revenue producing.

Why is a Gross Ton 100 Cubic Feet?

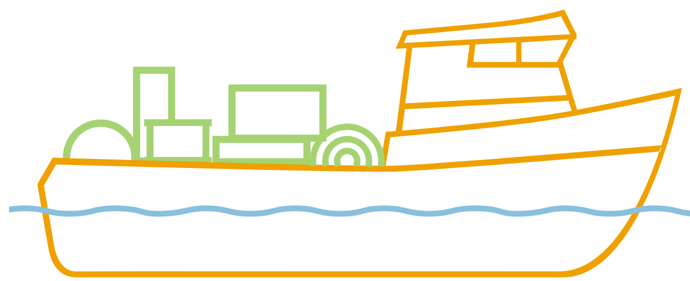
Originally wine was carried in vats or casks that were called "tuns". One tun of wine occupied approximately 100 cubic feet. Taxes were levied on wine carrying ships with the amount being based on the number of tuns of wine the ship could carry.



Lightship Weight: *actual weight of a vessel when empty.*



Deadweight: *actual amount of weight that a vessel can carry when loaded to the maximum permissible draft.*



Load Displacement: *lightship + deadweight = load displacement*

QUESTIONS *for discussion*

1. In your own words describe **Archimedes' Principle**.

2. Define **light displacement**, **deadweight**, and **load displacemen**t. If a boat has a light displacement of 80 tonnes and a loaded displacement of 100 tonnes, how much deadweight is on board?

3. If a fishing vessel's light displacement is 50 tonnes and 5 tonnes of fuel is taken on, and 10 tonnes of fish are loaded, what is the load displacement?

4. What is **freeboard** and why is it important?

5. If a vessel has a draft forward of 4 feet, and a draft aft of 6 feet, what is the **mean draft**?

6. What is the density of salt water? Explain your answer.

7. What is **gross tonnage**?

8. How do you read the **draft** of a vessel from the **draft marks**? Sketch your answer.

9. A vessel has a draft forward of 5 feet and a draft aft of 3 feet. What is the trim, and is the vessel trimmed by the head or by the stern?

10. Do you think the ark could have held all the animals and still have had sufficient r**eserve buoyancy**?

As a fisherman you already understand many of the terms and definitions in this chapter. *"Talking the talk"* is about putting proper names to what you may already know intuitively from experience, and explaining how all the terms and definitions work together to describe some principles of fishing vessel stability.

A stability "vocabulary" will enable you to discuss stability with a naval architect and other fishermen, and make sound operating decisions in your fishing operations.

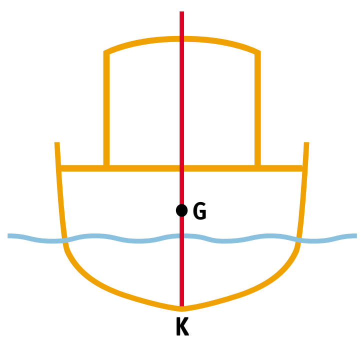
Transverse Stability

Stability is defined as a vessel's ability to return to the upright when heeled by an external force. The terms, definitions and principles in this chapter come under the general heading of **transverse stability**. There are other considerations that relate to **longitudinal stability**.

Centre of Gravity

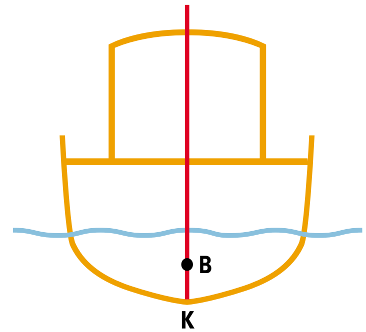
The **centre of gravity** (G) is the point at which the weight of the vessel and everything on board can be said to act vertically downwards through. The centre of gravity will *move towards weight added, and away from weight discharged*.

The **force of gravity** is equal to the displacement weight of the vessel in any particular condition of load.



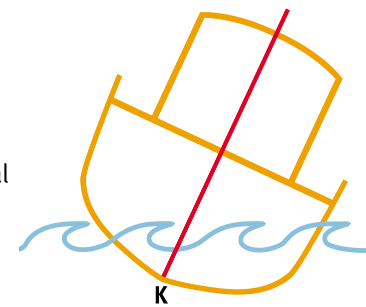
Centre of Buoyancy

The **centre of buoyancy** (B) is at the geometric centre of the underwater portion of the vessel. Because the shape of the hull is known, a naval architect can calculate where the centre of buoyancy is in different conditions of load and degrees of heel. The force of buoyancy acts upward and is equal to the displacement weight of the vessel in a particular condition of load.



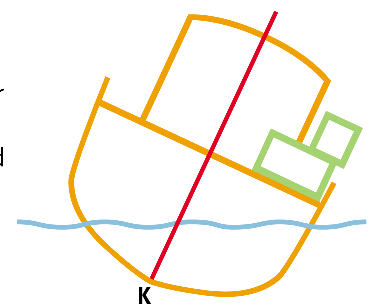
Heel

The term **heel** refers to the number of degrees a vessel is inclined from the upright by an external force such as wind or waves.



List

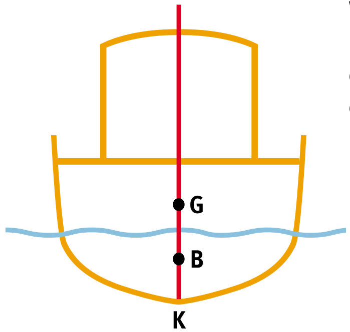
A vessel has a **list** when inclined by the off center loading of weights. A vessel with no list is said to be "on an even keel."



Talk the Talk

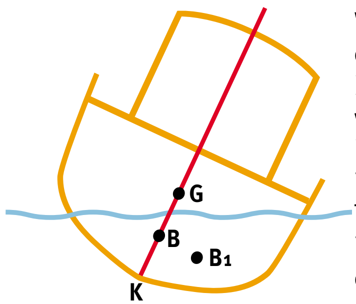
Centre of gravity
Centre of buoyancy
Heel
List
Metacentre
GM
GZ righting lever
Moment of statical stability
Stiff
Tender
Moment

Vessel in the Upright Condition



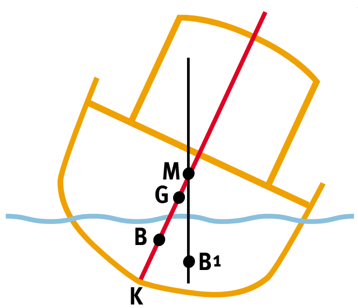
When a vessel is floating upright in still water the centre of buoyancy (B) and the centre of gravity (G) will be vertically in line over the keel (K).

The Shift of B to B1



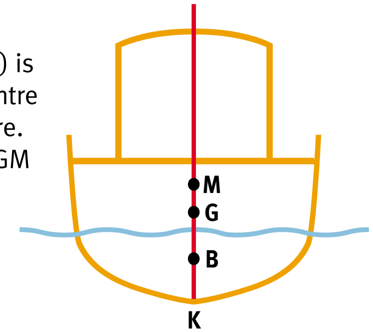
When a vessel is heeled by an external force, a wedge of buoyancy is brought out of the water on one side, and a similar wedge of buoyancy is immersed on the other side. The centre of buoyancy, which is always at the geometrical centre of the underwater portion, will move to B1.

Metacentre



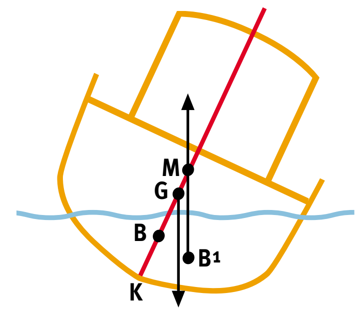
Vertical lines drawn from the centre of buoyancy (B1) at consecutive small angles of heel up to about 15°, will intersect the vessel's centreline at a point called the **metacentre** (M). Think of the metacentre as being a pivot point that the vessel inclines around at small angles of heel.

Metacentric Height



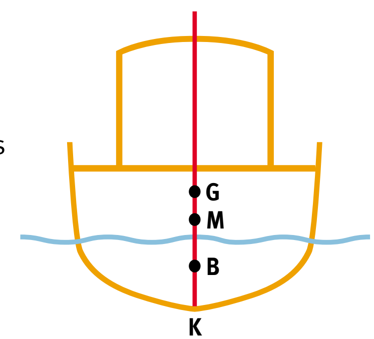
The **metacentric height** (GM) is the distance between the centre of gravity and the metacentre. If G is low in the vessel the GM will be greater than if G is higher in the vessel.

Stable Equilibrium



A vessel is **stable** if it tends to return to the vertical upright position when heeled. For a vessel to be stable, M must be above G, and the vessel is said to have positive GM.

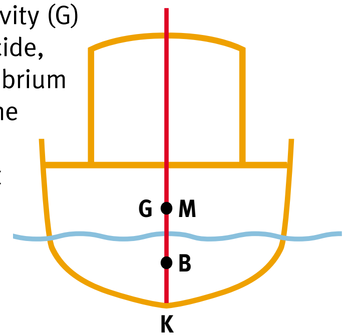
Unstable Equilibrium



If G is above M the vessel is said to be **unstable** and has a have negative GM. When a vessel with negative GM is heeled, it will tend to heel further over and could be in danger of capsizing.

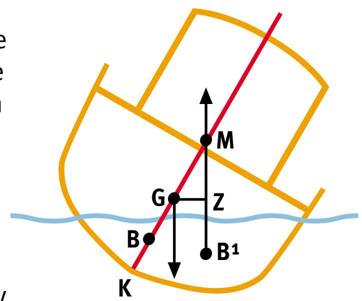
Neutral Equilibrium

When a vessel's centre of gravity (G) and the metacentre (M) coincide, the vessel is in neutral equilibrium meaning there is no GM. If the vessel is inclined to a small angle it will tend to remain at that angle of heel.



Righting Lever

When a vessel is heeled by an external force, the centre of gravity (G) remains in the same place if all weights on board are secure and do not shift. The centre of buoyancy (B) will move to the *geometrical centre of the underwater volume* to B1. Now the force of gravity will act vertically downwards, and the force of buoyancy will act vertically upwards.

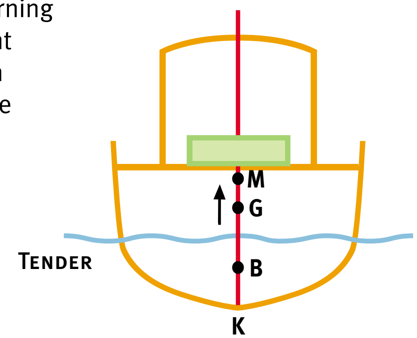


The horizontal distance from the centre of gravity (G) to the vertical line from B1 is called the **righting lever**. The length of the righting lever can be measured, and is often called GZ, or the GZ righting lever.

"At the time of departure, the vessel was heavily laden with traps and gear on deck which raised the vessel's centre of gravity." (TC Report No. 495)

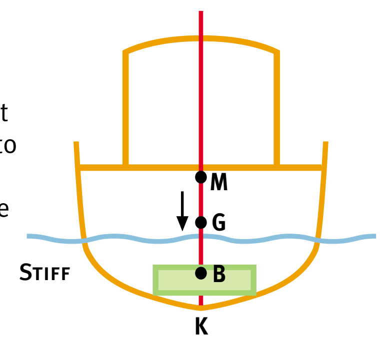
Tender Vessels

Vessels are sometimes described as being tender or stiff. If fish or other weights are added on deck or higher in the vessel, the centre of gravity (G) will move towards the weight added and decrease the metacentric height (GM). A **tender** fishing vessel has a small GM, will be easily heeled, and return slowly to the upright. If the vessel "hangs" at the end of each roll before returning to the upright, weight should be lowered in the vessel to increase the GM.



Stiff Vessels

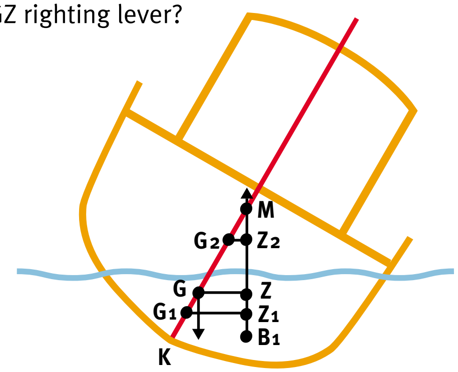
Weight added low in the vessel will cause (G) to move down towards the weight added, thus increasing GM. A **stiff** vessel has a large GM, is comparatively difficult to heel, and will return to the upright quickly.
A very stiff vessel can be quite uncomfortable.



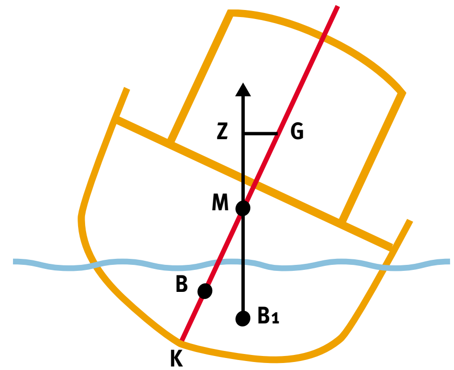
A Question

Look carefully at the picture below. GZ is the initial righting lever. If weight is added low in the vessel a new longer righting lever G_1Z_1 occurs. And if weight is added high in the vessel the righting lever is shorter, shown as G_2Z_2.

What general conclusions can you make about the relationship between metacentric height (GM) and the length of the GZ righting lever?

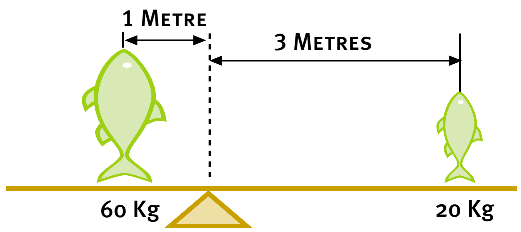


Describe what has happened in the illustration below.



What is a Moment

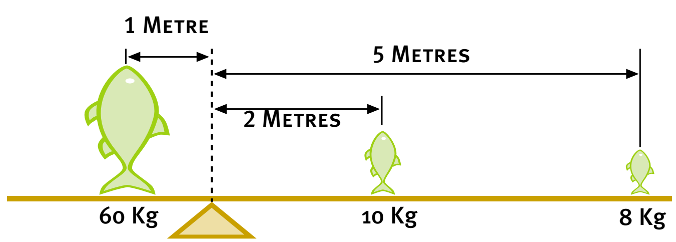
A **moment** is the combination of a distance and a force. A simple concept of moments can be shown with a picture of a seesaw.



The fish on the seesaw do not have the same force because they do not weigh the same amount. Why is the seesaw balanced? Because the big fish is two metres from the fulcrum point and the little fish three metres from the fulcrum point - which means their weight x the distance they are positioned from the fulcrum point have created the same **moment**.

big fish: 1 metre x 60 Kgs = 60 Kg/metres
little fish: 3 metres x 20 Kgs = 60 Kg/metres

We can also get the seasaw to balance if we load two weights at certain distances so that the total moments equal the total moment on the other end of the seasaw.



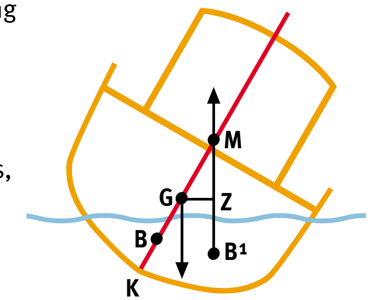
moment = 10 Kg x 2 = 20 tonne/metres
moment = 8 Kg x 5 = 40 tonne/metres

total moment = 60 Kg/metres

Another example of a **moment** is when a person jacks up a car to change a flat tire. The weight of the person acting on one end of the jack (which has a certain length) is creating a moment of force. A very small person might have difficulty jacking up a car. The solution would be to get a longer jack (or gain a lot of weight and come back later to fix the tire).

Moment of Statical Stability

Vessels return to the upright because the force of gravity acts downwards through (G), at the end of a distance which is the length of the GZ righting lever. Remember that the force of gravity acting downwards is equal to the displacement weight of the vessel. The length of the GZ righting lever depends on where the centre of gravity is, *which depends on how the vessel has been loaded.*



displacement = 60 tonnes
GZ = 1.2 metres
60 tonnes x 1.2 metres = 72 tonne/metres
∴ moment of statical stability = 72 tonne/metres

"The centre of gravity was raised because the load was stacked and secured on deck."
(TSB Report No. M96L0037)

"A larger seine net was being used (which was found to weigh 7.4 tonnes). This weight was heavier than the seine net usually carried, which weighed approximately 4.5 tonnes. The nets were routinely stowed on the power drum located 1.75 metres above the main deck, where their weight effectively raised the vessel's centre of gravity."
(Reflexions Issue 21, March 2004, p. 3)

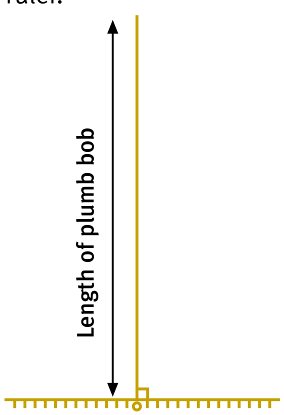
QUESTIONS *for discussion*

1. Sketch a vessel with positive stability showing the relative positions of the **centre of gravity, centre of buoyancy, keel** and **metacentre**.
2. What is the difference between a **list** and a **heel**?
3. What happens to a vessel's centre of gravity if weight is added high up? What then also happens to GM?
4. Sketch a stable vessel heeled showing the **GZ righting lever, metacentre, centre of gravity, centre of buoyancy and B1**.
5. Why is the position of the centre of gravity so important to vessel stability? How can a skipper control the height of the centre of gravity?
6. What does the roll period of a vessel indicate to a skipper if it is very slow? If the roll period is very quick?
7. What can make a fishing vessel unstable? Sketch your answer.
8. Describe events that might occur during a fishing trip that could cause a vessel to become unstable.
9. What is the **moment of statical stability**, and what determines the force of that moment?
10. A vessel has a KG of 7.4 feet and GM of 1.0 feet. What is the KM?
11. A vessel's KG is 6.9 feet and KM is 7.2 feet. What is the **GM**?
12. A vessel's KM is 8.1 feet and GM is 1.4 feet. What is the KG?

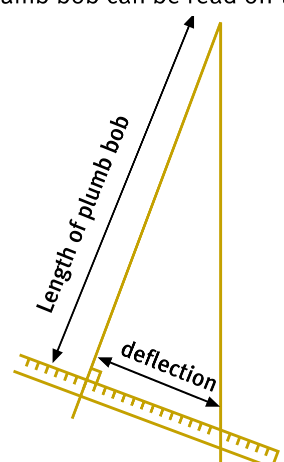
In the previous section you worked with *hypothetical* values for KM, GM, and KG and it was shown that if you know any two of these values, the third can be calculated. This section will explain how the real value for GM is determined by an inclining experiment and then how the actual centre of gravity of the vessel can be established in lightship condition. This section will also explain how a stability book is developed, and the information it contains, including notices to skippers about the stability of their vessel. Finally the roll period test will be explained, including its limitations.

THE INCLINING EXPERIMENT

An **inclining experiment** consists of shifting known weights transversely across the deck of a vessel through a known distance. The vessel must be free to heel when the weights are shifted. A measured plumb bob line is suspended amidships from a cross beam in a hatch. A graduated ruler is placed below the plumb bob with zero under the bob so that when the vessel is heeled, the deflection distance of the plumb bob can be read off the ruler.



VERTICAL UPRIGHT



VESSEL HEELED BY SHIFTED WEIGHT

For optimum accuracy, a minimum of eight weight shifts is made and deflections noted and tabulated:

SHIFT	WEIGHTS	DIRECTION	DEFLECTION
1	1,000 lbs.	P to S	2 5/16"
2	1,000	P to S	2 1/4"
3	1,000	S to P	2 5/16"
4	1,000	S to P	2 1/4"
5	1,000	S to P	2 1/4"
6	1,000	S to P	2 1/4"
7	1,000	P to S	2 5/16"
8	1,000	P to S	2 1/4"

total deflection $\dfrac{18.1875''}{8}$

∴ mean deflection 2.27"

In the following formula:

w = the weight moved

d = the distance through which the weight is moved

W = the displacement of the vessel at the drafts *as inclined*

$$GM = \frac{w \times d \times \text{length of pendulum}}{W \times \text{deflection of pendulum}}$$

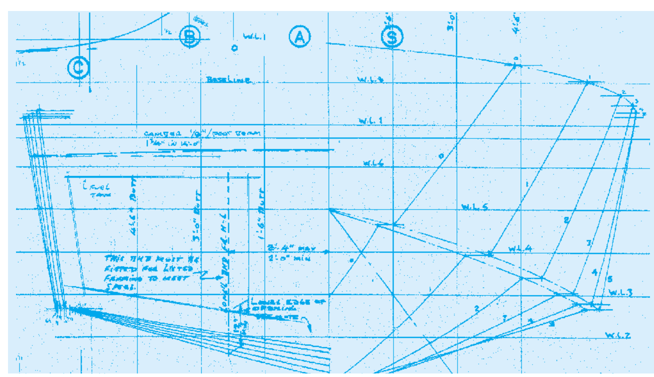
$$GM = \frac{1000 \times 19.83' \times 108.375''}{(2240 \times 155.22) \times 2.27''}$$

(The vessel in this example has a displacement of 155.22 tons)

2240 x 155.22 tons = 347692.8 lbs.

GM = 2.72' (Regulation requires that initial GM should not be less than 1.15')

The naval architect conducting the inclining experiment must have a set of **lines plans** for the vessel. These plans show the actual shape of the vessel hull.

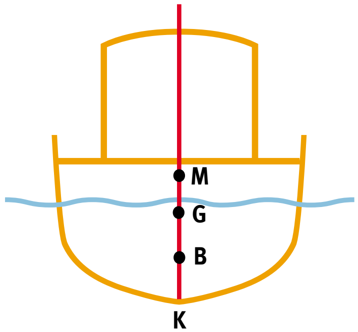


TALK THE TALK

Inclining experiment
Lines plans
Naval architect
Stability book
STAB 4
Stability curves
Area under curve
Tank soundings
Limiting KG
VCG
Notice to Skipper
Roll period test
Limitations to roll period test
Hydrostatic curves
Tonnes per CM immersion (TPC)

Before doing the test, the drafts f orward and aft are taken, and with this information and the lines plans, the underwater **volume** can be determined and hence the displacement weight of the vessel as *inclined*.
If you do not have lines plans for your vessel, a naval architect can create them by taking certain very precise measurements of your vessel when it is out of the water and then entering that information into a computer that will generate lines plans information.

With the lines plans a naval architect can also determine where M is for the specific vessel being inclined.



KM determined by naval architect: 13.19 feet
GM determined from inclining experiment: 2.72 feet

KG = KM – GM
KG = 13.19 feet – 2.72 feet

∴ KG = 10.47 feet (the centre of gravity as *inclined* is 10.47 feet above the keel)

In practice when an inclining experiment is conducted, the vessel may not actually be in lightship condition. To get the actual lightship displacement and lightship KG, the naval architect will subtract weights not part of lightship, and make a correction to the as inclined KG to get lightship KG.

The Stability Book

Once the lightship displacement and KG have been determined, the vessel's stability characteristics in other conditions of load can be calculated. Remember from the last section that the centre of gravity moves towards weight added, and away from weight discharged. The naval architect has drawings that show how high above the keel in the vessel different weights are located, such as a drum on deck. There are also tank capacity tables that show the weight of fuel oil or fresh water at different levels. Today, stability calculations for different load conditions are for the most part done by computer and made available to the owner and skipper in the form of a **stability book**.

Transport Canada requires in addition to lightship condition, that certain other conditions of load, as noted in bold, have stability information calculated.

1. **Departure** – 100% Fuel Oil, Fresh Water, and Stores
2. **Arrival grounds** – 75% Fuel Oil, Fresh Water, and Stores
3. **Half load** – 55% Fuel Oil, Fresh Water, Stores, 50% Fish
4. **Full load** – 35% Fuel Oil, Fresh Water, Stores, 100% Fish (*)
5. Arrival port – 10% Fuel Oil, Fresh Water,
6. After discharge – 10% Fuel Oil, Fresh Water, Stores

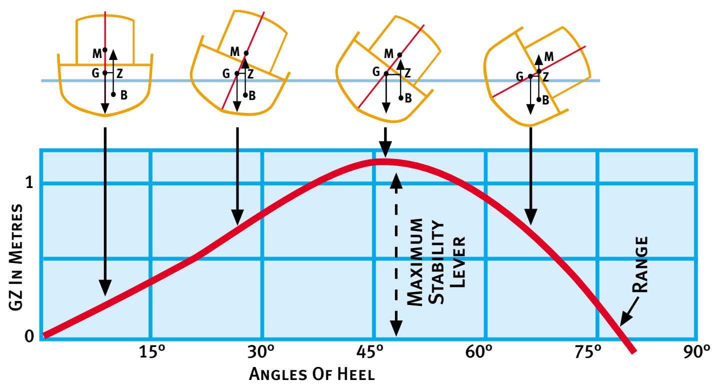
For the vessel above, conditions 5 and 6 have additionally been calculated. The "worst operating" condition must also be identified, which is the vessel in the above condition 4(*). This means that in condition 4 the vessel has the least amount of righting energy, although it still meets or exceeds minimum righting energy requirements, called Stability Standards for Fishing Vessels and referred to as **Stab 4**.

You can request that stability information be calculated for specific conditions of load that you know you operate in, but that are not required.

For each condition of load, stability information is calculated and presented as tables, graphs and stability curves.

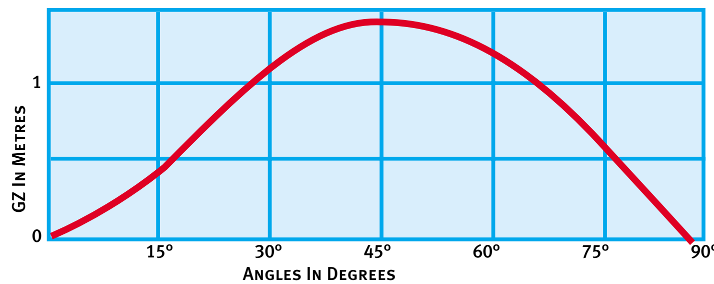
Stability Curves

Stability curves are drawn that show the righting levers developed in different conditions of load and angles of heel. In the example below the GZ righting lever at 10˚ of heel is about .25 of a metre. At just over 25˚ of heel, the righting lever is about .75 of a metre. The maximum righting lever occurs at just over 45˚ angle of heel, and is slightly over 1 metre. In a different condition of load the stability curve will look slightly different, but will still meet stability requirements.



STAB 4 requires that the righting lever GZ be at least 0.656 feet (0.2 metres) at an angle of heel equal to or greater than 30˚ angle of heel. Also, the maximum righting lever should occur at an angle of heel preferably exceeding 30˚ but not less than 25˚.

Different structural features will result in different stability characteristics such as the beam to draft ratio and the amount of freeboard. An increase in beam will result in an increase in the GZ righting lever at all angles of heel as shown below in comparison to the vessel in the previous illustration.



The area under the curve can be calculated and indicates the amount of righting energy a vessel has in that particular load condition.

Do the vessels in these illustrations meet the requirements of Stab 4 ?

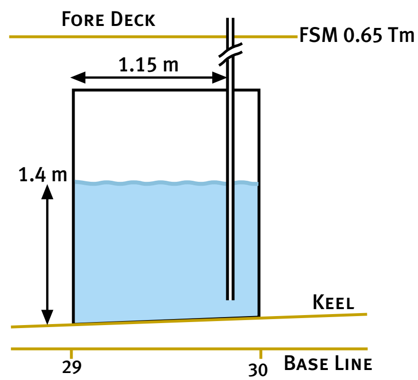
Limiting KG

Another way of presenting stability information is the concept of **limiting KG** which is a measure of the minimum stability required to ensure that a fishing vessel is stable throughout a voyage in different conditions of load. Remember that KG identifies how far above the keel the vessel's centre of gravity is located.

If the concept of limiting KG is used, the stability book will contain reference tables indicating changed values for weights in the various conditions of load. From these tables the vessel's KG can be calculated and compared to a predetermined curve of maximum acceptable limits to ascertain whether the vessel meets minimum stability requirements based on KG.

Below is an example of a fresh water tank capacity table. It is entered with the sounding obtained, which in this case is 1.4 metres. A sounding of 1.4 metres, from the table, means that the capacity at that sounding equals 1.70 tonnes. Also at that sounding, the VCG (vertical centre of gravity) of the 1.70 tonnes is 1.35 metres above the keel.

Fresh Water Tanks, Port and Starboard



Soundings (m)	Capacity (Tonnes)	VCG (m)	LCG (m)
0.2	0.1	0.65	4.7
0.4	0.2	0.75	4.72
0.6	0.4	0.85	4.74
0.8	0.65	0.95	4.77
1.0	0.95	1.15	4.8
1.2	1.30	1.25	4.82
1.4	1.70	1.35	4.85
1.6	2.1	1.45	4.88
1.8	2.45	1.55	4.91
2.0	2.85	1.65	4.94

The sounding information can then be entered into the following Displacement Table.

Displacement Table

Condition No. 5 Fishing 100% Catch 20% Fuel and Water

Item	Weight Tonnes (1)	VCG m (2)	Vertical Moment Tm (3)	LCG ford/aft amidship m (4)	Long-A1 Moment	Free Surface Moment (6)
Fresh Water	1.70	1.35	2.29	+ 4.85	+ 8.24	0.65
E. R. Wings FO	9.50	2.25	21.37	- 4.77	- 45.32	0.88
Lub, Oil	0.10	2.59	0.25	- 7.90	- 0.79	0.18
Crew & effects	1.00	4.00	4.00	+ 6.00	+ 6.00	—
Stores	2.00	3.00	6.00	—	—	
Provisions	0.40	2.00	0.80	+ 7.00	+ 2.80	—
Catch	24.00	2.60	62.40	+ 0.50	+ 12.00	
B Deadweight	38.70		97.11		- 17.07	1.71
C Lightship	148.46	3.48	516.61		- 96.00	
D Displacement	187.16	3.28	613.72	- 0.60	-113.07	

In this example Condition No.5 is for 100% Fish and 20% Fuel and Water. The sounding is greater than 20% capacity, and the prudent skipper wants to know if this extra water will adversely effect the vessel's stability.

The Displacement Table lists items on board. Each item listed in column 2 is located a certain distance from the keel and has its own vertical centre of gravity (VCG). Column 3 gives the vertical moment in tonne/metres of each item. Remember from the last section that a **moment** is a weight times a distance. In this case the VCG of each item is the distance.

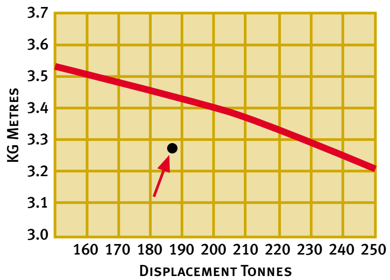
remember the formula moment = weight x distance

rearrange the formula $\text{distance} = \dfrac{\text{total moments}}{\text{total weight}}$

distance is the vessel's KG $\text{KG} = \dfrac{613.72 \text{ tonne/metres}}{187.16 \text{ tonnes}}$

the tonnes cancel and KG= 3.279 or 3.28 metres

Curve Of Limiting KG



In any condition of loading the KG from line D of the Displacement Table or as you just calculated, must lie within the area under the curve.

In Condition No. 5, with the actual amount of fresh water on board, the vessel's KG is 3.28 metres. Is this KG too high for adequate stability? Now consult the Curve of Limiting KG Table shown to the left. This curve tells us that in any condition of load the KG of the vessel must be below the curve indicated. Now enter the curve with the displacement of the vessel (187.16 tonnes) along the bottom, and the KG (3.28 metres) on the vertical. The black dot representing these two values is indeed below the curve of limiting KG and the vessel has adequate stability.

We want to know where the vessel's KG is given all the weights, each with their own vertical centre of gravity, including lightship displacement weight and the lightship KG.

Step 1: multiply the VCG and the weight to get vertical moment

Step 2: total the weights

Step 3: total the vertical moments

Item	VCG Metres		Weight Tonnes	Vertical Moment Tonne/Metres
Crew & Effects	4.0	x	1.0	
Lightship	3.48	x	148.47	516.61
Stores	3.0	x	2.0	
Catch Fish	2.60	x	24.0	
Lube, Oil	2.59	x	.10	
E/R Fuel/Oil	2.25	x	9.50	
Provisions	2.0	x	.40	
Fresh Water	1.35	x	1.70	
Vessel KG	?			
			Total Weight	Total Vertical Moments

$$KG = \frac{\text{total moments}}{\text{total weight}}$$

KG = ____________

Did you get the same answer as on the previous page?

Hydrostatic Information

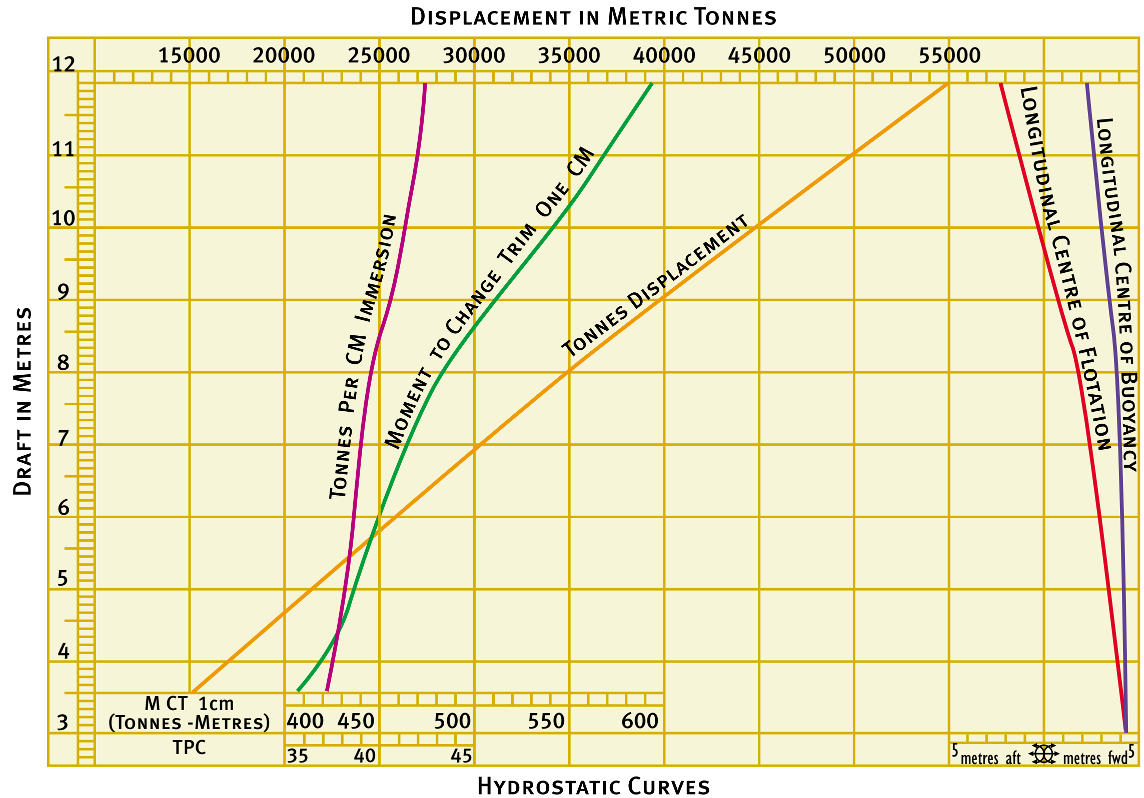
A stability book will also provide what is called **hydrostatic information** that is governed by the overall dimensions and underwater shape of the vessel. It may be presented in a table format, or more often as **hydrostatic curves**.

If the displacement of a vessel is required for a mean draft of 5 metres, locate the draft on the left hand vertical scale. Then draw a horizontal line through the draft to cut the Tonnes Displacement curve. Draw a perpendicular up to the horizontal scale at the top and read the displacement. In this example 22,000 metric tonnes.

The Tonnes per CM Immersion (TPC) curve tells you at a certain draft how many tonnes of deadweight added will increase the draft by 1 cm. Again, at a mean draft of 5 metres, move horizontally across to the TPC curve and drop a perpendicular to the TPC scale along the bottom. In this example it will take 38 tonnes to increase the draft of the vessel by 1 cm.

Hydrostatic curves are fundamentally the same in how they are used to obtain information that is relevant to the stability of a vessel. It is standard practice to assume the vessel is upright on an even keep, and floating is sea water with a density of 1.025.

Stability and Hydrostatic Curves



Notice to Skipper

A stability book, sometimes called a "trim and stability book", generally will have a section called **Notice to Skipper**. Here are examples of what you might expect to find in the notice.

1. The seagoing condition of operation set out in this book indicate that the vessel meets or exceeds the minimum stability requirements of Transport Canada for fishing vessels of this size. However, compliance with these minimum requirements does not ensure immunity against capsizing or foundering or absolve the skipper from his responsibilities with regard to prudence and good seamanship.
2. A high centre of gravity is detrimental to safe vessel operation and in heavy weather every effort must be made to reduce top weight such as lowering boom and stowing net in the hold.
3. Slack tanks should be kept to a minimum and bilges pumped out.
4. During the general operations of the vessel, weight additions must be kept to a minimum and any added weights should be placed as low in the vessel as possible. ***Care should be taken when stowing gear or fish to ensure that the vessel is not operated outside the conditions shown in this book.***
5. Use of oil, fuel and water, and filling of fishholds should be such as to ensure the minimum trim in any condition. Trim can be controlled by transferring F/W from one F/W tank to the other, either forward or aft whichever is required to minimize trim.
6. Before sailing care should be taken to ensure that the net and skiff are properly stowed and lashed down and that all manholes and hatches on the open deck have been securely battened down and that storm shutters have been fitted on the foc'sle hull side windows.

Note: The stability conditions in this book have been prepared based on the following:

1. There are 4.491 tonnes of permanent lead ballast at the forward end of the engine room.
2. A wet weight of seine net of 5.45 tonnes and skiff at 1.80 tonnes.
3. The net is on the drum in all working conditions.
4. The forepeak tank should be kept full at all times unless required for an emergency.
5. The full upright fee surface of two of the four fishhold tanks has been taken into consideration. To reduce the free surface effect it is recommended that the holds be filled to the hatch coamings whenever possible and that the two diagonal tanks be filled as quickly as possible. In filling the fishhold only two holds are to be filled at a time and the order of filling should be first one set of diagonal holds and the opposite two diagonal holds.
6. All openings in the superstructure are to be fitted with weathertight closing appliances. The first superstructure openings that are not fitted with weathertight closing appliances are the engine room vents.
7. In all conditions, and based on (6) above, the angle of downflooding is in excess of 40°.
8. When the boom exceeds 10° port or starboard of the vessel centreline, the stability of the vessel should be considered.

Vessels operating in trap fisheries could be expected to have a notice related to the number of traps and how they are placed on the vessel. Also, some vessels may have fuel oil transfer or ballasting sequences specified.

If your vessel has a stability book written for one fishery and you have modified the vessel for a different fishery, the conditions given in the stability book are no longer applicable, and a naval architect should be consulted. Keep in mind that operating outside of the parameters stated in the stability book, for example removing ballast that was part of the original calculations could in some circumstances have legal consequences if you are involved in an incident. It would be prudent to check your insurance policy to see if there is a clause that addresses vessel modifications other than as designed.

The Roll Period Test

It is possible to estimate a vessel's GM (metacentric height) by means of a **roll period test**. This has some value because GM is one measure of a vessel's stability. However, a roll period test is not a substitute for an inclining experiment, and the GM from a roll period test cannot be used to determine KG or to generate information about different conditions of load.

The roll period of a vessel depends on the beam of the vessel and height of the centre of gravity (KG). You can't do much about the beam, but you can endeavour to keep the centre of gravity low in the vessel by how you load it.

You can conduct a roll period test yourself. Select a calm day, secure all weights on board, and be sure there are no slack tanks. Loosen the mooring lines and set the vessel rolling by pulling on a masthead line from the wharf, or by getting several people to move athwartships in unison, or by having people forcibly generate free rolling of the vessel by pushing one side of the vessel down and then releasing it.

Use a stopwatch and time each complete roll period, which is from a start position full over to one side, over to the other side and then back to the start position. Repeat the procedure several times until the timed results are coming out consistently.

The formula for calculating GM is: $GM = \left(\frac{f \text{ x beam}}{\text{roll period}}\right)^2$

For example, the GM for a vessel with a beam of 5 metres, a roll period of 5 seconds, using .6 as the *f* coefficient would look like this:

$$GM = \left(\frac{.6 \text{ x } 5}{5 \text{ sec.}}\right)^2$$

$$GM = \frac{.6 \text{ x } 5}{5 \text{ sec.}}$$

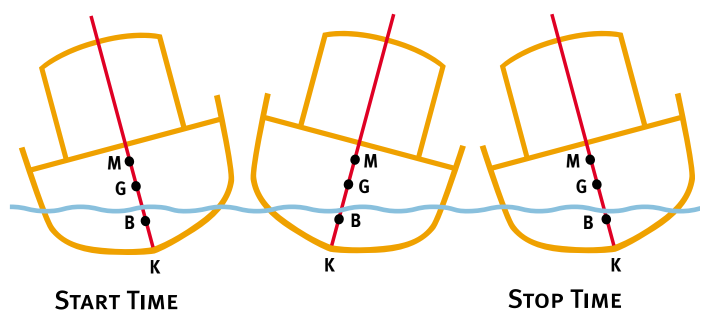
$$GM = \frac{3}{5} = .6$$

$$GM = .6 \text{ x } .6 = .36 \text{ metre}$$

To use this formula requires an *f* coefficient or factor. The *f* value may be anywhere from .6 to .8 depending on the design of your vessel. You might want to consult a naval architect as to what value they suggest you use based on your vessel. The beam is measured in metres and the roll period measured in seconds. What you use for the *f* coefficient will make a difference in the calculated GM. This is another limitation of the roll period test as an accurate indicator of stability.

Nonetheless a roll period test is a way you can monitor your vessel's GM. If at the beginning of each season you conduct a roll period test each time in a similar condition of load, and notice that the GM value is getting smaller, you might want to talk with a naval architect.

If you have a full inclining experiment done on your vessel, ask that a roll period test also be conducted. That way you have a roll period GM to compare roll period test results done the following year.



What it All Adds Up To

This section has presented a lot of information that included numbers and math calculations. You are not expected to be a naval architect and a whiz with the numbers. You are a fisherman and your job is to catch fish and make a living – *safely*. It is important though that you appreciate that the calculations and stability data that a naval architect presents in a stability book are not as obscure as they might look when you first open a stability book and try to make the information useful. Understanding a stability book begins with knowing the terms used and understanding what they mean. If this section has been confusing, talk with a friend and work through it again together.

You can't do much about the hull form of your vessel, but you are very much in control over the centre of gravity of your vessel by how you load it. In general terms the lower the centre of gravity the more stable your vessel will be. If you have a stability book, be sure you are familiar with the Notice to Skippers and operate accordingly. If you modify your vessel for a different fishery from what it was designed for, you should consult with a naval architect about how the modifications may affect your vessel's stability.

Conditions Necessary for the Inclining Experiment:

- *Mooring lines must be slack and the vessel clear of the dock so that it heels freely.*
- *The water must be smooth and there should be little or no wind.*
- *There should be no free surface water in the vessel, the bilges should be dry and tanks dry or pressed up fully.*
- *All moveable weights must be properly secured.*
- *All persons should be ashore except those actually engaged in the experiment.*
- *The vessel must be upright at the beginning of the inclining experiment.*

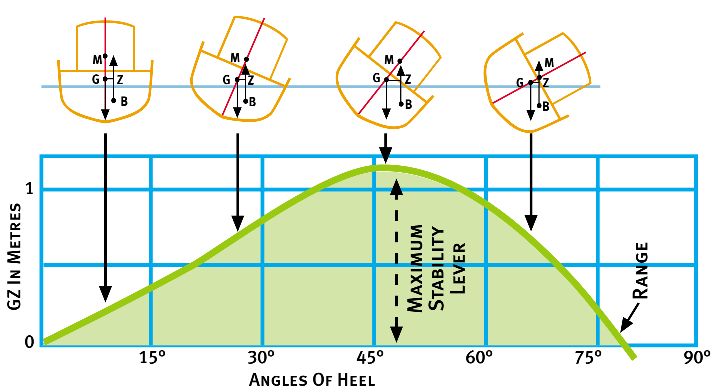
QUESTIONS *for discussion*

1. What information does an **inclining experiment** provide?
2. Why are **lines plans** necessary to conduct an inclining experiment?
3. What is meant by “worst operating condition” as indicated in a stability book?
4. In general terms what is meant by a **stability curve**?
5. What are some structural features that will affect a stability curve?
6. What is meant by a curve of **limiting KG**?
7. What information can be determined from a tank capacity table?
8. What information does a displacement table provide?
9. What kind of information is found in the **Notice to Skipper** included in a stability book?
10. What information does a **roll period test** provide, and what are the limitations of a roll period test?

The operation of a fishing vessel is considerably different from that of other commercial vessels who load in port and close the hatches until they are alongside to discharge cargo at their destination port. Catch and loading operations while at sea are a routine occurrence for commercial fishermen, often in less than ideal weather conditions.

Because loading for the most part is done at sea, it may be difficult to immediately observe the effect of the operation. You want to have a practical working knowledge of vessel stability, and know how to avoid operations or load conditions that sometimes, with no warning, can compromise a vessel's stability to the point of capsize.

In the last section we looked at how a naval architect determines a stability profile based on a vessel's KG in different conditions of load. The information is presented as tabulated data and with a righting curve that graphically shows the GZ righting lever at different angles of heel. The area under the curve represents the amount of *righting energy* a vessel has in different conditions of load and at different angles of heel.



When a fishing vessel capsizes it is generally not because of any one factor that has reduced the righting energy. It is the **cumulative** effect of multiple factors that have compromised a vessel's ability to return to the upright. This section identifies operating factors that, if combined, can lead to a fishing vessel capsize.

This section also talks about the factors that can compromise a fishing vessel's righting energy. The graphic presentations are not vessel specific, and only represent general principles about the loss of righting energy when factors that compromise vessel stability are present.

To help organize this information, factors that compromise stability have been grouped under four general headings:

- **Freeboard is Your Friend**
- **Free Surface**
- **Fishing Operations**
- **Stability and Weather**

Note: The examples on the following pages are pictorial representations of different factors that can compromise vessel stability. They are not intended to be an exact representation of how these factors effect any specific fishing vessel.

Talk the Talk

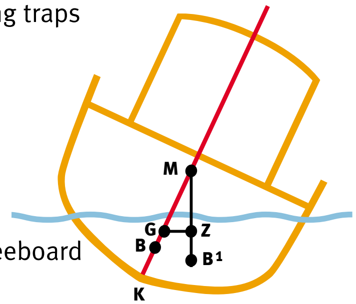
Deck edge immersion
Virtual rise of G
Downflooding
Angle of loll
Effect of suspended weight
Cumulative
Compromised stability
Effect of following seas
Effect of free surface
Towing
Shifting weights
Vessel modifications
Load height

FREEBOARD IS YOUR FRIEND... *why?*

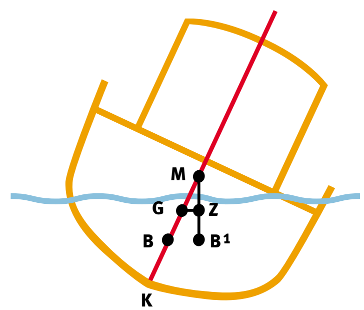
You cannot change the hull form of your vessel, which at different drafts determines the distance B will move to B_1 when the vessel is heeled, and thus the amount of righting energy available. However, as skipper and crew you are responsible for managing weight taken on board and how it is loaded.

How you manage weights on board determines the centre of gravity of your vessel and the vessel's righting energy. The center of gravity constantly changes because of how you load the vessel, the amount of consumables on board, fuel transfer and ballast sequencing, tanking down, fishing operations using the boom, towing a skiff, towing a trawl, or carrying traps for prawn, crab or black cod.

Condition 1: adequate freeboard



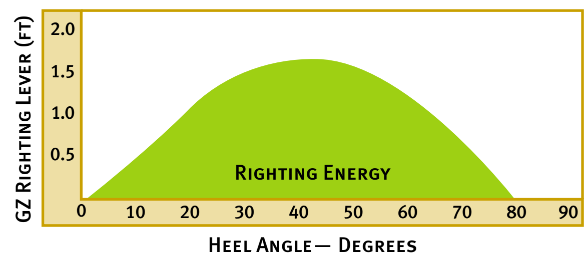
Condition 2: deck edge immersion

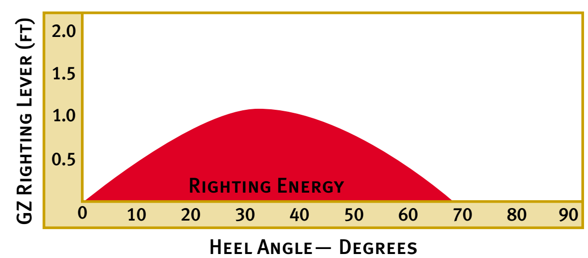


Always maintain adequate freeboard.

Deck Edge Imemersion

Transportation Safety Board investigations report that the lack of freeboard is consistently a major contributing factor in fishing vessel capsize. The reason is because deck edge immersion will happen sooner when there is reduced freeboard. When **deck edge immersion** occurs, the shape of the underwater portion of the hull changes, and dramatically reduces how far out to the low side B will move to B_1. This reduces the length of the GZ righting lever and the righting or energy available to return the vessel to the upright.





Overloading

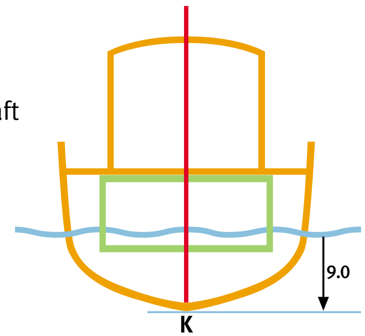
Overloading has been identified as another common cause of fishing vessel capsizings. If weight is on deck, the centre of gravity is higher. Added weight means the freeboard has been reduced and deck edge immersion will occur at smaller angles of heel.

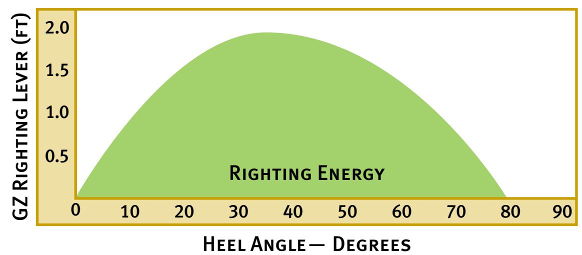
Vessels also get heavier as they get older. This can be due to accumulated equipment on board, and items stowed in the crew quarters, engine room, lazarette and on top of the wheelhouse.

"The cumulative weight of trawl fishing equipment and the additional gear stowed in the lazaret, on the wheel house top and lashed to the forecastle deck side railings, raised the vessel's centre of gravity and detrimentally affected the vessel's stability characteristics."

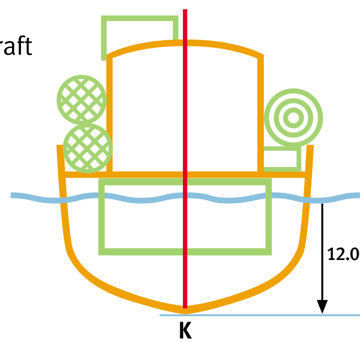
(TSB Marine Occurrence Report No. M97W0236)

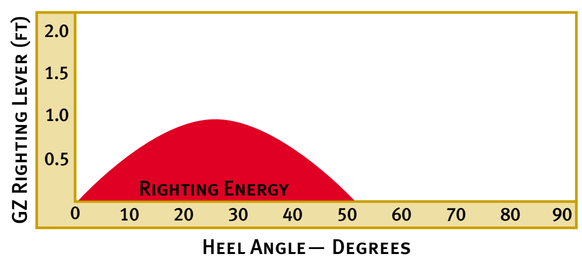
Condition 1: 9.0 foot draft





Condition 2: 12.0 foot draft



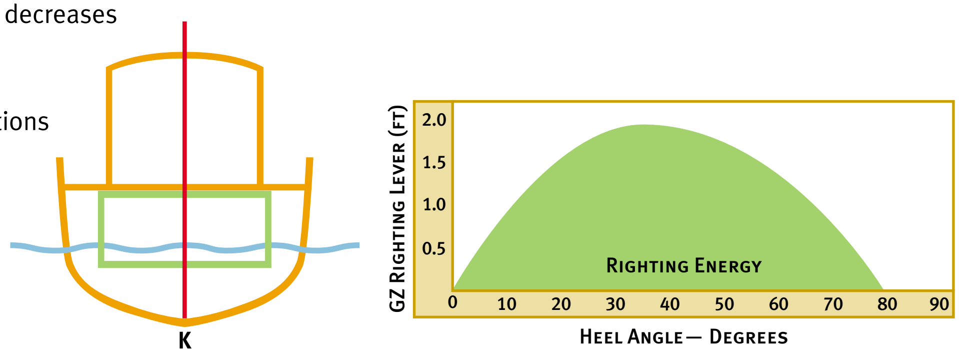


Overloading reduces freeboard.

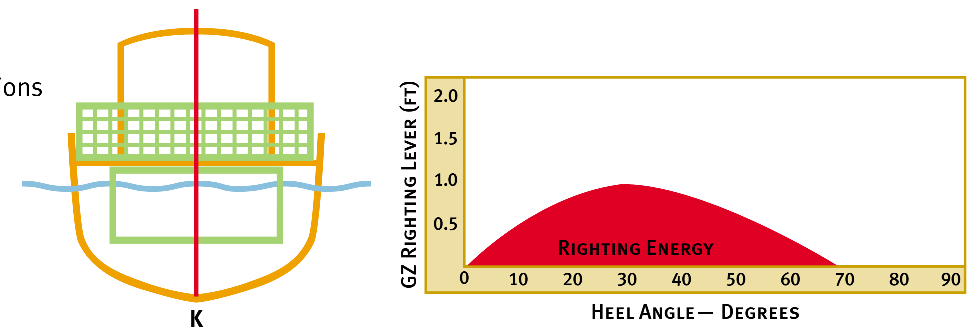
Vessel Modifications

When a vessel built for one fishery is modified to participate in a different fishery, the centre of gravity as designed is often raised due to adding additional gear. If the new fishery requires greater traveling distances, 45 gallon drums of fuel have on occasion been carried on deck. Carrying additional traps other than the number allowed by original design can also seriously compromise a vessel's stability and righting energy. This is because the exta weight increases the draft and decreases the freeboard.

Condition 1: before modifications



Condition 2: after modifications



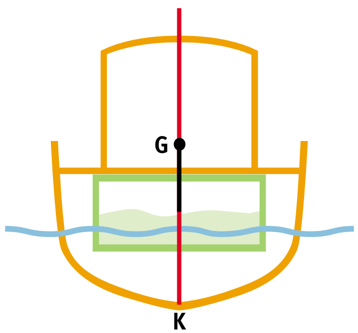
Get professional advice before making any major modifications to your vessel.

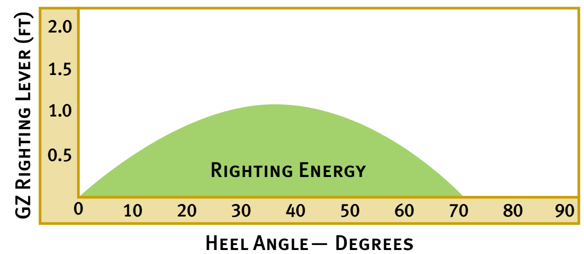
Load Height

Stowing the catch down below increases the vessel's stability, as opposed to carrying catch on deck which raises the centre of gravity. It is not just the height of the load carried, but fuel consumed will also increase the height of the centre of gravity. When traveling, seine nets are commonly stowed on deck or in the hatch to lower the centre of gravity and increase the vessel's righting energy.

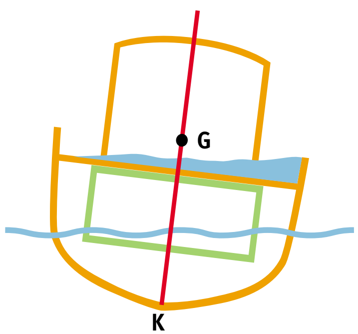
Larger vessels that have ballast tanks may have a Notice to Skippers in the stability book that give the acceptable sequence for fuel consumption, transfer and ballast operations. The naval architect has designed the vessel so that the instructions maintain optimum stability conditions.

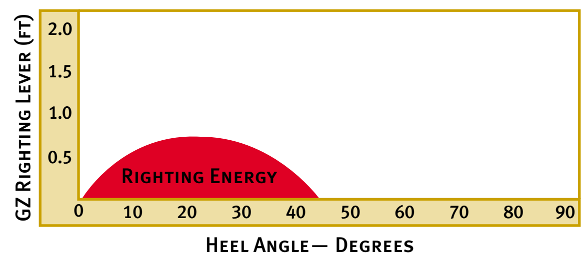
Condition 1: fish in hold half full (with centre line bulkhead)





Condition 2: fish on deck



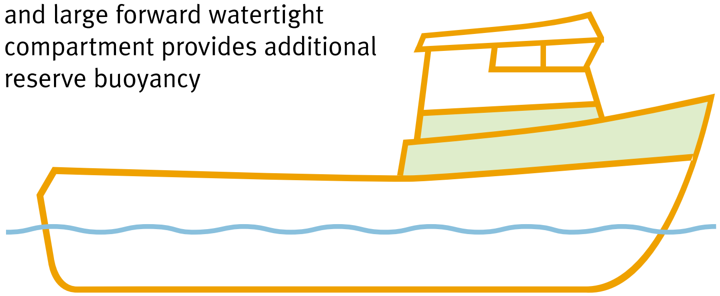


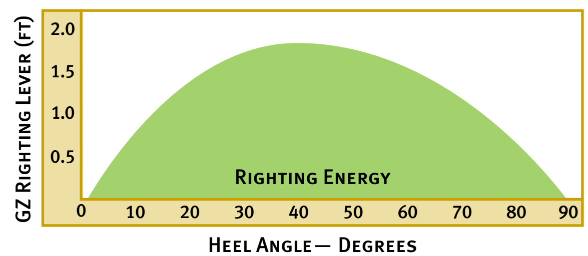
Reserve Buoyancy

Newer vessels are constructed with lots of **reserve buoyancy**. Look at your vessel and think about how much reserve buoyancy you have when the boat is fully loaded.

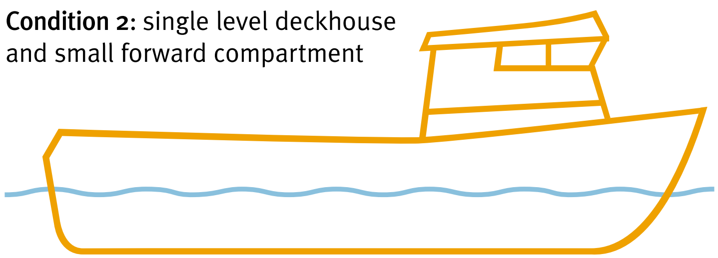
Open doors and hatches can allow flooding of compartments that are meant to be watertight and contribute to the vessel's reserve buoyancy. Watertight doors that are left open may compromise reserve buoyancy in the event of flooding and thereby compromise the vessel's stability.

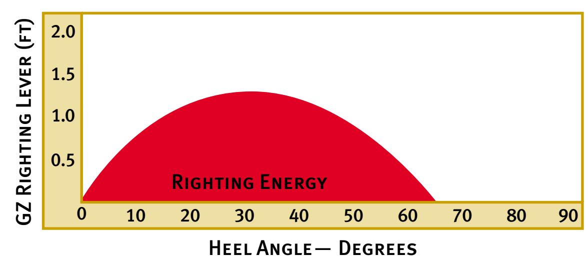
Condition 1: two level deckhouse and large forward watertight compartment provides additional reserve buoyancy





Condition 2: single level deckhouse and small forward compartment





FREE SURFACE

"In general, few fishermen fully understand free surface effect and fewer appreciate the substantial loss of transverse stability when water, even a few inches is shipped and retained on deck…when the deck edge is submerged, the effect can be disastrous."
(TC Marine Casualty Investigations, Report No. 495)

Water in the fish holds, a tank half full of water or fuel, a hold partly filled with herring in bulk, water on deck, and flooded bilges are all examples of free surface. A liquid surface that is free to move raises the vessel's centre of gravity and dramatically compromises the vessel's transverse stability.

In fact, the vessel will act as though the weight of the liquid with the free surface is higher in the vessel than in reality it actually is.

How much higher? Here is the calculation process.

- multiply the athwartships width of the free surface (in feet) by itself
- divide by 12
- divide by the average depth of the liquid (in feet)

Let's do some calculations. Suppose a tank is twenty feet wide from port to starboard and has two feet of salt water in it.

$$\frac{20 \text{ feet} \times 20 \text{ feet}}{12 \times 2 \text{ feet}} = \_\_\_\_\_ \text{ feet}$$

1. The vessel will act as though the weight of the water is __________ feet higher than it actually is. This reality is called the *virtual rise of G*.

2. To figure out the weight of water in this example, let us suppose the same tank measures 10 feet fore and aft. The volume of salt water will be:

   10 feet x 20 feet x 2 feet =__________ cubic feet

3. Salt water weighs 64.2 pounds per cubic foot. What is the weight of the water in the tank?

   64.2 pounds x ______ cubic feet = ___________ pounds

4. If there are 2,240 pounds to one tonne, how many tonnes does the water weigh?

   2,240 pounds x __________ pounds = ___________ tons

   The vessel will act as though ___________ tons has been moved _________ feet higher than where it actually is, significantly raising the centre of gravity and decreasing the vessel's metacentric height.

Tanks are generally baffled to prevent the detrimental effect of free surface. However, a flooded lazarette with no centre line division will seriously compromise a vessel's stability and righting energy.

From the calculation you just did, what conclusions can you draw about the effect of free surface on fishing vessel stability?

____

____

____

____

____

____

Effect of Free Surface on Deck

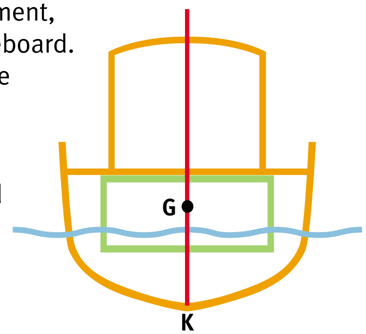
Water trapped on deck will seriously threaten a vessel's stability and dramatically reduce the righting energy. The greater the surface area covered, the greater the effect. The area covered with water is more significant than the depth of water.

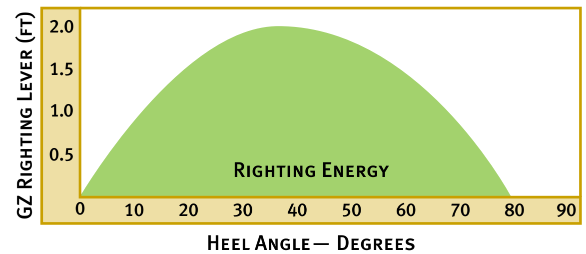
"Free surface is like lots of heavy canon balls rolling around all over the deck."
(David l. Green PE, Jensen Maritime Consultants)

Remember:

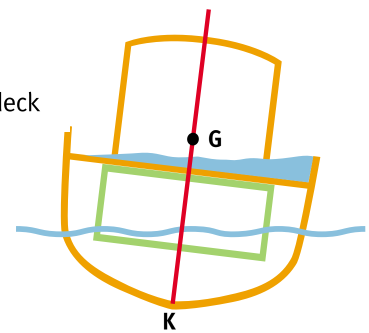
- The water will cause a rise in the center of gravity (as if the weight was actually higher in the vessel).
- The water will increase the displacement, increase the draft, and decrease freeboard.
- The vessel is vulnerable to deck edge immersion.

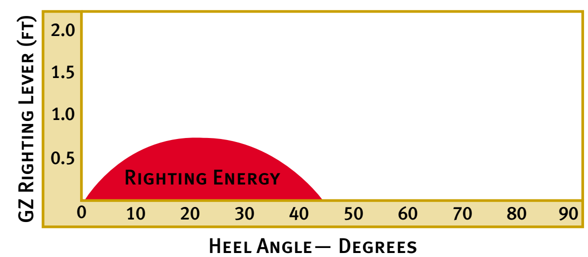
Condition 1: normal load





Condition 2: water on deck





Freeing ports must be large enough to shed water and never be plugged or covered.

Free Surface – Downflooding

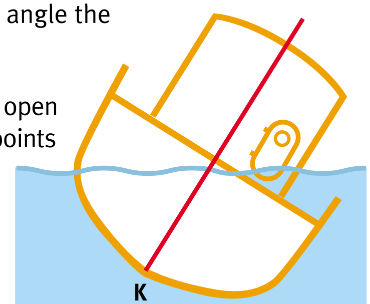
Downflooding is the entry of water into the hull which results in progressive flooding that pumps cannot keep up with. Watertight integrity is necessary to prevent downflooding. Downflooding introduces free surface, which raises the centre of gravity, increases the draft, reduces freeboard, can cause an extreme list and result in capsize.

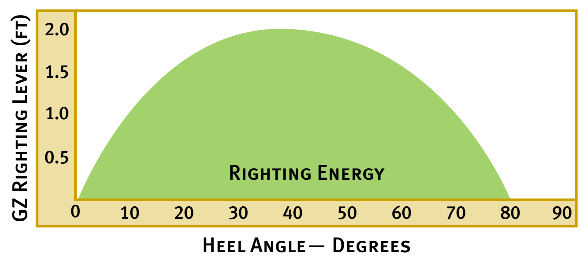
"The weathertight doors from the main deck to the accommodation area and the engine room were secured in the open position, compromising the watertight integrity of the vessel. This allowed shipped seawater to downflood into the hull."

(TSB Marine Occurrence Report. No. M97W0236)

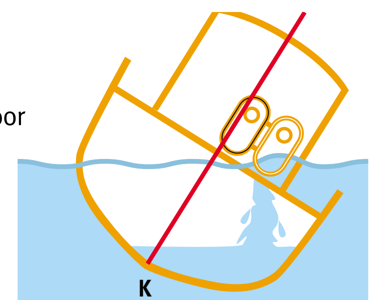
In the illustration where the vessel is downflooding, the area of the curve that shows righting energy stops at just over 40° because beyond that angle the vessel will not be able to recover.

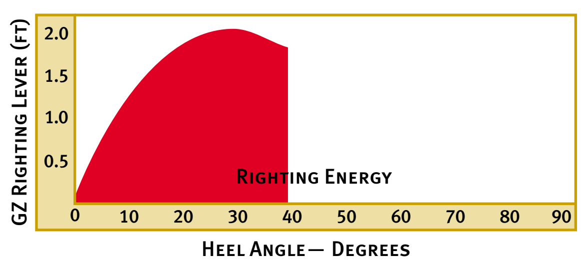
Condition 1: no open downflooding points





Condition 2: downflooding through open door



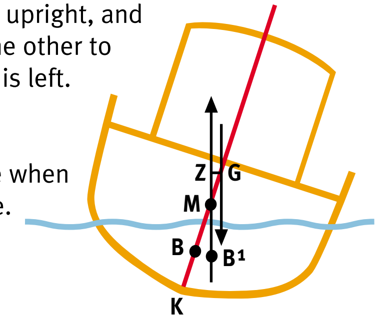


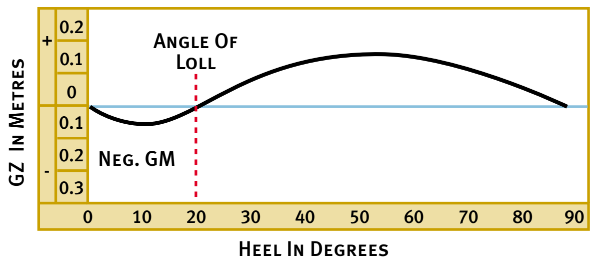
Carry spare pumps in case of downflooding.

Angle of Loll

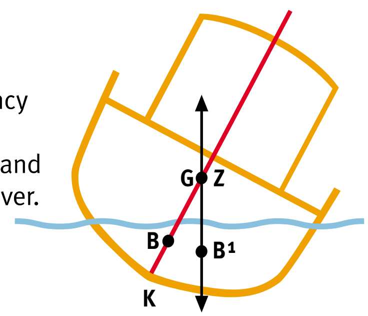
When a vessel refuses to stay in an upright condition, although there is no off centre loading to cause a list, then it may be at an **angle of loll**. This means the vessel is unstable when upright, and will loll to one side or the other to gain what little stability is left.

A vessel with an initial negative GM is unstable when inclined to a small angle.

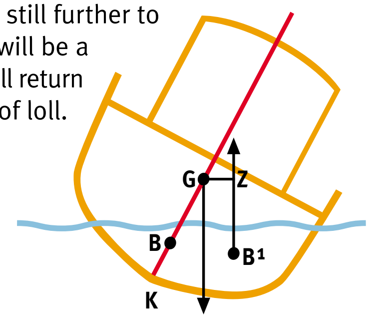




As the angle of heel increases the centre of buoyancy will move out still further to the low side until B_1 is vertically under G. The initial negative GM is gone and the vessel is at an angle of loll with no GZ righting lever.



If the vessel is heeled beyond the angle of loll, B_1 will move out still further to the low side and there will be a GZ righting lever that will return the vessel to the angle of loll.



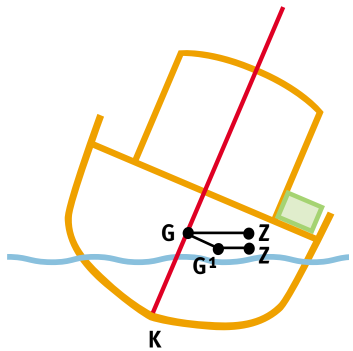
A vessel at an angle of loll may easily flop from one side to the other. An angle of loll requires an extremely high centre of gravity, initially a negative GM as we saw in the first picture. Generally, the only way the centre of gravity moves that high is because of excessive **free surface** and the *virtual rise of* G.

An angle of loll is extremely dangerous.

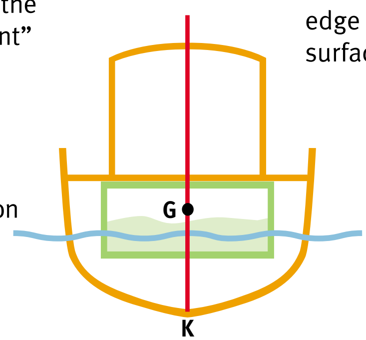
Fishing Operations

Load Shift

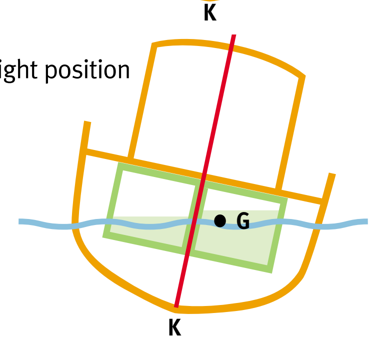
Weights not secured can shift when running in weather or as a result of fishing operations. A load that has shifted can compromise vessel stability by reducing the GZ righting lever and the amount of righting energy. Once the weight has shifted and causes a list, the boat will not return to the upright until the off centre loading is corrected. In heavy seas, a load shift may not be immediately noticed and the reduction in righting energy is a “silent” compromise in stability.



Condition 1: tanks pressed up
boat returns to upright position



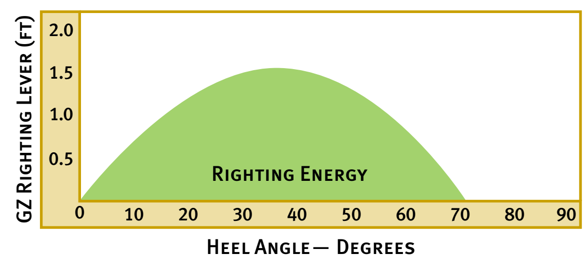
Condition 2: fuel migration
boat does not return to upright position

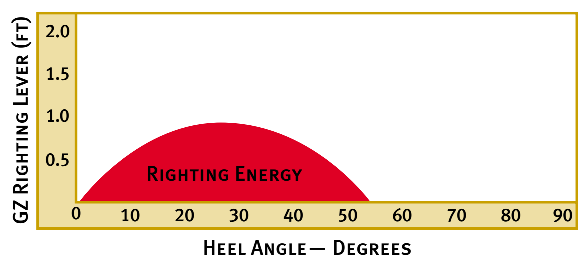


Don’t leave cross connections between fuel tanks open.

Fuel Migration

Fuel tanks that have an open cross connection can compromise vessel stability if left open, particularly if running in beam seas or with a slight list. As fuel migrates to the low side, the list increases and can result in deck edge immersion, accumulated water on deck and free surface.

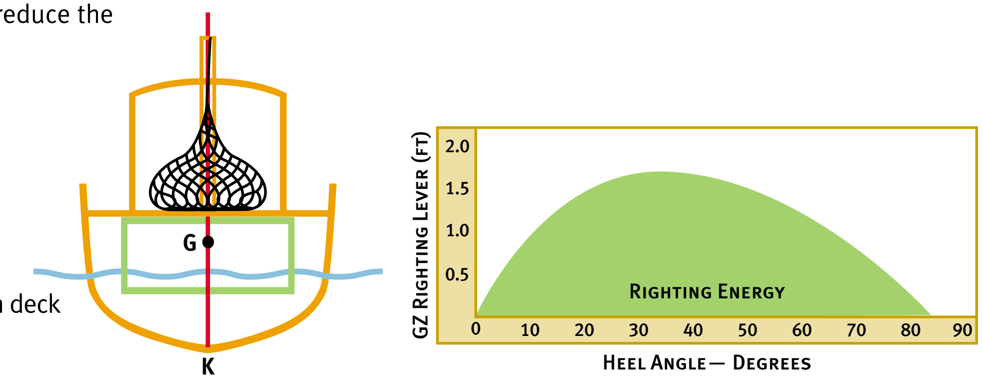




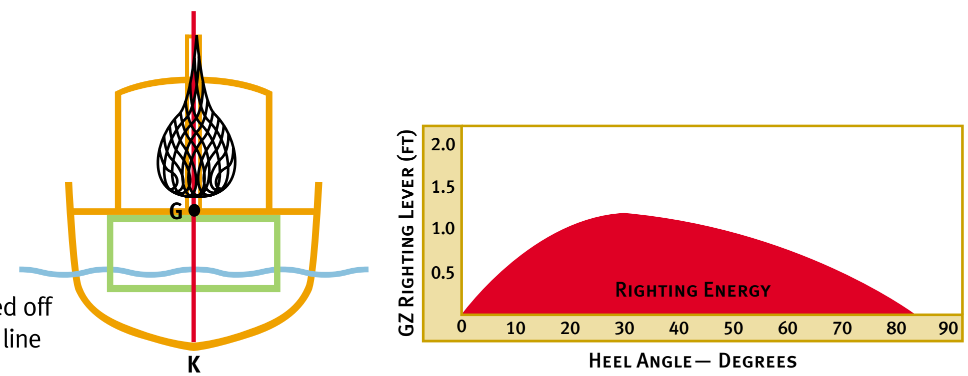
Suspended Weights

Lifting weights with the boom is part of many fishing operations. The weight lifted will act from the top of the boom at the point of suspension. If one tonne on deck is lifted with a boom topped at 20 feet, the weight will act as though it was 20 feet above the deck, which will raise the vessel's centre of gravity and reduce the righting energy.

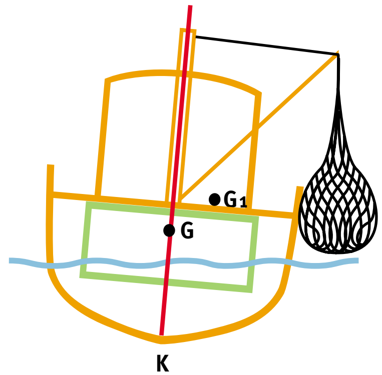
Condition 1: weight on deck and on centre line

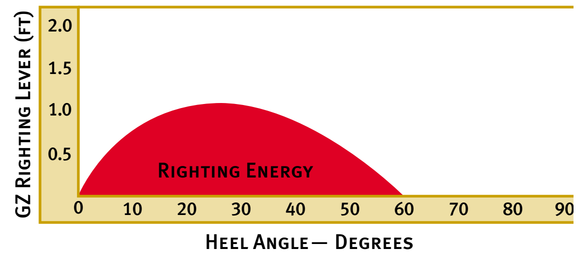


Condition 2: weight lifted off deck, but still on centre line



Condition 3: weight lifted over the side





Because the load is now off set from the centerline, the centre of gravity is shifted to the low side as well as being raised because the weight acts from the point of suspension, ie. from the top of the boom. The list the vessel experiences also means there is a further reduction in righting energy.

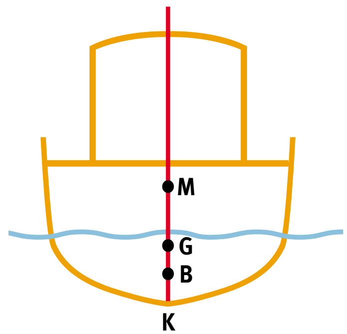
Towing Fishing Gear

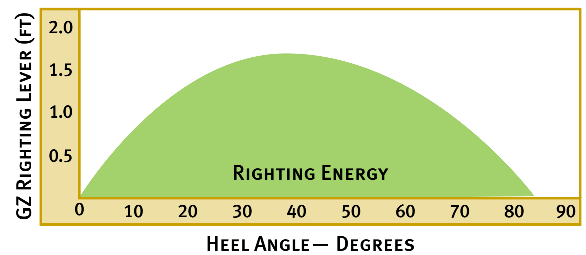
There are several combined factors that effect fishing vessel stability when towing gear. The weight of the load being towed will act from the point of suspension. The freeboard will be reduced, particularly at the stern. If the sea is on the beam or the quarter, the towing load is vulnerable to shifting.

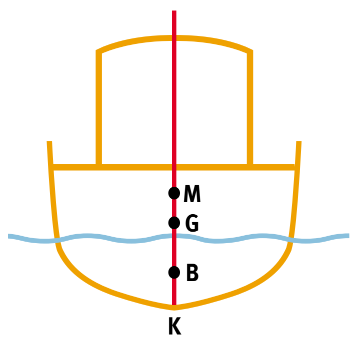
Stability will be affected because the centre of gravity is raised as the weight of the tow acts from the point of suspension.

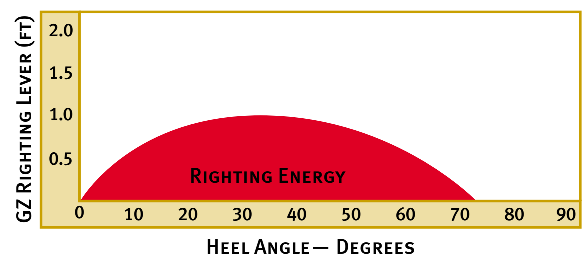
Because there is reduced freeboard and perhaps deck edge immersion, there is a reduction in righting energy because the movement of B to B1 will be less, and the GZ righting lever reduced.

The considerations while towing fishing gear also apply to towing a skiff. And, turning while towing can further compromise a fishing vessel's righting energy.







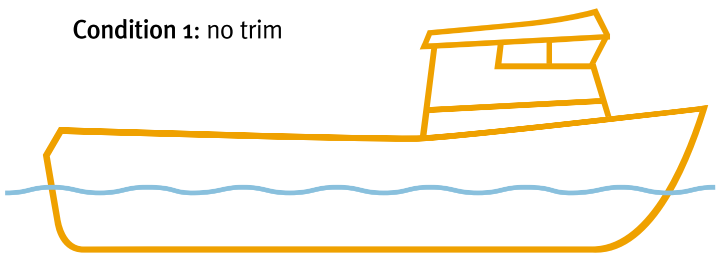


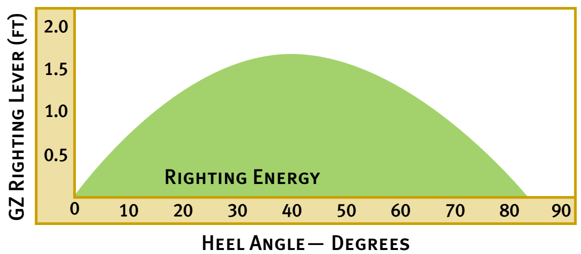
Excessive Trim

A fishing vessel trimmed significantly by the stern will lose righting energy. Although trim is generally discussed in terms of longitudinal stability, it can have an effect on transverse stability and the amount of righting energy available to return the vessel to the upright. This is because a vessel with excessive trim has a different underwater volume that will change the shift of B to B1, and can reduce the length of the GZ righting lever.

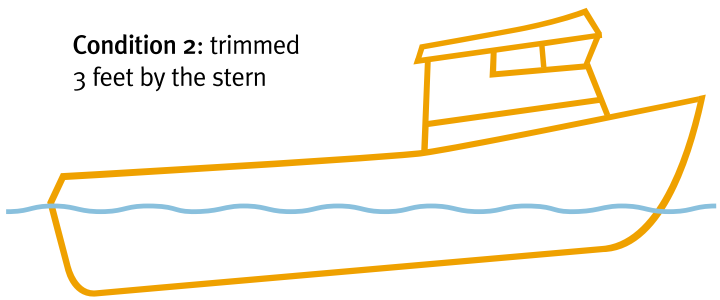
The effect of excessive stern trim may not be as obvious as other factors that compromise vessel stability, but it is one more condition that when other compromising factors are present, can be significant enough to reduce righting energy to the point where a vessel cannot recover.

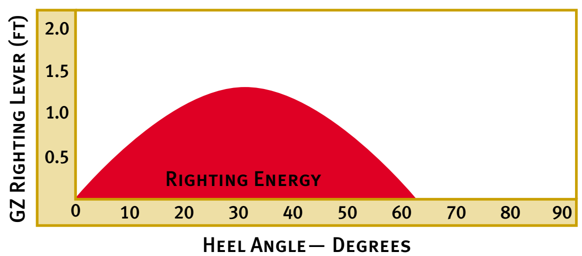
Condition 1: no trim





Condition 2: trimmed 3 feet by the stern





Significant trim can reduce stability.

Stability and Weather

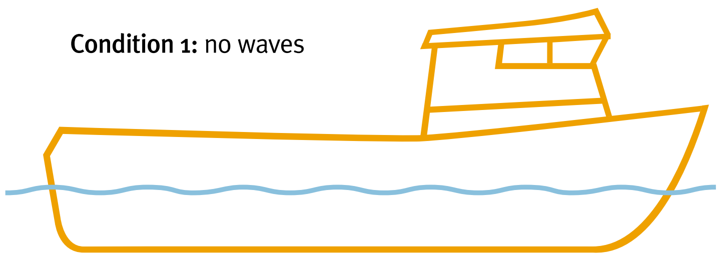
A fishing vessel with modestly compromised righting energy may be all right in moderate weather conditions, but getting caught out when the weather comes up and seas build can present other considerations.

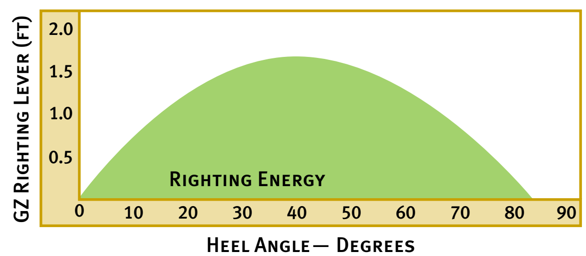
Following Seas

Operating in following seas can reduce the stability of a vessel. Running in a following sea where the length of the wave is twice that of the vessel, and the vessel's speed is the same as the wave speed, can result in the vessel being "perched" on a wave crest.

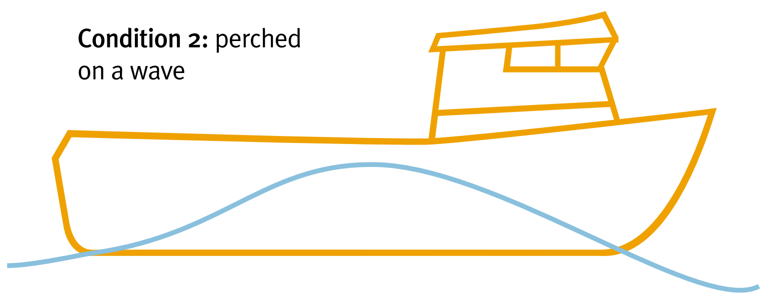
This means that only a small part of the underwater hull form is available to develop righting energy. When "perched" on a wave, amidship freeboard is decreased, bow and stern buoyancy are reduced, and the rudder may not be effective because it is partially out of the water. In confused seas it may be difficult to determine your vessel's relationship to the seas you are running in.

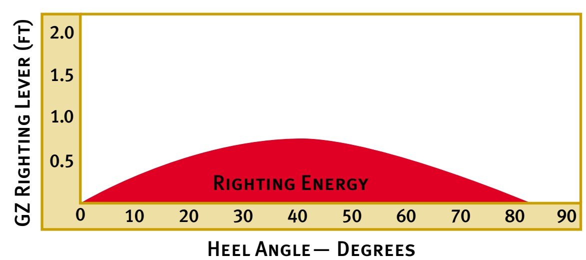
Condition 1: no waves





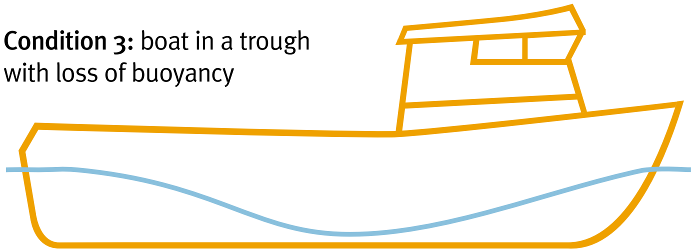
Condition 2: perched on a wave

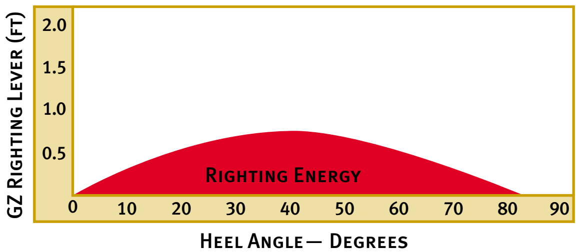




In heavy weather with a following sea, a vessel can also ride in the trough of the following sea, which will change righting energy because the underwater hull volume available to produce righting energy is less. In the trough, the amidship buoyancy and the stern freeboard can be significantly reduced.

Condition 3: boat in a trough with loss of buoyancy

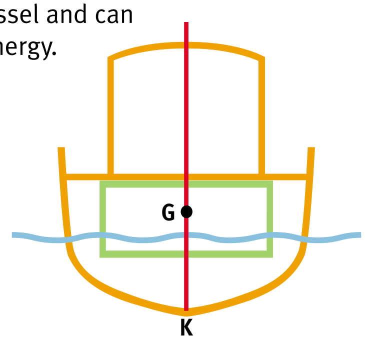


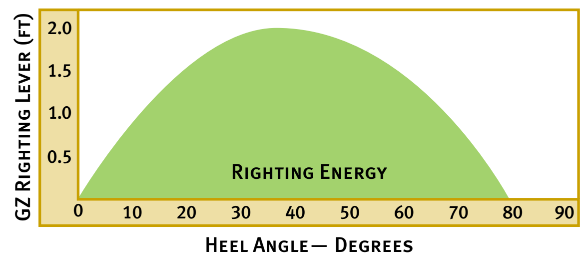


Effect of Icing

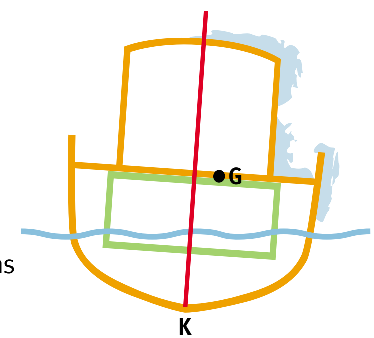
Ice accumulation on the superstructure and rigging of a fishing vessel is a very real threat to stability. Ice accretion can be from water droplets on the superstructure caused by spray from the vessel working in a seaway. Intensive ice formation occurs when the wind and seas are ahead. If the wind and sea spray are on a vessel's beam or quarter, then ice will collect to windward and cause the vessel to list. The weight of the accumulated ice can raise the vessel's centre of gravity very quickly, and if running into a sea can also result in a trim by the head. A raised centre of gravity and excessive trim both reduce the stability of a vessel and can seriously impair righting energy.

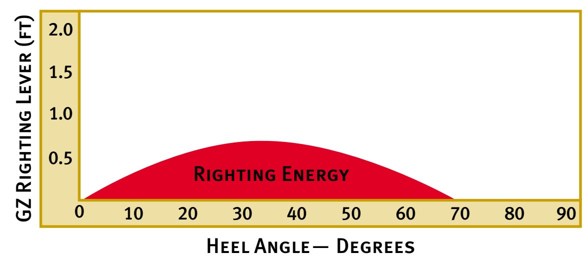
Condition 1: no ice on vessel





Condition 2: 20 tons ice 4 inches thick



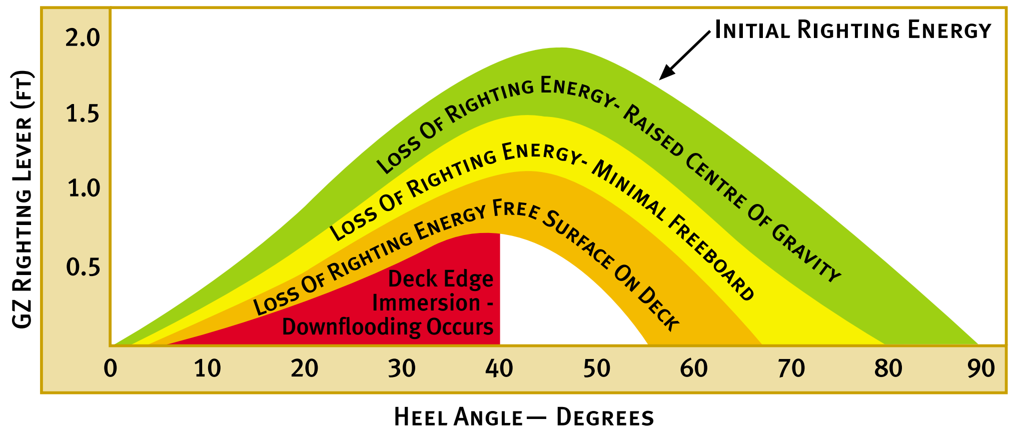


COMROMISED STABILITY... *a cumulative process*

FINDINGS

It would appear that the following factors contributed to the loss of transverse stability leading to the vessel's capsize:

- *At the time of departure, the vessel was heavily laden with traps and gear on deck which raised the vessel's centre of gravity;*
- *The total deadweight was increased and the freeboard and transverse stability reduced when the forward fish holds were pumped full of sea water;*
- *The reduced freeboard allowed water to be shipped on deck at relatively small angles of heel;*
- *The free surface effect and weight of water shipped and retained on deck severely reduced the vessel's transverse stability, and*
- *The reduced transverse stability retarded the vessel's rate of recovery from an initially moderate roll to port allowing time for downflooding to commence and continue until the reserve stability was overcome and the vessel heavily listed over and capsized. (TC Investigation Report No. 495)*



QUESTIONS *for discussion*

1. What does the **cumulative** effect of threats to fishing vessel stability mean to you?

2. Why is **freeboard your friend**?

3. Explain **deck edge immersion** and why it is such a threat to a vessel's transverse stability.

4. Discuss what is meant by **vessel modifications**. What examples are you familiar with?

5. How much of a change to a sister ship hull design do you think constitutes a vessel modification that could be a threat to stability?

6. What is meant by **fuel consumption, transfer**, and **ballast operations**, and why do you think it is it important to follow instructions given in a fishing vessel's stability book?

7. What does the term virtual rise of G mean?

8. Many stability books have "Subject to the Angle of Downflooding Being in Excess of 40 Degrees" stamped on the cover. What does this mean?

9. When lifting weights with the boom over the side, discuss what happens to the vessel's centre of gravity.

10. Describe the ways that weather can affect a vessel's righting energy.

Is it ever possible to single out any "one" factor that was the cause of a fishing vessel stability incident? An analysis of a fishing vessel capsize or marine incident almost always identifies a sequence of events that led up to the occurrence. It is also usually apparent that if any one of the events had not happened, the incident may not have occurred.

For example:
"The watertight integrity of the main deck was compromised by the ineffective gaskets of five flush-fitting manhole covers, which resulted in extensive downflooding, a marked increase in after trim, and reduced freeboard."
(TSB Report No. M02W0147)

"The weathertight doors from the main deck to the accommodation area and the engine-room were secured in the open position, compromising the watertight integrity of the vessel. This allowed shipped seawater to downflood into the hull." (TSB Report No. M97W0236)

"The vessel was unprepared for the open sea. The hinged transom bulwark was left open and the hatch covers were not secured." (TSB Report No. M91W1075)

Stable boats have the potential to become unstable as a result of inadequate maintenance and imprudent operating practices. A major fishing vessel insurer has claimed that their findings indicate maintenance and operational issues are frequently the "proximate" factors that lead to a vessel becoming unstable and capsizing. What this means is we do not read headlines in the paper saying "unstable boat causes hatches to leak".

With this in mind it is important to focus our attention on what we mean by maintenance and operating practices as they relate to vessel stability.

The routine maintenance and safe operating practices on your vessel may not be exactly the same as those for another vessel, but they all serve the same purpose. That purpose is to eliminate all of the possible "one" things that could start a sequence of events that might lead to a capsize. This means knowing all the areas on your vessel and the fishing operations that have the potential to make your vessel unstable.

You don't ever want to have an incident at sea where in retrospect you say to yourself "if only I had checked to be sure the ____________________". Whatever answer you put in the blank is probably the "one".

For fishing vessels that have a stability book it is critically important that the skipper consult the book and follow any operating instructions that the naval architect has specified for the vessel. If you don't have a stability book with specific instructions, you should draft your own operating practices in order to maintain adequate stability throughout each fishing trip.

Instructions given in the "Trim And Stability Book" for the F.V. Summers Only:

- *At no time should the port of starboard cargo hatch be left open at sea. These hatches must be secured watertight. They may be used in protected waters, but must be secured before returning to sea.*
- *The access door to the accommodation must be kept closed at sea. It may be used for going into and out of the accommodation, but otherwise must be kept closed.*
- *All weights in this stability booklet are considered to be on the centre line of the vessel. Care and attention to keeping weights centred, and minimizing a list condition must be adhered to.*
- *Fuel tanks and water tanks are considered to be separate tanks. To this end only one tank of each can be in operation at any one time. Failure to do so (i.e. cross connection open) may result in non-compliance with the regulations*

The Wreck of the Edmund Fitzgerald, Gordon Lightfoot *(1976 Moose Music Ltd.)*

"The captain wired in he had water comin' in
and the good ship and crew was in peril
and later that night when 'is lights went out of sight
came the wreck of the Edmund Fitzgerald"

Activity Sheet... *find your "one"*

List all the areas on your vessel that have the potential to be the "one" factor and what maintenance and operating practices can eliminate the possibility of the "one" happening. The list you create can be the basis for your vessel's maintenance and stability instructions that should be posted and all crew familiar with.

Questions *for discussion*

1. Which came first, the chicken or the egg? And how does this relate to events leading up to a fishing vessel stability incident?

2. Some skippers use checklists to stay on top of maintenance and operations. Why are checklists a good tool, and what are the limitations of checklists?

3. If you have ever had a "near miss" in terms of stability, what was the one thing that you would attribute it to?

4. The folks that analyze marine accidents and conduct research say that 80% of occurrences can be attributed to "human error". What do you think human error means in the context of commercial fishing operations?

5. What are three things about stability that you could always ask yoursef when you commence fishing operations or before traveling?

6. What impact on fishing operations and safety do you think fatigue has?

7. Many skippers use the "feel" of their vessel as an indication of stability. Do you think this is a good measuring stick? Why or why not?

8. If you are a crewmember and don't like the "feel" of the vessel, how would you present your concerns to the skipper?

Lessons Learned

The **Fishing Vessel Stability – Make it your Business** handbook has explained fundamental stability principles that should be central to your everyday reality when making any decisions that affect your vessel's operations. The handbook has profiled survivor stories and findings from TSB Reports because lessons learned from the past can carry a powerful message into the future.

One of the most documented and unforgettable losses was the capsizing of the *Cap Rouge II* on August 13th, 2002 off the Fraser River in British Columbia. This loss will continue to be a resounding wake-up call to regulatory bodies and everyone in the commercial fishing industry as it is a stark reminder of several lessons to be learned.

While the TSB Marine Investigation Report (M02W0147) outlines findings and recommendations regarding the loss of the *Cap Rouge II*, an independent investigation into the capsizing was also conducted by Robert Allen Ltd., Naval Architects and Marine Engineers at the request of the Workers' Compensation Board of BC. Not only does the Robert Allan Report make it clear that **the design, construction and operation of a fishing vessel are a shared responsibility,** it also identifies specific factors that led to the loss of the *Cap Rouge II* and summarizes some key lessons to be learned.

Lessons Learned… *Cap Rouge II*

The tragic loss of the *Cap Rouge II* could unfortunately have been avoided if a few simple rules of vessel loading and stability had been better understood and implemented. The vessel's hazardous conditions and resulting lessons learned are outlined below as a reminder and guidance to other fishing vessel owners and operators.

1. A series of gear modifications were made to the *Cap Rouge II*, virtually all of which impacted negatively on the vessel's stability by adding weight and raising the centre of gravity.

   lesson learned:

   The impact of structural and outfitting changes to any boat must be closely monitored to determine that their impact on the vessel's stability characteristics are not overly detrimental to the vessel's safety.

2. The *Cap Rouge II* was carrying a net which was too large and heavy for the vessel, impacting very negatively on the vessel's trim and stability. In addition, the net drum had been raised to facilitate loading fish under the net, further eroding initial and dynamic stability.

   lesson learned:

   The size of net and the position of the drum must be carefully considered for their impact on the stability of the vessel.

3. The holds on the *Cap Rouge II* were too large to be safely carried on a boat that size. Filling all the hold and fuel tanks would cause the *Cap Rouge II* to sink.

   lesson learned:

   No fishing vessel should have holds that cannot all be filled and still meet appropriate stability standards. Holds which are proven too large to meet this criteria should be foamed in to prevent any possible ingress of water or the addition of excessive cargo.

4. The *Cap Rouge II* was loaded deeply in the water reducing its dynamic stability in fairly severe sea conditions.

   lesson learned:

   There must be a reasonable amount of freeboard in any load condition to ensure both good dynamic stability characteristics and the minimization of water on deck in poor weather conditions.

5. The aft fuel tanks on the *Cap Rouge II* were cross-connected and open allowing fuel to migrate from one side of the boat to the other.

   lesson learned:

   Fuel tank cross-connections should not be open when traveling to avoid fuel migration under other heeling influences.

6. The *Cap Rouge II* was loaded with a large trim by the stern.

   lesson learned:

   A heavily trimmed attitude reduces the dynamic stability characteristics of most vessels, and should be avoided.

7. The gaskets on the manholes accessing the fish holds and the lazarette on the *Cap Rouge II* were found to be in poor condition permitting leakage into those spaces under water pressure from above.

lesson learned:

The condition of all manhole (and door) gaskets should be reviewed regularly and gaskets should be replaced if there is any evidence of deterioration. Hose testing should be performed to verify gaskets are effective.

8. The skiff contributed to the loss of GM of the *Cap Rouge II* by reducing GM and by exerting a starboard heeling moment.

lesson learned:

Towing arrangements for skiffs should be carefully considered such that the load exerted on the towing vessel is both minimized and kept low on the centreline of the towing vessel.

9. The two aft holds of the *Cap Rouge II* were only partially loaded permitting a large free surface effect which reduces initial and dynamic stability.

lesson learned:

Whenever possible, fish-holds should either be empty or pressed fully to the top to prevent the migration of liquids in the holds, and the associated free surface effect on stability. Inherent in this recommendation is the assumption that the vessel has sufficient buoyancy and stability to support full holds.

You are a Teacher

Most commercial fishermen have a stability story to tell that is as important a lesson as theoretical knowledge about fishing vessel stability. Your stories are important because they are real and told by your authentic voice as a commercial fisherman. Tell your stories, listen and learn from one another. Commercial fishing is your industry and you have a strong voice in the development of a safety culture.

QUESTIONS *for discussion*

1. At the beginning of this course you wrote down a question about stability. What is the answer?

2. You are the author of this final chapter. What are the lessons that you have learned and will take back to your vessel?

3. What is the most significant thing you have learned from this stability handbook or from the course?

4. The introduction suggested that a safety culture can be fostered from lessons learned. Do you think this is possible? Why or why not?

ACTIVITY SHEET... *safety check*

Make a list of the **FISH SAFE** Stability Checks

References and Credits

Illustrations, pages 19-21:
Reproduced with permission from Transport Canada from publication *TP8161*. An **Introduction to Fishing Vessel Stability**. *Cat. No. T31-60/1987*. *ISBN 0-662-5212-3*

Hydrostatic Curve Illustration, page 22:
Adapted from D R Derritt. **Ship Stability for Masters and Mates**. Stanford Maritime Limited. Fourth Edition, 1984. *ISBN 0-540-073388*

Illustrations used in Chapter 4 referenced from the North **Pacific Vessel Owners Association Vessel Safety Manual**. Used with permission.

Safety regulations within the fishing industry are governed by both 1) **WorkSafeBC** which has a provincial jurisdiction to oversee and regulate worker safety and 2) Transport Canada Marine Safety which has a federal jurisdiction to regulate vessel safety. Since vessel stability includes both structural and operational considerations, there has been some overlap between WorkSafeBC and Transport Canada Marine Safety in developing stability requirements. As a result, WorkSafeBC and Transport Canada Marine Safety are working together to ensure a practical process for meeting the two regulatory requirements for stability.

WorkSafeBC (Workers Compensation Board of BC)

Implementing the Regulation

Part 24 of the Occupational Health & Safety Regulation of Worksafe BC outlines the requirements of an owner and master in regard to stability. WorkSafeBC published a guideline for implementing the regulation as it relates to vessel stability.

In part it states:

“ **Vessel Stability – Owner and Master Responsibilities**
The responsibility for ensuring the vessel continues to possess stability characteristics that render it seaworthy under all anticipated sailing conditions rests with the vessel owner. The vessel owner should limit vessel operations so that it does not operate in conditions that would render the vessel unstable. In addition, the owner should undertake any necessary vessel modifications to ensure no workers are put at risk by the possibility of the vessel becoming unstable during anticipated operating conditions. A vessel owner is also responsible for ensuring that documentation describing vessel stability characteristics is readily available to crew members on board the vessel” (see OHSR **s. 24.72(b)**).

The vessel master is responsible for ensuring that the fishing vessel is capable of safely making the voyage planned, with due consideration being given to the seaworthiness and stability of the vessel (see OHSR **s. 24.76**). The master should refer to the vessel stability documentation provided by the owner in accordance with OHSR **s. 24.72(b**) in making this assessment. A copy of the documentation setting out the vessel's stability characteristics must be readily available on the vessel for reference by master and crew (see OHSR **s. 24.72(b)**).

Enforcing the Regulation

When conducting inspections and investigations, Board officers will evaluate whether the vessel has been supplied with meaningful and clear vessel stability documentation.

Prevention Policy **R24.70-1** describes the process that a board officer will follow if they encounter a vessel where stability may be a concern:
“Where a Board officer considers that a vessel is clearly unseaworthy, he or she will make an order to correct the situation. Where the officer has a concern over seaworthiness but is not sure, and the vessel is over 15 tons, the officer may require production of the vessel's

Canada Steamship Inspection certificate issued under the Canada Shipping Act. If no certificate is available, the officer may order that one be obtained.
Where the vessel is less than 15 tons, the officer may consult with the Canada Coast Guard [now Transport Canada Marine] for advice as to the seaworthiness of the vessel and whether applicable federal regulations have been complied with. The officer may order that a survey be conducted by a marine surveyor, architect or engineer if he or she considers that there is a serious question as to the seaworthiness of a boat.

Where an officer has reasonable grounds to believe that a vessel's lack of seaworthiness presents an immediate danger to its crew, the officer may issue a stop work order (see Workers Compensation Act **s. 191**)requiring an assessment of the vessel's stability and work undertaken to the vessel to ensure its stability in accordance with the assessment."

Transport Canada Marine Safety

Transport Canada is responsible for establishing stability criteria, as well as determining which vessels are required to meet those criteria by completing an incline test.

Transport Canada, however, is currently in the process of Canada Shipping Act (CSA) 2001 Regulatory Reform. *The Small Fishing Vessel Inspection Regulations*, under CSA 2001 will be replaced by the more comprehensive Fishing Vessel Safety Regulations.

Some basic features of the proposed *Fishing Vessel Safety Regulations* include:

- Vessel sizes will be expressed in units of length rather than tonnage.
- Equipment carriage requirements to be determined by risk management principles, the greater the risk the more stringent the requirements. Carriage requirements will be based on voyage classes rather than vessel lengths.
- The hull of every fishing vessel shall be marked to indicate its maximum permissible operating draft.
- Every fishing vessel shall be subject to an assessment of its stability. It is proposed that a simplified stability assessment for vessels under 15 meters may be substituted, except in higher risk cases.

The current *Small Fishing Vessel Inspection Regulations* only require that fishing vessels over 15 gross tonnes engaged in the herring or capelin fisheries undergo an inclining test and carry a stability book. As noted above, it is anticipated that stability assessments will be extended to a wider range of fishing vessels.

A lengthy public consultation process has been carried out with regard to the proposed *Fishing Vessel Safety Regulations* and the preliminary *Stability Standard for Small Fishing Vessels* under 24 metres in length, as well as other proposed regulatory changes under CSA 2001.

CSA 2001 also includes proposed Marine Personnel Regulations that address certification requirements for commercial fishermen.

In support of CSA 2001 Regulatory Reform that will affect commercial fishermen, Transport Canada has been clear that an essential component is awareness programs and education.

Transport Canada has funded the development of the Fish Safe Stability Education Program in order to provide a national education program for fishermen.

WorkSafeBC
WORKING TO MAKE A DIFFERENCE
worksafebc.com

Transport Canada Transports Canada

For more detailed information on regulations, policies and guidelines:
www.worksafebc.com
www.tc.gc.ca
www.fishsafebc.com

QUESTIONS *for discussion*

1. Do you think regulations are a necessary tool like speed limits on the highway?

2. Why do you think regulations do or do not work?

3. Why do you think we have regulations on stability?

4. What would make regulations more effective?