Iceberg Right Ahead

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We all know the story how lookout Frederick Fleet had sighted an iceberg at about 11:40 PM on April 14th 1912, went to the lookout bell and struck it 3 times to indicate that something was seen ahead, and then went to the telephone and called down and spoke to Sixth Officer James Moody and uttered those famous words, "Iceberg right ahead." However, the question has come up many times concerning the number of icebergs that may have been sighted earlier that evening, before that fatal berg was sighted. From the sworn testimony of both Frederick Fleet and Reginald Lee, we are left with the impression that the fatal iceberg was the one and only iceberg that was seen prior to the collision. Yet many people believe it to be improbable for the *Titanic* to have steamed deep into iceberg infested waters and suddenly find a single isolated iceberg dead ahead in its path. It just seems that other icebergs should have been sighted earlier especially since we know that in the morning, after the sun came up, many icebergs were seen all around the area of the wreckage. In his book, *Titanic: Safety, Speed and Sacrifice,* George Behe develops the proposition that three separate icebergs were sighted between 11:15 PM and 11:40 PM and reported to the bridge that night by Fleet and Lee, not just one.[1] George develops his case on indirect evidence taken from several statements made by passengers and crew, some of which was based on hearsay and rumor, and some on apparent conversations that supposedly took place with Fleet while on board the *Carpathia*. Others, such as authors Steve Hall and David G. Brown, have independently put forth theories that two icebergs were actually seen that night in relatively close proximity to each other. In Steve's case, he suggested (as far back as October 1999) that there may have been two icebergs side by side. The second iceberg the lookouts could not see because it was lower in profile than the one they sighted. The *Titanic* then impacted with the smaller berg jammed between the ship and the larger one.[2] In Dave Brown's theory, the first was sighted about 5 to 8 minutes before the accident which was successfully avoided, and a second iceberg, the fatal one, was the one that was struck because of a loss of situational awareness.[3]

Icebergs and Seeing Distances

The purpose of this short study was to quantify the probability of multiple iceberg sightings using a stochastic approach. Like all such analysis, several assumptions have to be made. To begin with we need to know how far can an iceberg be seen on a clear, dark, but moonless night. We also need to know what was the density of icebergs in the region that the *Titanic* was steaming through. Since icebergs come in different shapes and sizes, we also need to know the distribution of these in order to develop a realistic model. The International Ice Patrol (IIP) classifies icebergs into different size categories ranging from what are called Growlers and Bergy Bits up to Very Large.[4] These are given in the table below.

Category	Height (ft)	Length (ft)
Growlers and Bergy Bits	Less than 14	Less than 46
Small	14-50	47-200
Medium	51-150	201-400
Large	151-240	401-670

Very Large	Over 240	Over 670

Based on the observations of Fleet, Lee, Olliver, Scarrott, and Rowe, we know the iceberg that Titanic struck was only a Medium sized iceberg that reached a height of about 70-75 ft, a little higher than *Titanic's* boat deck. But we also know that the region that *Titanic* entered had icebergs that ranged in various sizes, from Growler to Large. In the morning of April 15th Capt. Rostron sent one of his officers to the top of the wheelhouse on the *Carpathia* to count all the icebergs he could see that were 150 to 200 feet high. What he reported was a total count of 25.[5] Based on the above table, these 25 would in the Large size category. The height of *Carpathia's* bridge was about 50 ft above the waterline, and taking the top of the wheehouse to be 10 feet higher, we find that the visible horizon seen by that officer was out to about 9 nautical miles. Thus we have a count of 25 Large icebergs seen over an area of 255 square nautical miles. There were no bergs reported in the Very Large category.

But how many icebergs were there in total in that region? For this we also can go to IIP data. The table below shows the distribution of icebergs in the IIP operations area for the 1994 season.

Size Category	Percentage of total (%)
Growler [and Bergy Bits]	5.6
Small	15.3
Medium	15.3
Large	12.5
Very Large	2.8
Size unknown	48.5

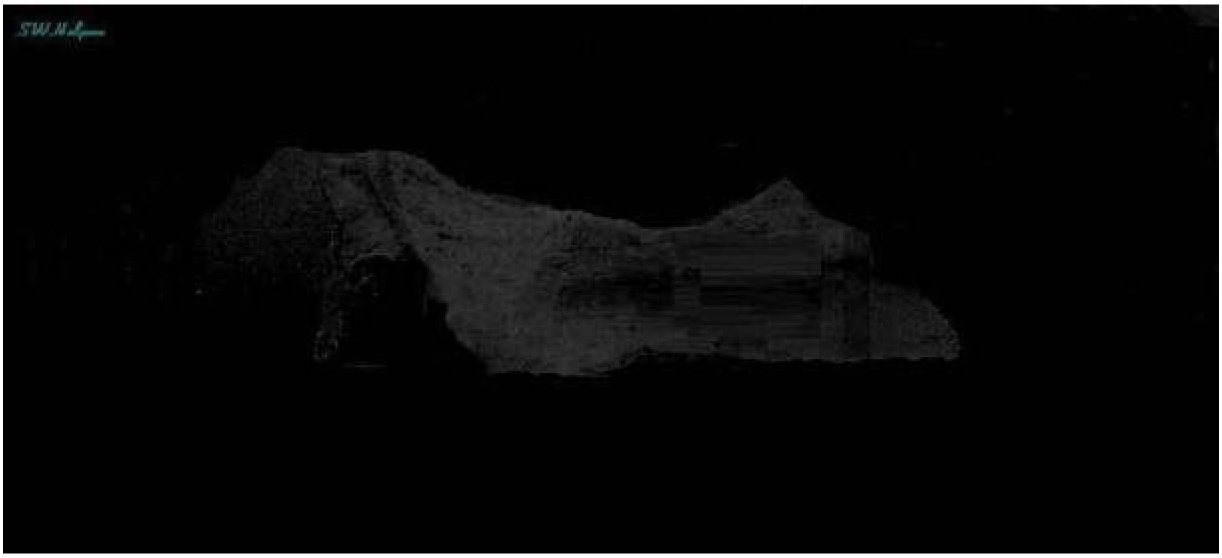
We can't do much for the 48.5 % of the bergs where size data was not obtained, but we can take the distribution of iceberg sizes from those that were reported as the best guess distribution for bergs ranging from Growler to Very Large. For what we are interested in, we see that there are about as many Medium bergs as there are Small bergs, and there are about as many Large plus Very Large bergs as there are Medium bergs. Therefore, if take what was counted by Rostron's officer on the morning of April 15th to be the average number of Large icebergs seen over 255 square miles, we can assume that there were on the average about 25 Medium bergs and 25 Small bergs in the same 255 square miles. In other words, the average number of icebergs that were 14 feet or higher in the region where the *Titanic* sank is taken to be 75 over 255 square miles, or 0.29 bergs per square mile. This of course does not count any of the smaller stuff and pack ice that was also seen in that region, just the icebergs that are more than 14 feet in height. And it also assumes a uniform distribution of those bergs over the 255 square miles. There is evidence to suggest that there was a greater concentration of Large icebergs to the southeast and fewer to the west that was mixed in with the pack ice.[6] This also tends to explain why the *Carpathia* encountered so many icebergs on her way to reaching Boxhall's lifeboat as she was coming up from the southeast. However, lacking any specific data on the directions to these large icebergs we will assume a uniform distribution of all types of bergs for our purposes.

Now for the seeing distances. From the 2002 Bicentennial issue of Bowditch:[7]

> The distance at which an iceberg can be seen visually depends upon meteorological visibility, height of the iceberg, source and condition of lighting, and the observer. On a clear day with excellent visibility, a large iceberg might be sighted at a distance of

20 miles. With a low-lying haze around the horizon, this distance will be reduced. In light fog or drizzle this distance is further reduced, down to near zero in heavy fog. In a dense fog an iceberg may not be perceptible until it is close aboard where it will appear in the form of a luminous, white object if the Sun is shining; or as a dark, somber mass with a narrow streak of blackness at the waterline if the Sun is not shining. If the layer of fog is not too thick, an iceberg may be sighted from aloft sooner than from a point lower on the vessel, but this does not justify omitting a bow lookout. The diffusion of light in a fog will produce a blink, or area of whiteness, above and at the sides of an iceberg which will appear to increase the apparent size of its mass. **On dark, clear nights icebergs may be seen at a distance of from 1 to 3 miles, appearing either as white or black objects with occasional light spots where waves break against it.** Under such conditions of visibility growlers are a greater menace to vessels; the vessel’s speed should be reduced and a sharp lookout maintained. The Moon may either help or hinder, depending upon its phase and position relative to ship and iceberg. A full Moon in the direction of the iceberg interferes with its detection, while Moonlight from behind the observer may produce a blink which renders the iceberg visible for a greater distance, as much as 3 or more miles. A clouded sky at night, through which the Moonlight is intermittent, also renders ice detection difficult. A night sky with heavy passing clouds may also dim or obscure any object which has been sighted, and fleecy cumulus and cumulonimbus clouds often may give the appearance of blink from icebergs.

It should be noted that in the above description concerning dark, clear nights they do not specify a completely moonless night. It is also noted that they refer to the breaking of waves around the base of the bergs showing up as occasional light spots. The night of the 14th of April 1912 had a perfectly calm sea and no moon. The only light coming off of the icebergs would be reflected starlight. There would be no breaking waves on the base of the berg to help spot them earlier.[8] The photograph below depicts what an iceberg under those seeing conditions would look like when close up.[9]



In 1925 data on iceberg visibility distances was collected by Lt. Commander Fred Zeusler of the USCG who was the Ice Observation Officer for IIP that season. His results are given in the table below.[10]

Visibility Conditions	Distance (nautical miles)

Excellent day visibility and clear sky	36 maximum
Generally good day conditions	12 to 20
Daytime with hazy conditions	9
Daytime with light fog and rain	1
Clear moonlit nights	2
Clear moonless nights	1/2

In Sir James Bisset's book, *Tramps & Ladies*, he says:[11]

Bergs are visible at great distances in clear weather in day-time, and even in moonlight they stand out clearly at several miles distance, for they refract light. **On a dark clear night a berg can be seen from half a mile away.**

And speaking about the risk that Capt. Rostron took in driving the Carpathia at forced speed in darkness into the ice region, Bisset said:

He knew – as every shipmaster of experience gained in the North Atlantic, and to the south of Cape Horn, knew – **that icebergs are visible by starlight half mile ahead in clear weather.**

On April 15th 1912 James Bisset was 2nd Officer on the *Carpathia*. As they raced to the rescue it was Bisset who spotted the first iceberg from the starboard wing of the bridge catching "the glimmer of a starbeam in an iceberg three-quarters of a mile ahead of us on the port bow." Bisset went on to become Commodore of the Cunard Line later in his career. It should be noted that Capt. Rostron estimated that the first iceberg that was seen by Bisset was 1½ to 2 miles away. That would be double the distance that Bisset quoted. Rostron also thought that 1 to 2 miles was about the distance that other icebergs were seen as they passed about half a dozen until they came up to Boxhall's lifeboat about 4 AM.[12] And when they came close to Boxhall's boat, they starboarded their helm to get around one more iceberg, a low-lying berg about 30 feet high and only ¼ mile ahead of them.[13]

So we see that that we have different estimates of iceberg visibility for clear, dark, moonless nights. The real problem is that that we don't have much scientifically derived data for what we want to do. People's estimates of distances to objects seen at night are quite varied. Even the data from Zeusler is not specific enough for what we want. So for the purpose of this study I had to make a few assumptions. The first is that the size of an iceberg will affect the range that it will be seen. Obviously the larger the berg, the greater the distance it should be seen at. The second assumption is that a small berg of about 30 feet in height can be seen at a range of about ¼ mile away, or 1500 feet. This was the only data point we have that directly ties a distance to the height of a berg. The next assumption is that an iceberg that is twice the size of another can be seen at twice the distance. Specifically, an object that is twice the size in average height and average width will have four times the cross sectional area, and will therefore reflect four times as much starlight. With four times as much reflected starlight, such an object could be seen at twice the distance because the intensity of light from an object drops off as the square of the distance from the object. Thus, the distance to an object at night will be proportional to its size. Even if seen through binoculars, an object twice as far but twice as large as another object will take up the same angular field of view as well as being equally as bright.

Based on the table of iceberg sizes from the IIP, we can get the approximate average heights and average lengths for small, medium, and large icebergs. We can then get the ratio of relative cross sectional areas as well as the ratio of relative average sizes for these three categories of icebergs.[14] This is shown in the table below.

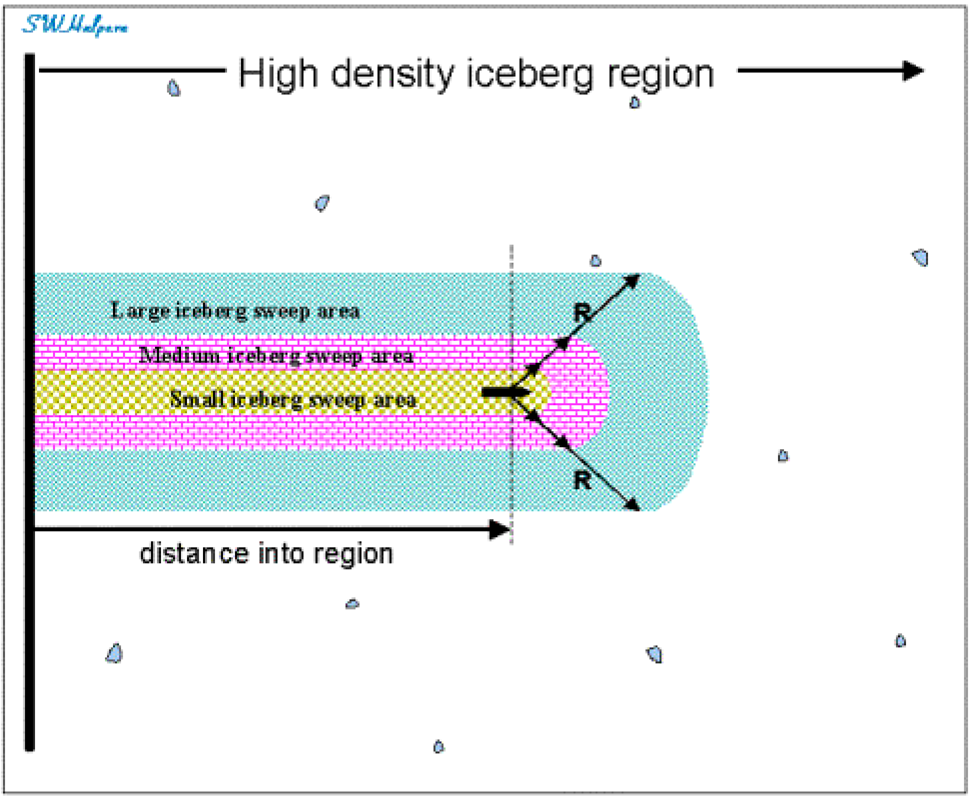
Category	Ave. height (ft)	Ave. length (ft)	Ave. height x length (ft^2)	Relative area ratio	Relative average size ratio	Percentage of total icebergs for the region
Small	32	124	3968	1	1	33.3%
Medium	100	300	30000	7.6	2.75	33.3%
Large	196	536	105056	26.5	5.1	33.3%

Since the distance that an iceberg can be seen would be proportional to its relative size, we have the following average sighting ranges that we will use in our model for each of the three iceberg size categories:

Size Category	**Average sighting distance, R**	
	(feet)	(nautical miles)
Small	1500	0.25
Medium	4125	0.69
Large	7650	1.28

Notice that the sighting distance derived for medium sized bergs, about 0.7 miles, is not too much greater than the ½ mile distance referred to by Bisset and Zeusler, although they did not qualify their distances by size of berg. Pending any better data that someone may find, I decided to use the sighting distance model shown in the above table.

With these assumptions, we can develop a model that estimates how many icebergs can be spotted on the average for a ship that penetrates a given number of miles into a region of known iceberg density. To do this we need to consider the area of most concern to the OOW and the lookouts as the ship raced through the ice region. I assume that their greatest attention would be anywhere from 4 points off the port bow to 4 points off the starboard bow. In other words, they would be scanning an area covering a 90 degree field of view in front of them most of the time. The number of icebergs that would be seen for a given size category would therefore be proportional to the area swept through by the ship extending from a distance of R miles at 45-degrees off the port bow to R miles at 45-degrees off the starboard bow taken over a penetration distance of D miles into the region for the ship. Since we have three size categories to consider with different visual ranges, R, we wind up with three overlapping sweep areas as shown in the diagram below.



Once we calculate each of these sweep areas we have only to multiply the area by the iceberg density for the particular size category to get the expected number of bergs that would be seen in that size. We then could add up the total for the three categories to get the overall expected number of icebergs that should have been seen over the distance penetrated by the ship. The distance of penetration by the ship is simply the speed of the ship multiplied by the amount of time it was steaming into the region. At 22.5 knots, the Titanic was making 38 feet per second as it entered the high density region on the night of April 14, 1912. When we go through the mathematics, we obtain an expression for the average number of icebergs, from Small through Large, that can be expected to be seen by those on the lookout at T minutes from the time the ship entered those icy waters at 22.5 knots.

The result is simply: $\mu = 0.274 + 0.115\ T$ (where T is in minutes of time)

The constant of 0.274 takes into account the small chance that an iceberg will be seen in the area ahead of the ship just as the ship itself begins to enter the region. This is the shaded areas ahead of the small dashed line in the above figure. The model does not take into account some scattered icebergs outside of the high density region. In other words we are assuming the iceberg density outside the region of interest is small enough that the probability of an iceberg being sighted at night is relatively remote.

The table below shows the expected number of icebergs sighted for different values of T.[15]

Time steaming in region, T (minutes)	Distance traveled into region (nautical miles)	Average number of icebergs expected to be sighted, μ
0	0	0.27
6	2.25	0.96
12	4.50	1.65
18	6.75	2.34
24	9.00	3.03

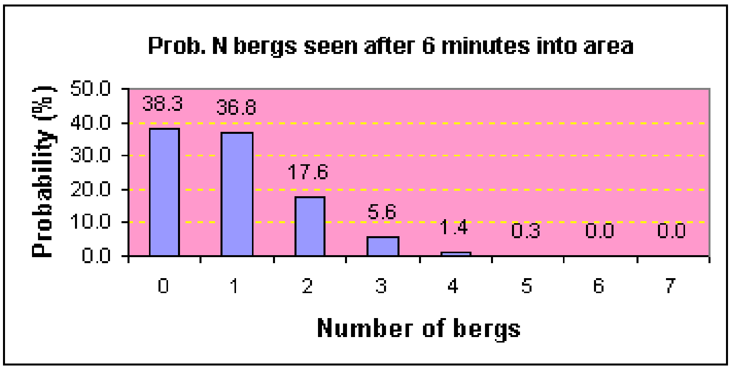
Probability of Seeing N Icebergs

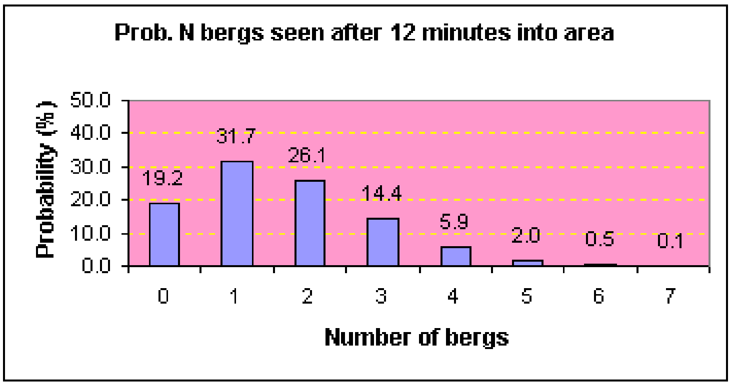
Averages may be somewhat interesting, but what we really want to know is the probability of sighting a given number of icebergs after being in the region for a certain amount of time. The answer we are looking for was discovered by Siméon-Denis Poisson in 1838 and published in his work *Recherches sur la probabilité des jugements en matières criminelles et matière civile* (Research on the Probability of Judgments in Criminal and Civil Matters). What he came up with was a mathematical expression that gave the probability that N occurances of something will take place if the average number of occurances is known. For those mathematically inclind, the probability that N icebergs were seen after time T is given by:

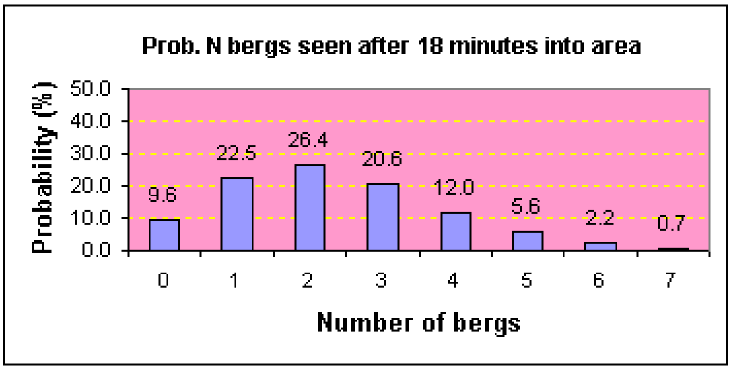
$P(N) = e^{-\mu} \mu^{N} /N!$

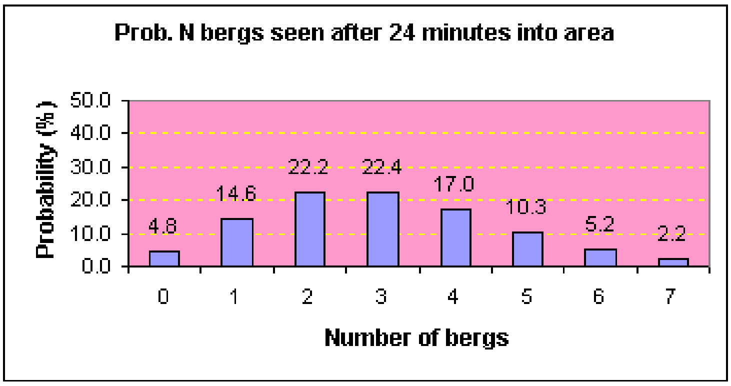
where values of μ are taken from the above table.

Let's show some results. Suppose we ask what is the probability that 3 icebergs were seen after the Titanic steamed 6 minutes into the high density iceberg region? The answer turns out to be 5.6%. If you ask what is the probability that 0 bergs were seen after 6 minutes, the answer comes out to 38.3%. For each of the times listed in the above table we can find the probability distribution that N icebergs were seen. The results are shown in the figures below.









We must keep in mind that that these are just probabilities. Even if the ship had been in the region for 24 minutes, there is almost a 15% chance that only one iceberg was seen, the berg that the *Titanic* struck at 11:40 PM. This is higher than rolling a “6” with a pair of dice.

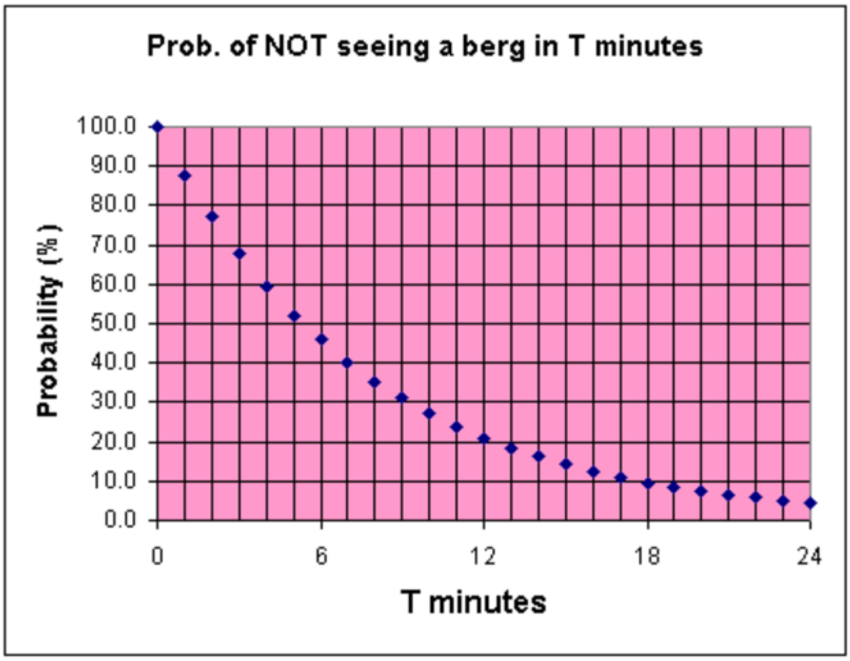
Time Between Sightings

Another thing we can do is find the probability distribution for the time between iceberg sightings. This is just the probability that an iceberg was not seen for an interval of T minutes while steaming through the region. On the average, an iceberg should have been spotted every 8 minutes and 42 seconds according to our model. But an average is just an average. The probability that an iceberg was not seen over a time interval of T minutes is given by what is called an exponential distribution. Again, for those into the math, the probability of not seeing an iceberg in T minutes is:

$P_0 = e^{-\lambda T}$

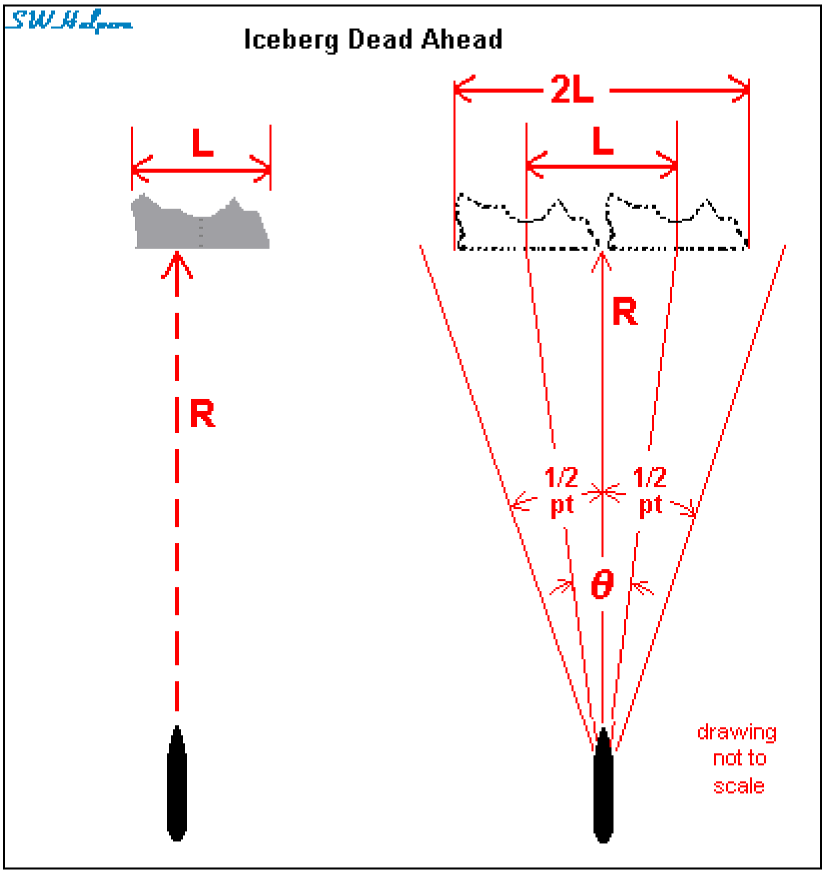
where λ= 0.115 bergs per minute, the average iceberg spotting rate for the ship steaming at 22.5 knots into our region.

A plot of this probability is shown below.

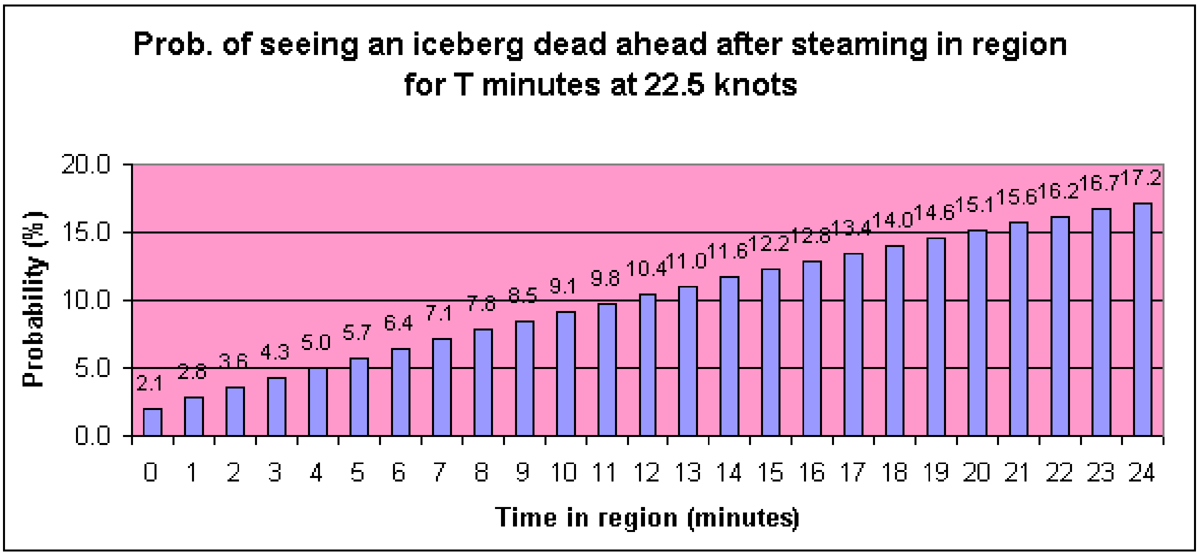


Iceberg Dead Ahead

Another question that some people have asked is what are the chances that an iceberg would actually suddenly appear dead ahead in the path of the ship? For this we have to define what is meant by dead ahead. Let us say that an iceberg is dead ahead if any part it lines up in the direct path of the ship. Referring to the diagram below, on the left is an iceberg that appears ahead of the ship at a distance R such that if no action is taken, the ship will strike the berg as indicated by the dashed line. If we were able to place the berg anywhere to the left or right of the ship's centerline, we see that the ship will strike the berg if the center of the berg's waterline length falls to either side of the extended centerline of the ship within a distance equal to the length of the iceberg. When we take the average length of an iceberg for each of our three size categories from table above and divide that average length by the average sighting distance for that category, what we get is a ratio from about 0.07 to 0.08. This represents an angular arc, θ, from center point to center point of about 4 to 4.5 degrees, or just under ½ point of arc. We will therefore define an iceberg to be dead ahead if, when first sighted, any part of the berg was seen within an arc that is ±½ point (±5.625°) to either side of the ship's extended centerline as shown in the diagram below.



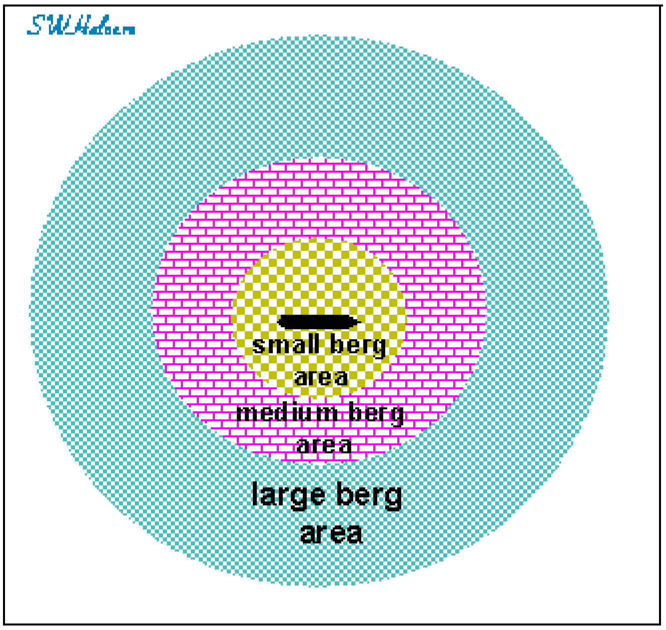
We can now work out the probability that a single iceberg would be sighted within that arc using the same technique as before; i.e., taking the area swept in T minutes that falls within a ½ point arc of dead ahead to get an average number to apply to the Poisson distribution. The results of this gives us the probability of a single iceberg being sighted "dead ahead" as a function of time steaming in the high density iceberg region. This is shown in the graphic below.



What we see is that the longer the ship steams through the high density iceberg region at 22.5 knots, the greater the chance of seeing an iceberg "dead ahead." The finite probability at T=0 in the above chart simply means that as the ship first enters the region there is a 2.1% chance that an iceberg will be seen within an arc of ½ point of dead ahead. Since the observation area from the *Carpathia* covered a region of 9 nautical miles to the horizon, let us assume that the high density iceberg region reached out that far to the east from the collision point. If the *Titanic* had been steaming for 24 minutes into this high density iceberg region before an iceberg was seen right ahead (i.e., a penetration of 9 nautical miles), then we can say that the probability of that happening was 17.2%, or better than the probability of rolling a "7" with a pair of dice.

Icebergs All Around

Another question that always seems to come up is why weren't icebergs seen from the *Titanic* after she came to her final stop? To answer this we have to look at the probability that there were no icebergs within the visual nighttime range of the stopped ship. The technique is to find the average number of bergs for all three categories within their respective sighting circles around the stopped ship as shown in the figure below, and then add these together to get the total average number of bergs that would be within sight. Once we have that we can apply it to the Poisson distribution formula with a parameter value of N = 0 bergs to quantify the probability that no iceberg would be seen. What we find is a probability of not seeing any icebergs at night from the stopped ship was 51%. In others words, the chances of seeing an iceberg in those waters for a ship that was stopped is about the same as coming up "heads" when tossing a coin.



How does this play into some of the reported actions taken after the ship collided with the fatal iceberg? One the established events, based on several eyewitness accounts, is that the ship steamed ahead again for a short time after it first came to a stop following the collision.[16] It has been the subject of speculation that one possible reason for doing this was to get clear of some ice so that lifeboats can be safely launched. Based on the above derived probability, it should not have taken very long for the ship to be moved into an area where no icebergs would be seen if the original stopping point had one or more icebergs in view. Was this the reason for moving the damaged ship again? That we may never really know.

It should be obvious to the reader that all of these results are dependent of the visibility distances we derived for our three iceberg size categories. We have also seen that in Bowditch they talk about a nighttime sighting distance from 1 to 3 miles, but they did not specifically say that this was for a completely calm sea and moonless night, or for what size icebergs. If we take their 3 mile distance to correspond to large bergs and the 1 mile distance to correspond to small bergs, then we can plug these into our model to see how the probabilities change. So taking a 1 mile radius for Small bergs, a 2 mile radius for Medium bergs, and a 3 mile radius for Large bergs, what we find is that the probability that one or more icebergs should have been seen from the stopped *Titanic* is 98.7%. In fact, the average number of icebergs that should have been seen, assuming icebergs could be seen that far away that night, is between 4 to 5. So if an iceberg of the size that the *Titanic* struck was capable of being seen as far as 2 miles ahead as some people believe,[17] then the statistics say that one or more icebergs should have been seen from the ship after she came to a stop with almost complete certainty. Yet this is not what was observed after the ship had stopped, or after people had taken to the boats. Only after the sky began to brighten with the rising dawn did the full extent of what was surrounding them finally become revealed.

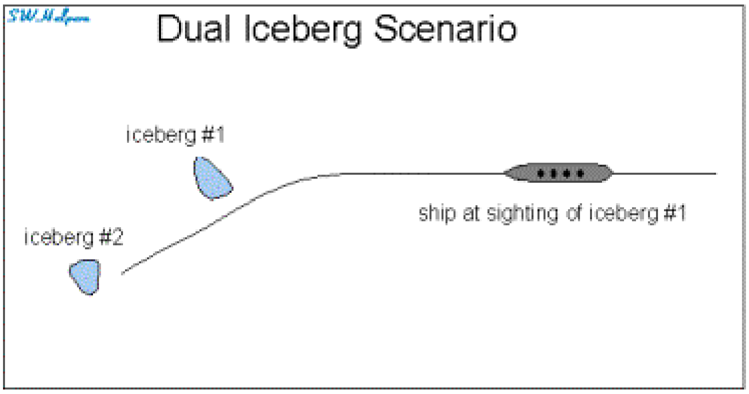
Esther Hart:

> Gradually the welcome dawn broke; and as the sun rose and we looked at where the sky and sea met, we saw one of the most wonderful sights that could be imagined. Right away there, stretching for miles and miles, there appeared what seemed to us, an enormous fleet of yachts, with their glistening sails all spread. As the sun grew brighter they seemed to sparkle with innumerable diamonds. They were icebergs.[18]

From a statistical sense, if icebergs were able to be seen from 1 to 3 miles that particular night, then we should have heard much more about people seeing icebergs well before the break of dawn. Such was not the case.

A Tale of Two Icebergs

Another scenario that can be tested by stochastic analysis is what some people call the “two iceberg” theory. In essence, what the two iceberg theory says is that a first iceberg was seen a few minutes before the accident and successfully avoided by a “hard-astarboard” turn to port. As soon as the ship was ordered to steady up after turning two points another iceberg was discovered that lay in her direct path with little opportunity to avoid. A picture of the situation is shown below.



This scenario can be analyzed using the methods already developed. We already have considered the probability of an iceberg seen dead ahead after entering the region after T minutes. We also know that the longer the ship was in the region the higher the probability that an iceberg will be seen dead ahead. So consider the ship having been in the high density area for T=24 minutes, 9 miles of penetration at 22.5 knots. As we have seen, the probability that an iceberg will be encountered dead ahead works out to be 17.2%. Assuming the ship successfully avoided that iceberg, the probability of seeing a second iceberg appear dead ahead with little time to avoid is not too different from seeing an iceberg dead ahead just as the ship entered the high density iceberg region at T=0.[19] From the above table, that probability is 2.1%. Since these are independent events, the total probability of both of these events happening is the product of the two probabilities. Therefore, the chance of such a scenario or similar having occurred turns out to be 0.36%. Statistically speaking, it just didn’t happen that way. Even if we remove the restriction that a second iceberg was seen dead ahead immediately after the ship successfully avoided the first one, we find that the probability of encountering two icebergs dead ahead at different times is no greater than 2%. From a purely probabilistic sense, there was only one iceberg that the Titanic had to evade that night, and it was not successful in doing so.

Conclusions

The results of this stochastic analysis point to several interesting conclusions:

- For a region of iceberg density such as that which the *Titanic* was steaming in on the night of April 14, 1912, the probability that an iceberg would be seen dead ahead would have increased the longer the ship continued to steam in the region.
- After 24 minutes of steaming into the high density region the probability of an iceberg looming up dead ahead was a little over 17%, better than rolling a “7” on a pair of dice.
- The probably that 3 icebergs were seen over the same 24 minutes of penetration into the high density region is a little over 22%. The probability that only one iceberg was seen is almost 15%.
- If the average sighting distance for a medium sized iceberg on the night of April 14th was as far as 2 miles, as some people thought it was, then once the Titanic came to a stop

there should have been about 4 to 5 icebergs on the average within viewing range of the stopped ship. This clearly was not the case. On the other hand, if the average sighting distance to a medium sized berg was just a little over ½ mile, then there was a about a 50% chance of not seeing any icebergs within viewing range of the stopped ship.

- The probability that the ship encountered a second iceberg dead ahead after successfully avoiding a first iceberg seen dead ahead is a fraction of a percent. In other words, it is statistically insignificant.

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[1] George Behe, *Titanic: Safety, Speed and Sacrifice*, Transportation Trails, 1997.

[2] http://www.encyclopedia-titanica.org/cgi-bin/discus/show.cgi?tpc=5664&post=153184#POST153184.

[3] David G. Brown, et at., *How They Sank Titanic*, draft copy presented at the Maine Maritime Academy Titanic Seminar, Castine, Maine, April 2004.

[4] Growlers and Bergy bits are usually pieces calved from icebergs, but they may also be the remains of a mostly melted iceberg.

[5] Testimony of Capt. Arthur Henry Rostron before the British Inquiry (25501).

[6] Testimony of Capt. Stanley Lord, before the American Inquiry (p.723-724).

[7] "The American Practical Navigator," Pub. 9, National Imagery and Mapping Agency, US Government printing Office.

[8] Testimony of 2nd Officer Charles Lightoller, British Inquiry, 13615 -13622.

[9] This nighttime photograph was obtained by taking a daytime photograph and electronically reducing the brightness to create nighttime seeing conditions.

[10] Leo Shubow, *Iceberg Dead Ahead!,* Bruce Humphries, Inc., 1959.

[11] James Bisset and P. R. Stephensen*, Tramps & Ladies*, Angus & Robertson, 1988.

[12] Rostron said he was moving about to get between half a dozen icebergs as he was coming up to Boxhall's boat. It does not mean that any of them were directly in his path. He certainly wanted to give them all a wide berth and so he altered his course a few times and was forced to slow down.

[13] The very last iceberg he encountered was seen dead ahead ¼ mile off which is why he starboarded his helm to avoid. (British Inquiry, 25425.)

[14] The observed cross sectional area will be proportional to the height times the length. The relative size is defined as the square-root of the cross sectional area.

[15] You may ask how can we have a fraction of an iceberg sighted in a given time period? Icebergs come in whole integers. The answer is best explained by a simple example. Suppose the birth rate in a certain municipality is one baby every 5 minutes. What is the average number of babies born per minute? The mathematical answer is 1/5. That is all that this table is telling us. The average of anything is useful only in how it is applied.

[16] See Dillon, Scott, Beesley, and Olliver.

[17] *Titanic's* 2nd Officer Charles Lightoller believed you could see a medium sized iceberg from

1½ to 2 miles away under the conditions that they were experiencing that night. He even thought that if it were a very white berg, flat topped or had a flat side facing towards you that it could be seen as far as 3 or 4 miles away (British Inquiry, 13652). Because of this ill founded belief, no additional steps were taken that night to enhance the safety of the ship. They did not slow down. They did not alter course well to the south to avoid the known ice region. They took no additional steps to increase the number of lookouts either on the bridge or on the forecastle head as was done in some other ships.

[18] *Ilford Graphic,* Friday, 10th May 1912.

[19] This is because the inter-arrival time between iceberg encounters follows an exponential distribution which is a memoryless process. In other words, the probability of an encounter with another iceberg T minutes after the first encounter is independent of the time that first encounter took place. It is just the probability of encountering an iceberg in T minutes.

Courtesy of Samuel Halpern