Safety Investigation Report of the Sinking of the Fishing Trawler, 501 Oryong

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Special Investigation Team, Korea Maritime Safety Tribunal

NOTE

NOTE: The objective of this report is to determine the cause of the maritime casualty. It was not written with an intention to ascertain fault, liability or claims. Therefore, it is advisable that the report is not used as evidence for court proceedings in accordance with Article 18:3(6) of the 「Act on the Investigation and Inquiry into Marine Accidents」. Relevant legislations and names of institutions in the report are from the time of occurrence of the marine casualty.

Contents

1. Summary (in local time)

1.1 The Fishing Trawler 501 Oryong departed from Gamcheon Port in Busan to catch pollack in the North Pacific Ocean at around 14:00, on July 10, 2014.

1.2 501 Oryong set its net to catch pollack in the sea (N62° 09' 47" W176° 31' 44") at around 05:00 on Monday, December 1, 2014. At around 10:30 of the same day, the net was being towed when the weather [1)] deteriorated and the hull of 501 Oryong shook violently.

1.3 In worsening weather conditions, the captain of 501 Oryong ordered the crew to haul in the net. They began to haul the net at 11:00 and finished the operation at 11:35 of the same day, then closed the breakwater.

1.4 Even after hauling the net and closing the breakwater, waves continued to flow into the deck. Despite the objection of the Korean boatswain, citing water inflow, the captain ordered the fish bunker[2)] hatch cover[3)] to be opened in order to empty the fish net in the fish bunker.

1.5 By opening the hatch cover, a large amount of seawater flowed into the fish bunker along with the catch of fish. Although the hatch cover was closed immediately, the net got caught in between the hatch cover and the deck allowing water to continue gushing in through the gap.

1) According to the surviving crew members and weather analysis data, the wind was blowing to the east at a speed of 10m/s, and waves were 2m high. However, from 10:30 on December 1, 2014, the speed of the easterly wind increased to over 15m/s and waves reached higher than 4m. Intermittently, strong winds of 25m/s and waves of 5m were generated.

2) Fish bunker: Space in a trawler where fish are stored temporarily after hauling the net on the deck. The fish bunker provides fish to the processing room as they are connected.

3) Hatch cover: a cover, that lies above deck, of an opening to a cabin below the deck of the vessel

1.6 From 12:06 on the same day, 501 Oryong began to navigate to the Port of Navarin[4] in Russia for refuge, with waves hitting the stern.

1.7 The wooden wall separating the fish bunker from the processing room[5] was destroyed from the starboard side due to pressure from fish and seawater pouring into the fish bunker. Then, the fish and seawater flowed into the processing room, and caused the hull to tilt starboard by 30°.

1.8 Crew in the engine room tried to pump out the water in the processing room using the bilge pump[6], but fish and other waste blocked the bilge well[7] making it impossible to pump out the water with the bilge pump. From around 12:30 of the same day, water was removed by using a portable submersible pump.[8]

1.9 From 13:00 of the same day, in order to restore the balance of the hull, fuel oil in the starboard tank was transferred to the port tank in the engine room, and cargo stocked on the starboard side were moved to the port side in the fish hold. At the same time, water flowed into the steering room through the starboard passage, fixing the rudder at hard port.

1.10 At around 14:00 of the same day, the hull was restored and maintained its balance, and at around 14:30, Carolina 77, which approached 501 Oryong for support, transferred one portable submersible pump by connecting a tow line.

4) MYS Navarin: a port in Russia located in the West Bering Sea. It is about 107 miles off, and 285° from the site of the accident.
5) Processing room: space where fish caught on the vessel are handled, frozen, and made into products.
6) Bilge pump: a pump used to remove waste water from the vessel.
7) Bilge well: space underneath the deck used to collect waste water.
8) Portable submersible pump: a mini pump that can be moved manually. It is used to remove water by placing the inflow hose in the water and positioning the outflow hose outside the vessel.

1.11 However, from around 15:00, 501 Oryong was hit by wind and waves on the starboard, resulting in a rapid incline towards the port side after a violent fluctuation from port to starboard. With the hull tilting to the port, a large amount of seawater flowed into the vessel through the sewage discharge outlet on the port side, which had been left neglected even after the shutter[9] had fallen apart.

1.12 The vessel, which rapidly tilted to the port, started to sink below water level from the left side stern from around 15:30. At around 16:49, the navigation signal transmitted from ARGOS[10] satellite was lost, and the vessel sank completely at N61° 54' 36", W177° 09' 00" at about 17:06.

1.13 As a result of this casualty, only 7 (1 Russian, 3 Filipinos, 3 Indonesians) of the 60-man crew (11 Koreans, 1 Russian, 13 Filipinos, 35 Indonesians) survived. 27 were confirmed dead and 26 missing.

1.14 The surviving crew had abandoned the vessel at around 16:40. Although nearby vessels, Zaliv Zabiyaka and Carolina 77 rescued 2 people (1 Indonesian, 1 Filipino) and 6 people (1 Korean, 2 Filipinos, 2 Indonesians, 1 Russian) respectively, one Korean died, leaving only 7 survivors.

1.15 This casualty occurred as 501 Oryong set its net to catch pollack despite the bad weather forecast, and in the process of pouring fish into the fish bunker in deteriorating weather conditions, a large amount of water also gushed into the fish bunker.

9) Shutter: a switchgear installed on the outer surface of the sewage discharge outlet that is operated by oil pressure to maintain waterproof performance. This is described in more detail with the image on 3.1.4.

10) Advanced Research & Global Observation Satellite (ARGOS): The U.S.'s advanced research and global observation satellite

1.16 With the net getting caught in the hatch cover as the hatch cover of the fish bunker was being closed, water continued to flow in. Water also gushed in through the sewage discharge outlet on the port side, which made it impossible to pump out a sufficient amount of seawater. The resulting loss of stability and buoyancy are assessed to be the cause of the casualty.

1.17 It is estimated that the 315 ton-catch of fish stored in 501 Oryong, excluding fishing equipment, and fuel oil of 608 kiloliters remain inside the fish hold and the fuel tank.

1.18 Although the rescue operation began at around 17:06 after vessels in the area arrived at the site of the casualty, it stopped after only saving 5 rafts and rescuing 8 crew (one died after being rescued) due to bad weather and lack of light.[11] This is assessed to be due to the sudden sinking, which prevented crew members from abandoning the ship on time.

1.19 Furthermore, a safety management system was not being operated on this vessel. Due to the lack of systematic training on abandoning ship during normal times, it is viewed to have hindered execution of appropriate measures related to life rafts and wetsuits in an actual situation requiring ship abandonment.

1.20 In the case of deep-sea fishing vessels, there is no legislation governing the safety management system. It is customary for companies and crew to enter into contracts centered on the captain. Therefore, safety on the vessel depends largely on the personal ability and preference of the

11) The time of sunset on the day of the accident was 14:33

captain.

1.21 Furthermore, although the officers, including the captain, did not meet the qualifications of the Ship Personnel Act with their licenses, the company permitted them to board the ship as there had not been any issues in their previous voyages. In addition, the overall navigation capacity of the vessel was undermined as some officers had not boarded the ship at departure.

1.22 In order to prevent a recurrence of such casualty, this report proposes improvements are made to the safety management system of deep-sea fishing companies, including stronger safety management of operators, and to confirm whether sufficient crew is on board prior to departure.

1.23 Furthermore, regarding the hatch cover of the fish bunker and the sewage discharge outlet, which have been found to be the main cause of water inflow, it is proposed that the structure or operation mechanism is improved to fundamentally prevent a large inflow of water.

1.24 The timeline of the casualty is as follows.

Time	Situation
2014. 12. 1. 05:00	Begins to set the net
11:00	Begins to haul the net
11:35	Drops net on deck (finishes hauling), closes breakwater, water starts to flow in
12:00	Opens the hatch cover and closes it incompletely
12:06	Starts to get underway towards Port of Navarin
12:30	Tilts starboard by 30°, starts pumping out seawater (submersible pump)

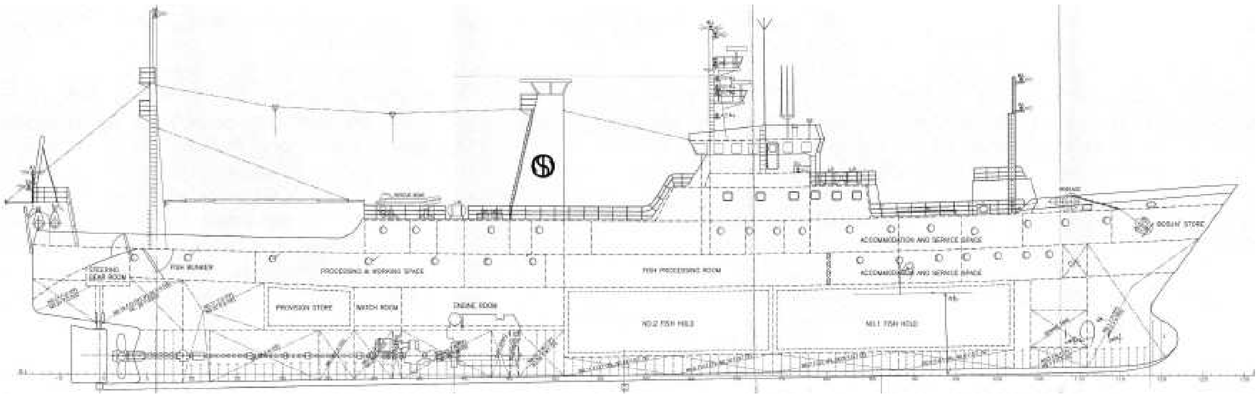
13:00	Rudder out of control, transfers fuel and cargo from starboard to port
14:00	Recovers balance temporarily
14:30	Carolina 77 delivers one submersible pump
15:00	Hull turns left, rapidly tilts to port, large inflow of water through the sewage discharge outlet
15:30	Part of the portside stern sinks below water level
16:00	Hull tilts port by 40°
16:30	Sinks from stern
16:40	Crew starts to escape
16:49	Satellite location disconnected
17:06	Receives EPIRB)[12] signal, hull sinks

12) Emergency Position-Indicating Radio Beacon (EPIBRB): a device that automatically transmits location signal in order to detect the location of survivors in rescue operations

2. Facts

2.1 Key Ship Information

Vessel Name	501 Oryong
Flag	Republic of Korea
Port of Registry	Busan Metropolitan City
Call Sign	6KCA8
Fishing Vessel Registration Number / IMO Number	1402001-6261401 / 7388504
Vessel Type	Vessel for Deep-Sea Trawl Fishing
Main Target Species	Pollack, cod, halibut, herring, other demersal fish
Fishing Area	North Pacific Ocean (Russia EEZ and midway)
Owner / Operator	Sajo Industries
Max. Number of Allowable Persons on Board	70 crew members
Shipbuilder	CONSTRUCCIONES NAVALES SANTODOMINGO (SPAIN, VIGO)
Date of Keel Laying / Launching	1976.04.26 / 1978.11.1
Classification Society	Korean Register
Overall Length (m)	76.17
Depth (m)	8.40
Breadth (m)	13.00
Gross Tonnage (t) / International Gross Tonnage (t)	1,753.00 / 2,151.00
Deadweight Tonnage (t)	911.350
Full Load Draft (m)	6.35
Main Engine	RBV 6M 358
Maximum Output	1,619kW x 2
Fuel Consumption	279.18 gr/㎾.hr
Propeller (inward)	2
Rudder	1
Design Speed (knot)	13



[Image 1] General layout of 501 Oryong

[Image 2] View of 501 Oryong (1)

2.2 Vessel Structure and Characteristics

2.2.1 501 Oryong, built in Spain in 1978, engaged in fishing operations only on the coast of Argentina before being acquired by Sajo Industries and Orion, a joint shipping company registered in Russia. It was then modified into a stern trawler equipped with a processing room and fish bunker that enables operation in the North Pacific Ocean.

2.2.2 Below the upper deck of the vessel, the fuel tank was at the bottom, ballast water tank above it, then two fish holds, the engine room, and the steering room. On top of the fish hold and the engine room lies the finish bunker and the processing room. There is one floor of living quarters below deck and three above deck. The wheelhouse is located on the third floor, which is the top floor of the vessel.

2.2.3 There are two diesel engines for propulsion (main engine) and propellers, but only one rudder. The side thruster that helps to dock the ship at pier was not installed.

2.2.4 The catch of fish gets hauled in at the stern and poured into the fish bunker. Then, the catch gets transferred from the fish bunker to the processing room to undergo the sorting and freezing process. Afterwards, it gets stored as units of pan[13] in the fish hold.

13) Pan: a unit for a box of frozen fish products, roughly weighing about 21.5kg per pan.

2.2.5 Two derricks, which help to lift the fish stored in the fish hold, have been installed at the top of the fish hold. In the center of the upper deck, a winch has been set up to reel in fishing equipment.

2.2.6 The stern of the vessel is in the slipway form to facilitate net lifting. The breakwater has been installed to block waves from the slipway after hauling in the net.

2.2.7 The steering room of the vessel is located below the stern, about 0.5m closer to the upper surface than the upper surface of the 2nd deck where the fish bunker and the processing room are located. It can be accessed through the passageway to the right of the fish bunker.

2.2.8 In order to process the bilge generated in the fish bunker and the processing room, two bilge wells (1.2m wide, 0.8m long, 0.3m high) have been installed in the processing room, each of which is connected to the engine room and the bilge pump.

2.2.9 The instruction manual to the pump connected to the bilge well in the processing room has been lost so it is difficult to confirm its capacity. Also when the Korean Register conducted the classification survey after construction, it approved the inspection by the previous class and did not undertake a separate inspection. The Korean Register estimated the pump's capacity to be more than 40 tons per hour, given the drainage system, after the casualty.

2.2.10 The steering room is located behind the processing room and the fish bunker. The coaming on the doorway of the steering room is 45cm and the door is weather-tight. In the processing room, there is a passageway connected to the engine room, and its coaming is 45cm and the door is weather-tight.

2.2.11 There are two fish holds below the processing room in the vessel. The volume of the first fish hold is 471.3㎥, and that of the second fish hold is 635.2㎥, which adds up to be a total of 1,106.5㎥.

2.2.12 The capacity and arrangement of the fuel tank, fresh water tank, and ballast water tank are as shown in Table 1.

[Table 1] Status of Various Tanks

Category	Location (Frame No.)	Capacity (㎥)	Notes (use)
F.P.Tank(P)	111 ~ FE	61.95	Ballast water
F.P.Tank(S)	111 ~ FE	61.95	Ballast water
Subtotal		123.90	
NO.3 F.O. TANK(P)	102 ~ 111	16.47	Fuel
NO.4 F.O. TANK(S)	102 ~ 111	48.10	
NO.5 F.O. TANK(P)	88 ~ 102	18.60	
NO.6 F.O. TANK(S)	88 ~ 102	18.60	
NO.7 F.O. TANK(P)	74 ~ 88	32.52	
NO.8 F.O. TANK(S)	88 ~ 88	32.52	
NO.9 F.O. TANK(P)	63 ~ 74	37.63	
NO.10 F.O. TANK(S)	63 ~ 74	37.63	
NO.11 F.O. TANK(P)	51 ~ 63	38.23	
NO.12 F.O. TANK(S)	51 ~ 63	38.23	
NO.15 F.O. TANK(P)	12 ~ 28	54.15	
NO.16 F.O. TANK(S)	24 ~ 28	17.10	
NO.17 F.O. TANK(P)	9 ~ 18	83.85	
NO.18 F.O. TANK(S)	12 ~ 24	25.30	
NO.19 F.O. TANK(P)	0 ~ 9	30.00	
NO.20 F.O. TANK(S)	9 ~ 18	68.25	
NO.21 F.O. TANK(P)	AE ~ 0	37.20	
NO.22 F.O. TANK(S)	0 ~ 9	30.00	
NO.24 F.O. TANK(S)	AE ~ 0	37.20	
NO.25 F.O. TANK(C)	-1 ~ 9	66.50	
Subtotal		768.08	
NO.27 L.O. TANK(P)	28 ~ 32	8.90	Lubricating oil
NO.28 L.O. TANK(S)	28 ~ 32	8.90	
Subtotal		17.80	
NO.29 F.W. TANK(P)	33 ~ 43	37.50	Fresh water
NO.30 F.W. TANK(S)	33 ~ 43	37.50	
NO.31 F.W. TANK(P)	45 ~ 51	34.43	
NO.32 F.W. TANK(S)	46 ~ 51	29.43	
Subtotal		138.78	
SEWAGE TANK(P)	104 ~ 110	16.17	Waste water
SLUDGE TANK(P)	45 ~ 46	5.08	Sludge
BILGE TANK(S)	44 ~ 45	1.80	Bilge

2.3 Vessel Modification and Vessel Inspection by the Russian Register

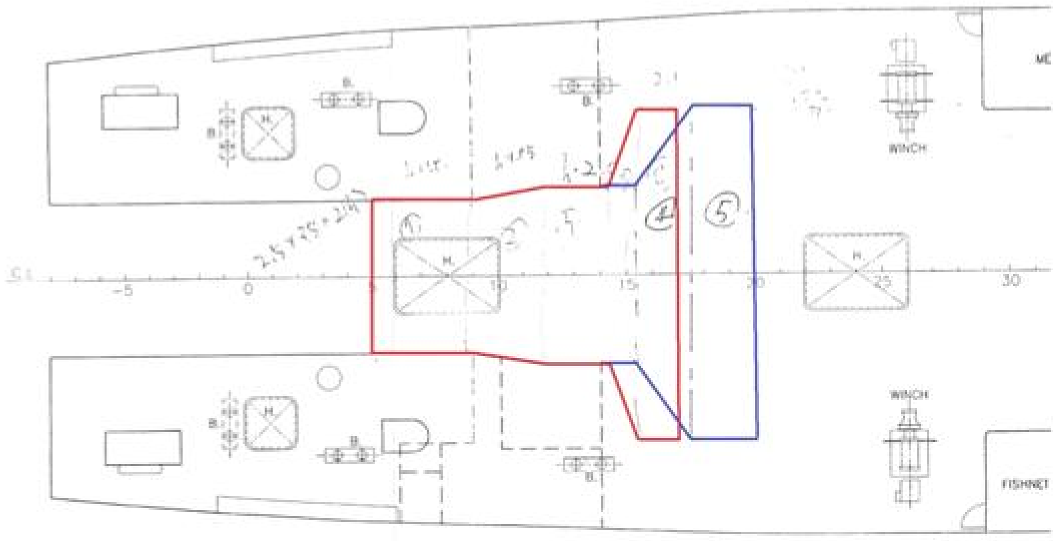
2.2.1 The keel was laid for 501 Oryong on April 26, 1976 in Spain, and construction was completed on November 1, 1978. It was purchased and inspected by Bureau Veritas, the French classification society, and undertook operation on the coast of Argentina. When Sajo Industries and Orion, a Russian joint shipping company, acquired the vessel, the name changed to ORION 501 and was placed under the Russian flag. The Russian Maritime Register of Shipping issued a certificate for the delivery on October 2010, and many modifications were made to the ship.

2.3.2 After acquiring the vessel from Argentina in August 2010, Orion initiated reconstruction work at Gamcheon Port in Busan and planned for its departure in March 2011.

2.3.3 As the vessel mainly caught and filleted fish along the coast of Argentina, there was many filleting[14)] equipment in the processing room and no unloading device at the time of purchase by Orion.

2.3.4 The main modifications made to the vessel at Gamcheon Port are as follows. First, in order to process a large amount of pollack caught in the North Pacific Ocean at once, the fish bunker where the fish are temporarily stored was expanded by 2m to the fore.

14) Filleting: removing the head, guts and bones of the fish on the ship so only the flesh is extracted and ready to be sold as a product

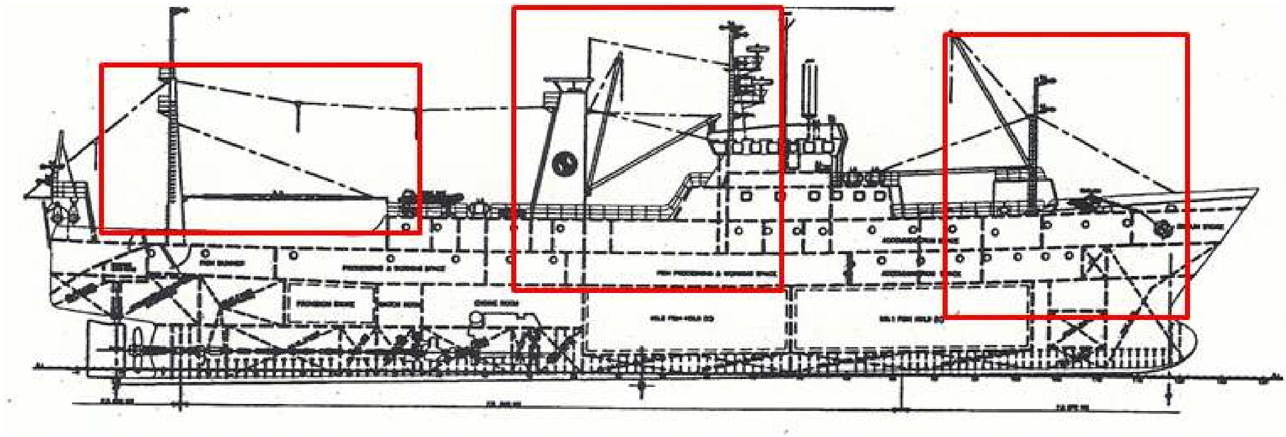


[Image 3] Expansion of fish bunker (blue line)

2.3.5 Second, previously installed equipment to facilitate filleting were removed and a round system[15)] better suited for processing pollack was installed.

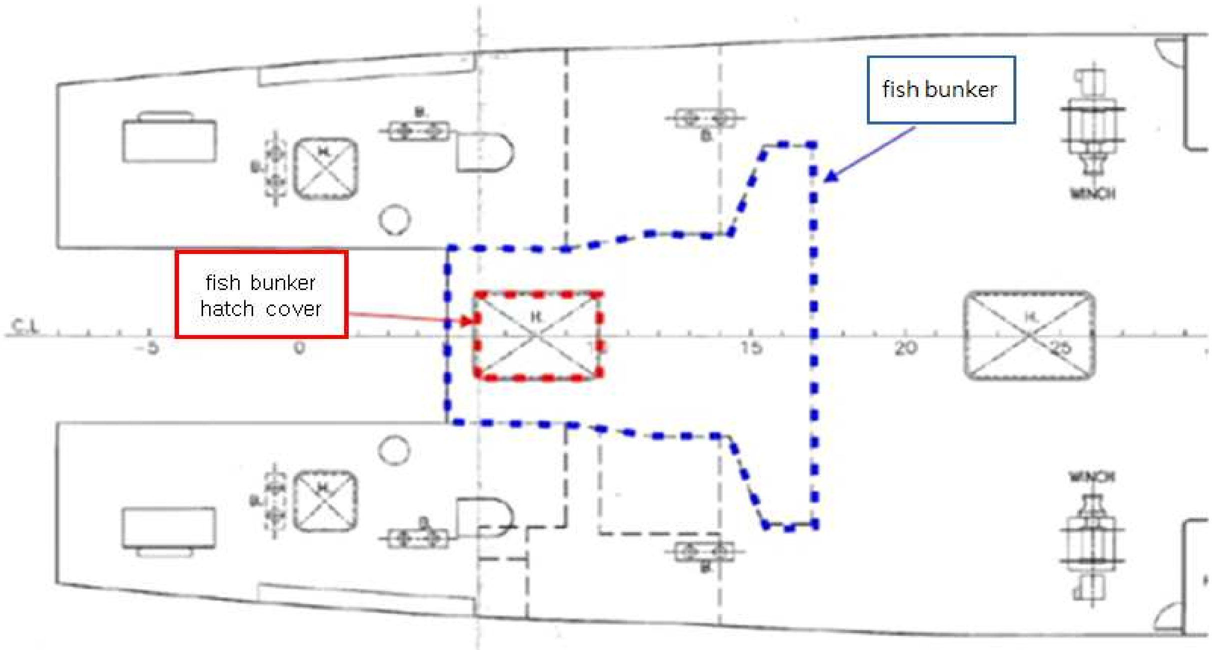
2.3.6 Third, two derricks, used for unloading, were each installed on top of fish holds number one and two. As the previous operation was mainly along the coast, it was possible to unload the catch using unloading equipment on land. However, in the case of pollack fishing in the North Pacific Ocean, the vessel needs to be equipped with an unloading device because the catch has to be transferred to a carrier.

15) Round system: freezing the catch of fish in units of pan rather than processing it on the ship



[Image 4] New installation of derricks (the two boxes from the right)

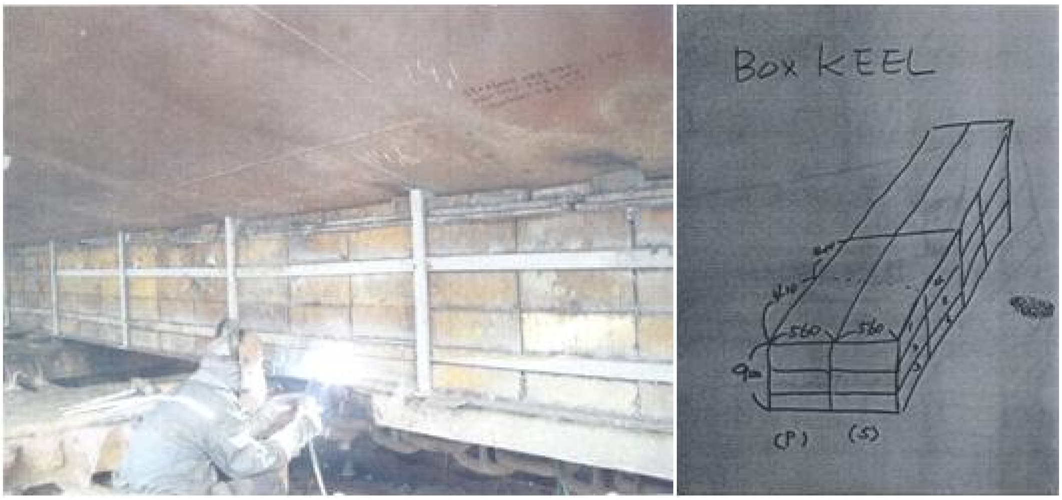
2.3.7 Fourth, there were previously two small fish bunker hatch covers (1.5m x 1.5m) but these were replaced with one large hatch cover in the middle (transverse 1.5m x length 2.4m). This was because the captain who oversaw this work on site deemed it necessary for the convenience of operation.



[Image 5] Expansion of the fish bunker hatch cover (red box)

2.3.8 Previously, the fish bunker hatch cover lifted outwards for opening and closing, but also for the convenience of operation, it was re-installed as a flap hatch cover, which opens downwards and closes upwards.

2.3.9 In addition, as the classification society changed from BV to RS, an incline test was conducted prior to the departure from Gamcheon Port in March 2011. As a result, it was instructed not to operate with a full fuel tank in tanks number 9, 10, 11, and 12 in order to improve the stability of the vessel. It was then informed to complement its stability by installing a box keel of 175 tons by August 2011.



[Image 6] Installation of box keel at the bottom of the ship

2.3.10 Therefore, from June 3, 2011 to June 28, 2011, the vessel was lifted to Gangnam Shipyard at Gamcheon Port for regular repair. The ballast (about 17 tons) in a small box keel form was removed and 260 ballasts of box keel (height of 0.3m, width of 0.41m, length of 0.56m, weight of 0.54 tons) were manufactured and installed at the bottom of the ship.

2.3.11 After installing the box keel, the light load displacement weight increased by 157.6 tons, from 2,329.54 tons to 2,487.14 tons, but the balance point was lowered, thereby negating the conditions imposed on the use of fuel tank mentioned in 2.3.9.

2.4 Vessel Inspection by the Korean Register

2.4.1 The Korean Register executed a preliminary inspection of 501 Oryong from February 12, 2014 to February 14, 2014 for the transfer of classification society (withdrawal from the previous classification society on January, 21, 2014). From the 17^{th} to 28^{th} of the same month, the vessel underwent the classification survey after construction (TOC, Transfer of Classification), annual survey, and regular inspection on behalf of the Korean government, and received a fishing vessel survey certificate valid through May 5, 2018 in accordance with the Ship Safety Act on February 28, 2014.

2.4.2 The maximum number of allowable persons on board according to the fishing vessel survey certificate is 70 crew members.

2.4.3 The classification survey after construction is required to accept inspection results of the previous classification society in accordance with regulations of the International Association of Classification Societies. Thus, for the floor plan, the Korean Register only approved the general layout and the fire control plan, and for data, it approved the stability data and the Shipboard Oil Pollution Emergency Plan (SOPEP).

2.4.4 In regard to the approval of the stability data, as the data of the previous classification society was accepted, the previously written calculations were approved without conducting an incline test. The deadweight tonnage of the standard loading conditions stated in the data are summarized in Table 2.

[Table 2] Deadweight Tonnage of Standard Loading based on Stability Summary Table

(Unit: tons, meters)

Summary	Light load	Full load (departure from port)	Departure from fishing area	Entry into home port	Entry into home port with 20% of catch
Condition No.	1	2	3	4	5
Displacement (t)	2,487.140	3,374.591	3,398.490	3,277.599	2,795.830
Draft (m)	5.196	6.321	6.350	6.203	5.599
G○M	0.182	0.938	0.681	0.586	0.408
Constant	-	87.765	98.527	98.527	98.527
Fuel oil	-	634.126	158.532	63.413	63.413
Lubricating oil	-	15.380	11.535	7.690	7.690
Clean water	-	138.780	34.695	13.878	13.878
Corrosion etc.	-	7.400	1.850	0.740	0.740
Fish	-	-	606.211	606.211	121.242
Paper box, vinyl	-	4.000	-	-	3.200
Ballast (seawater)	-	-	-	-	-
Deadweight	-	887.451	911.350	790.459	308.690

2.4.5 According to the stability calculations, the summer freeboard is 2.710m, summer load water line is 6.350m, lightweight tonnage is 2,487.240 tons, and full load displacement is 3,398.490 tons.

2.5 Operational Status and Problems after Construction

2.5.1 501 Oryong, which was built in Spain, was acquired by crew members of Sajo Industries from Argentina in August 2010. 501 Oryong was acquired along with Orion 505, which were both registered under the Russian flag. They were then operated as joint company vessels with a Russian shipping company.

2.5.2 At the time, 501 Oryong mainly caught sea bream in the midway fishing ground (N32° and to the west of Hawaii in longitude) during the first half of the year. In the second half of the year, it caught pollack in the North Pacific Ocean fishing ground (near the Bering Sea).

2.5.3 When the vessel was purchased in August 2010, the transverse equilibrium was not achieved, which resulted in a severe incline towards either the starboard or port side during navigation. It was difficult to find the equilibrium by transferring fuel in the engine room, and the main engine sometimes stopped during operation.

2.5.4 The problem with the transverse equilibrium was improved after the fixed ballast in the form of box keel was installed at the bottom of the ship in June 2011. The issue of automatic cessation of the main engine was resolved naturally with regular repair and the crew's knowledge of its characteristics. The main engine almost never failed after October 2012.

2.6 Trawling License and Operation of Sajo Industries in the North Pacific Ocean

2.6.1 Sajo Industries obtained the permit for trawl fishing in the North Pacific Ocean with 501 Oryong from the Ministry of Oceans and Fisheries on March 4, 2014. Sajo Industries manages 501 Oryong, sailing under the Korean flag, and 5 trawlers sailing under the Russian flag in the North Pacific Ocean.

2.6.2 501 Oryong was operated by Orion, a joint company of Russian nationality, after being acquired from Argentina in 2010. Then, following the issuance of the certificate of nationality from Seo-gu, Busan, on February 25, 2014, the nationality of the vessel changed to Korean. 501 Oryong obtained the permit for trawl fishing from the Ministry of Oceans and Fisheries on March 4, 2014.

2.7 Acquisition of Pollack Quota and Distribution Status

2.7.1 The Ministry of Oceans and Fisheries held a fisheries committee meeting annually since the fishing agreement between Korea and Russia was signed in September 1991 to negotiate fishing quota and other conditions. In the case of the quota for pollack, Korea obtained 46,800 tons in 2010, 50,001 tons in 2011, 40,001 tons in 2012, 40,000 tons in 2013, and 40,000 tons in 2014.

2.7.2 The season for fishing pollack is from 00:00 on May 16th to 00:00 on December 31st each year. There is one Russian inspector on board each fishing vessel to keep watch over the operation, and because the pollack gets shipped to Korea on a separate carrier, it is possible to continue fishing if conditions are favorable, regardless of the size of the vessel (fish hold).

2.7.3 The pollack quota obtained through the fishing agreement is distributed to companies based on the fishing capacity of each vessel, calculated based on the tonnage and engine power, by the North Pacific Fishery Committee of the Korea Overseas Fisheries Association, in accordance with the standards set by the Ministry of Oceans and Fisheries. However, the five existing companies[16)] are distributed about 20,000 tons based on acknowledgement of their grandfathered interests. In 2014, there were five pollack fishing vessels from five deep-sea fishing companies. The distribution of the quota is as shown in Table 3.

[Table 3] Share of Pollack Quota Distribution

Shipping Company	Gross Tonnage	Share (%)	Engine Horsepower	Share (%)	Final share %)
Keukdong Fisheries	4,375	24.05	6,000	24.69	24.37
Nambuk Fisheries	5,545	30.51	5,700	23.46	26.98
Sajo Industries	**1,555**	**8.55**	**3,300**	**13.58**	**11.07**
Sajo Oyang	3,527	19.39	4,500	18.52	18.96
Hansung Enterprise	3,182	17.50	4,800	19.75	18.62
Total	18,188	100.00	24,300	100.00	100.00

16) In the past, some 30 fishing vessels operated in the waters of Russia but following Russia's policy to reduce quota given out to foreign vessels, most vessels were placed under joint companies (2002-2003). The five vessels that continued to operate despite the small quota of about 20,000 tons, provided the basis for the expansion of the quota to 40,000 tons. For this reason, their vested rights for some 20,000 tons of quota is accepted.

* Fishing vessels: Sajo Industries (501 Oryong, 1,753 tons), Sajo Oyang (Oyang 96, 392 tons), Nambuk Fisheries (Nambuk, 5,549 tons), Hansung Enterprise (Junsung, 2,866 tons), Keukdong Fisheries (Junsung 5, 3,571 tons)

2.7.4 Once the quota is assigned, a fishing fee (350 dollars per ton in 2014) must be paid upfront regardless of whether fishing actually takes place. So in order to use all of the quota secured, the Korea Overseas Fisheries Association makes adjustments autonomously and then submits it for the approval of the Ministry of Oceans and Fisheries. Necessary compensation from the adjustment is handled within the scope of the fishing fee already paid.

2.7.5 The Korea Overseas Fisheries Association received 30,000 tons of pollack quota from the Ministry of Oceans and Fisheries during the first round in 2014 and allocated it to relevant companies on May 2. It received 10,000 tons in the second round and allocated it to relevant companies on October 8. Then, after adjustments, the share of the quota was confirmed.

2.7.6 For 501 Oryong, Sajo Industries received 3,321 tons in the first round and 1,107 tons in the second round. But after the adjustment, it received additional quota and secured a total of 7,928 tons. The acquired quota and the amount consumed are as shown in Table 4.

[Table 4] Comparison of Quota and Amount of Catch by Month

(unit: ton)

Month	Secured Quota	Amount of Catch	Quota Consumed	Remaining Quota
2014. 5	3,321 (allocated)	-	-	3,321
6		-	-	3,321
7		811.41	819.52	2,501.48
8	2,000 (adjusted)	1,903.18	1,922.21	2,579.27
9		1,476.79	1,491.38	1,087.89
10	2,607 (allocated 1,107) (adjusted 1,500)	1,189.38	1,201.27	2,493.62
11		877.20	885.97	1,607.65
Total	7,907	6,258.15	6,320.36	1,607.65
Monthly avg.	-	1,251.63	1,264.07	-
Daily avg.	-	41.7	42.1	

2.8 Status and Duty Shifts of Crew Members on 501 Oryong

2.8.1 With gross tonnage of 1,753 tons and main engine output of 3,238 kilowatts (two 1,619 kilowatt engines), 501 Oryong must have 4 deck officers, 4 engineer officers, and 1 radio officer with qualifications on board, in accordance with the minimum safe-manning standards related to Article 22 (1) of the Enforcement Decree of the Ship Personnel Act.

2.8.2 While a qualified chief officer and 3rd officer were on board, there were no 2nd engineer, 3rd engineer or radio officers on board. The 2nd officer, chief engineer, and 1st engineer who did board possessed licenses that did not meet the minimum qualifications. This is summarized in Table 5.

[Table 5] Status of Crew on Board 501 Oryong

Manning Standard			Actual Crew on Board		
Category	Gross tonnage/engine output	Crew (qualification)	Name	Officer license (valid through)	Qualification
Deck	1,600~3,000 tons	Captain (2nd class officer)	Kim oo	BS-F3-14-0000 (~'20.02.06.)	X
		Chief Officer (3rd class officer)	Yoo oo	BS-F3-14-0000 (~'19.02.25.)	O
		2nd Officer (4th class officer)	Kim oo	BS-G5-12-0000 (~'17.02.02.)	X
		3rd Officer (5th class officer)	Kim oo	BS-G5-12-0000 (~'17.02.14.)	O
Engine	3,000~6,000KW	Chief Engineer (2nd class engineer)	Kim oo	BS-E3-14-0000 (~'15.10.18.)	X
		1st Engineer (3rd class engineer)	Kim oo	BS-E4-12-0000 (~'17.02.08.)	X
		2nd Engineer (4th class engineer)	-		X
		3rd Engineer (5th class engineer)	-		X
Radio	5000~20,000 tons	Radio Officer (2nd class radio operator)	-		X

2.8.3 In January 2014, 11 Korean crew members including the captain, chief officer, 2nd officer, 3rd officer, boatswain, quarter master, no.1 oiler, an officer in charge of freezing fish, and an officer in charge of processing fish boarded the vessel at Gamcheon Port in Busan, and entered into a crew labor contract in early March of 2014.

2.8.4 Foreign crew members including 13 Filipinos, 35 Indonesians, and one Russian inspector boarded the vessel on July 18th at Petropavlovsk-Kamchatsky. The inspector who had been present at the time of the casualty had replaced the prior inspector on October 10th on the waters of the northwest Bering Sea.

2.8.5 Sajo Industries transferred all crew members except for the chief engineer who were on board Oryong 503, one of its vessels that was being scrapped, to 501 Oryong.

2.8.6 However, as 501 Oryong is greater in gross tonnage and engine output than Oryong 503, higher level ship operater licences are required of officers on 501 Oryong. Accordingly, the number of officers who did not meet the qualifications increased, and some crew members who did not board the vessel at departure could not be substituted.

2.8.7 With regard to hiring crew members, Sajo Industries continuously contacted officers who had boarded its other ships on previous voyages and encouraged their embarkation. It also hired officers through the Korea Seafarer's Welfare & Employment Center, contacted officers who had boarded vessels of the same industry of other companies, and were also introduced to new officers through the Radio Officers' Association.

2.8.8 As for foreign crew members, the number of necessary foreign crew could be calculated sent to Sajo International, a subsidiary of Sajo Industries at the request of the captain. Then, Sajo International contacts local crew management companies in Indonesia and the Philippines to secure crew members who would be able to board the ship after an interview with the captain.

2.8.9 Like other deep-sea fishing companies, Sajo Industries signed a labor contract with crew members at each fishing season before departure. The labor contracts were terminated when the fishing season ended.

2.8.10 On 501 Oryong, crew duty was often conducted in two shifts with the captain and the 3rd officer as a pair and the chief officer and the 2nd officer as a pair in instructing the setting and drawing of the net. As for the engineering department, the chief engineer and an engineer were paired and the no.1 oiler and fish processing worker were paired in conducting the two-shift duty. Five foreign crew members participated in the duties of the engineering department.

2.8.11 There were about 30 people in the processing room of the vessel. They were divided into three groups who took alternated shifts of working for 12 hours and resting for 6 hours. The shifts rotated at 06:00 and 18:00, led by Korean and Indonesian officers in charge of processing fish.

2.9 Life-saving Equipment on 501 Oryong

2.9.1 The safety management of fishing vessels flying the Korean national flag is based on the Fishing Vessels Act under domestic law, and both the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention on the Control of Harmful Anti-fouling Systems on Ships, international protocols, can be applied internationally. With regard to the fire control and life-saving equipment, the Standard of Fishing Vessels Equipment (Ministry of Oceans and Fisheries, no. 2013-278) stipulates relevant information in accordance with Articles 3, 5 and 5(2) of the Fishing Vessels Act.

2.9.2 In addition to the life-saving equipment that needs to be equipped on Korean vessels, Russian vessels must load life rafts and wetsuits that amount to 100% of the maximum number of allowable persons on board.[17)]

17) Korean vessels are required to load life jackets that match 100% of the persons on board.

2.9.3 The main life-saving equipment that were actually on 501 Oryong are four 20-person life rafts, four 16-person life rafts, 74 life jackets, and 74 wetsuits. This satisfies not only Korean regulations, but also that of Russia.

2.9.4 However, on the life saving plan of the vessel, there are only two 8-person life rafts, four 16-person life rafts, one rescue boat, and 80 life jackets, which differs from what was actually on board. Moreover, wetsuits were not included on the list.

2.10 Safety Management of the Fishing Trawler by Sajo Industries

2.10.1 Sajo Industries has independently developed a ship safety management manual that regulates safety management procedures before departure, during navigation, when fishing, during rough conditions, in entering a port, and when mooring.

2.10.2 Furthermore, in consideration of the nationality of crew members, separate safety manuals have been published and enacted in English (Filipino), Indonesian, Chinese, and Vietnamese.

2.10.3 In the safety management regulations for when the vessel is in fishing operation, fishing in bad weather or rough water due to storms is prohibited. In addition, the officer on duty, on deck must be wearing a personal life jacket.

2.10.4 When fishing under rough conditions, the safety management regulation stipulates that “the vessel should prepare for rough

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There are no regulations on the need to load wetsuits.

conditions by reading updated weather forecasts and seeking a nearby shelter preemptively. Fishing equipment and cargo should be moved further below the ship to lower the center of the vessel, and fishing gear, including nets, should be secured tightly. In rough weather and during navigation, fishing gear holes as well as openings including windows and door should be closed."

2.10.5 In Sajo Industries, the overall safety management is conducted by the fisheries team of the main Busan office, but once the vessel departs the port, the fisheries headquarters at the main office takes charge. In the case of 501 Oryong, Trawl Team 2 was in charge of safety management after its departure.

2.10.6 Sajo Industries received the safety management checklist during fishing from each vessel every Friday. A training checklist by type of safety casualty has also been posted on each vessel.

2.10.7 Since its departure, 501 Oryong filled in the safety management checklist during fishing and sent it to Trawl Team 2 at the main office every Friday. However, it did not execute specific safety training for different casualties.

2.10.8 After departure, the chief officer held one training session for all crew members on the use of fire extinguishers and life jackets but did not execute any fire control or ship abandonment training. [18)]

18) According to Article 15 (muster list and training) of the Seafarers Act, "the captain of a vessel of gross tonnage over 500 tons must post the muster list that assigns the duty of crew members in emergency situations in places where it can be easily seen. Also, training for emergency situations such as fire drill and lifeboat drill needs to be executed on all persons on board. In this case, crew members must engage in training as is written on the muster list."

2.10.9 Furthermore, although the muster list was posted on the deck house and the dining area, it was written in Russian and almost none of the crew members understood its meaning.

3. Details of Marine Casualty

3.1 Departure from Gamcheon Port in Busan and Fishing Operation

3.1.1 Departure and Crew Status

3.1.1.1 501 Oryong entered Gamcheon Port in Busan at around 06:00 on July 2, 2014, for the purpose of unloading its catch and departed for a fishing operation at around 14:00 on the 10th of the same month after regular repair including replacement of engine parts and packing.

3.1.1.2 At the time of departure from Gamcheon Port in Busan, 11 Korean crew members boarded the vessel in March 2014 (the actual boarding was in January but the labor contracts were signed together on March 8th). On the 10th of the same month as the departure, 11 Filipinos and 33 Indonesians boarded, resulting in a total of 55 crew members on 501 Oryong.

3.1.1.3 After departure, 2 Filipinos and 2 Indonesians transferred to another vessel, and a Russian inspector who boarded on July 18th at Petropavlovsk-Kamchatsky in Russia changed places with another Russian inspector on the waters of the northwest Bering Sea.

3.1.2 Deadweight Tonnage Including Fuel Oil at Departure

3.1.2.1 At 14:00 on July 10, 2014, the marine gas oil (MGO) of 501 Oryong at departure was about 780 kiloliters, with lubricating oil (LO) of about 16.430 kiloliters and fresh water of about 160 tons.

3.1.2.2 The entire load status based on the load of MGO and the deadweight tonnage in the stability review includes 87.8 tons of constant)[19], 670.8 tons of MGO (0.86 in share), 14.7 tons of LO (0.90 in share), 160 tons of freshwater, 7.4 tons of corrosion, and 4.0 tons of paper box.

3.1.2.3 The deadweight tonnage given the load status of the vessel at the time of departure is 944.7 tons, and displacement is 3,431.84 tons including the light load displacement of 2,487.140 tons. Therefore, at the time of departure, the average draft is 6.39m, which is over 4cm of the full load draft.

3.1.3 Status after Departure and Changes in Deadweight Tonnage

3.1.3.1 On July 11, 2014, the day after departure, 501 Oryong sent an email to the main office of Sajo Industries that “all machinery have been functioning well since departure, and that the vessel is headed towards the north. It also said that best efforts will be made to ensure safe navigation and operation and to generate a result that meets the expectations.”

3.1.3.2 This vessel consumed 10 kiloliters of MGO, 0.070 kiloliters of LO,

19) Constant: the weight of articles on the ship including personal belongings and storage items, spare parts of the vessel, and, residue in fish holds and pipes from vessel deterioration.

and 15 tons of fresh water per day. It was capable of producing 15 tons[20] of fresh water per day using a fresh water generator.

3.1.3.3 On the 18th of the same day, at local time[21] around 09:00, the vessel arrived at Petropavlovsk-Kamchatsky and a Russian Inspector boarded. Then, it continued to sail towards the fishing ground. At around 01:00 on the 22nd of the same month, it arrived at the fishing ground and began its operation.

3.1.3.4 Then, after storing the catch in the fish hold of its vessel, it transferred the catch to the carriers. It continued its operation by receiving MGO on the waters. The changes in displacement of the vessel from fishing operation and MGO are shown on Table 6.

20) The freshwater generator installed on this vessel is Il-Seung ISF-70 with a capacity to produce 15 tons of freshwater per day.
21) 3 hours earlier than Korea (12 hours earlier than UTC)

[Table 6] Changes in Displacement on Key Dates

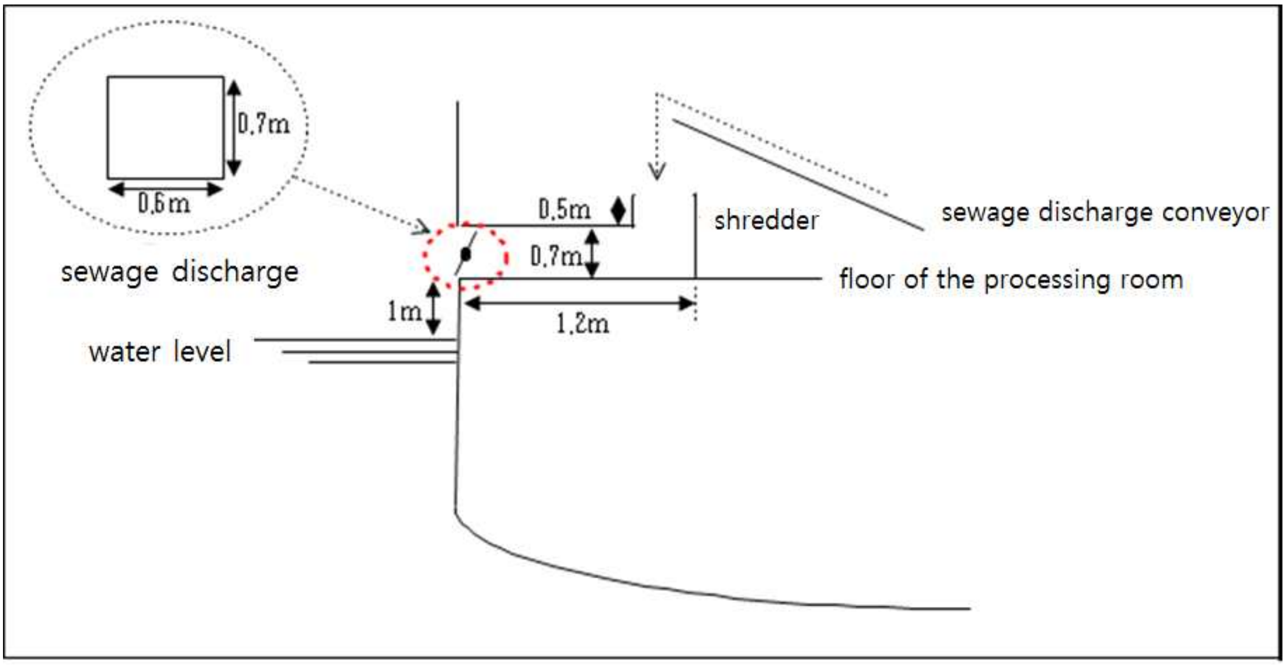
(Unit: tons, meters)

Date	MGO	LO	Remaining Products	Other Items	DWT	Displacement	Assumed Draft	Notes
7.10	670.8	14.7	-	259.2	944.70	3,431.84	6.39	At departure
7.22	554.8	14.0	-	194	762.80	3,249.94	6.17	Arrived at fishing ground
7.27	500.9	13.7	391.3	194	1,099.90	3,587.04	6.58	
8.1	445.7	13.4	811.4	194	1,464.51	3,951.65	7.01	Day before transfer
8.3						Completes transfer and receives 200kl of MGO		
8.4	593.9	9.54	5.6	194	803.04	3,290.18	6.22	after transfer
8.5	582.9	13.1	87.3	194	877.30	3,364.44	6.31	
8.6	571.8	13.1	170.7	194	949.60	3,436.74	6.39	Exceeds full load draft
8.14	468.3	12.5	824.3	194	1,499.10	3,986.24	7.05	
8.16	451.9	12.3	7.3	194	665.50	3,152.64	6.05	After transfer
						Continues same pattern of work		
11.25	586.9	5.6	64.5	194	851.00	3,338.14	6.28	
11.26	575.9	5.5	104.5	194	879.90	3,367.04	6.31	
11.27	566.1	5.4	150.5	194	916.00	3,403.14	6.36	Exceeds full load draft
11.30	537.3	5.2	275.2	194	1,011.70	3,498.84	6.47	
12.1	527.7	5.1	315.2	194	1,042.10	3,529.24	6.51	

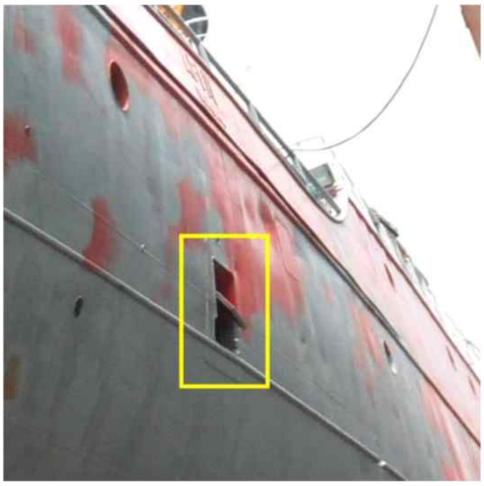
※ After departure, 100 tons of fresh water, 4 tons of corrosion and paper box, 90 tons of constant were added together as 194 tons of other items. The light load displacement is 2,487.14 tons.

3.1.4 Damaged Sewage Discharge Outlet

3.1.4.1 A sewage discharge outlet (0.6m wide and 0.7m high) has been installed on the floor of the processing room (6.8m high) between portside frame numbers 17 to 19, as can be seen on Image 7 and Image 8, to discharge waste produced from processing fish in the processing room.



[Image 7] Installation status of sewage discharge outlet



※ For 501 Oryong, it is installed in the same location but on the left side

[Image 8] Installation status of sewage discharge outlet of a vessel of same model (right side)

3.1.4.2 Waste generated in the processing room gets moved by a conveyor belt into a crusher that crushes waste into small pieces, which is then discharged from the vessel through the sewage discharge outlet. The shutter of the outlet operates by hydraulic pressure, and because it is located on the outer surface below the upper deck, it must be watertight for safety.

3.1.4.3 After the vessel departed from Gamcheon Port in Busan in July 2014, the shutter of the sewage discharge outlet fell off in mid-September of the same year during operation at the fishing ground, but it was left neglected until the day of the casualty without any repair.

3.1.4.4 Therefore, whenever the vessel fluctuated from left to right or when waves were high, seawater sometimes flowed into the vessel, and there were times crew members stood duty in order to monitor it.

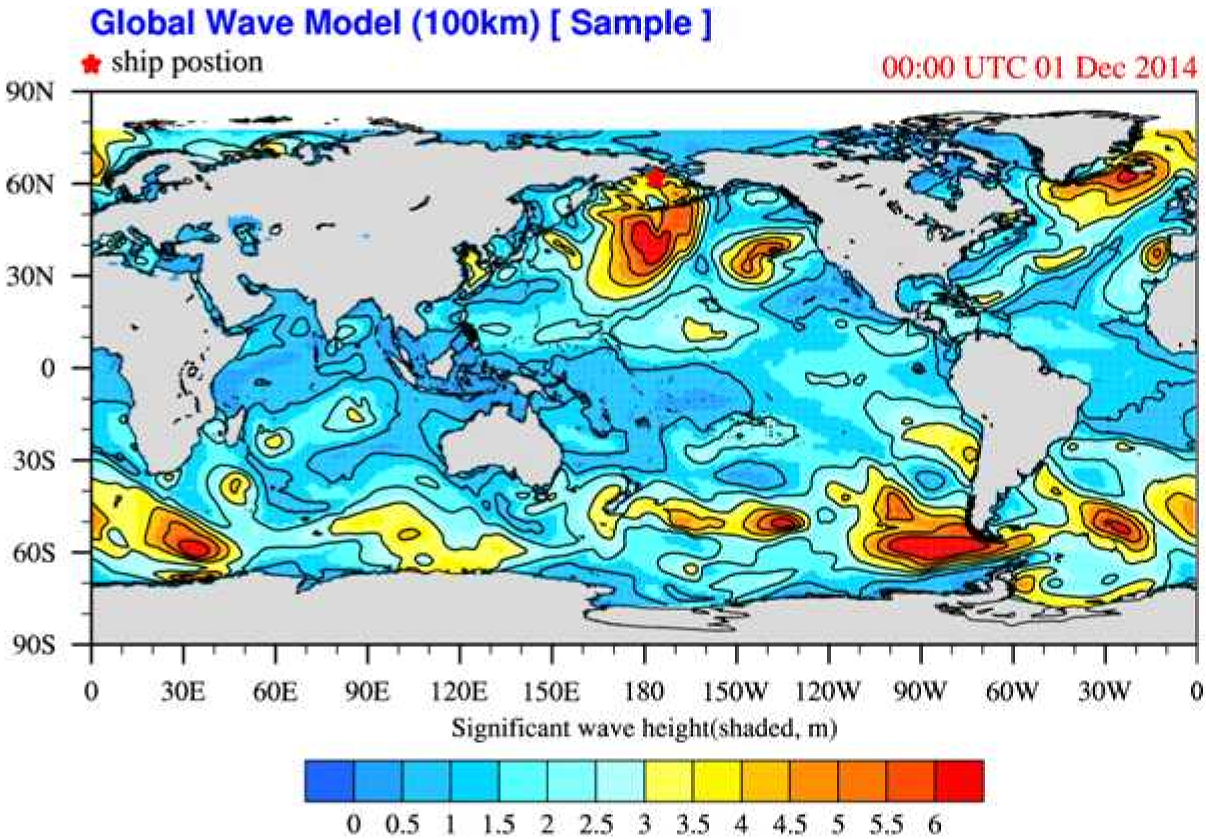
3.2 Local Weather Conditions before and after the Casualty (in local time)[22]

3.2.1 At around noon of December 1, 2014, the day of the casualty, the weather was cloudy and easterly wind blew at a speed over 15 m/s. The waves were as high as 4.0m with a 8 second wave period. However, there was an intermitten wind of over 25m/s and waves as high as 5.0m. The water temperature was about 1-2°C, visibility about 6 miles, and the depth of water about 108m.

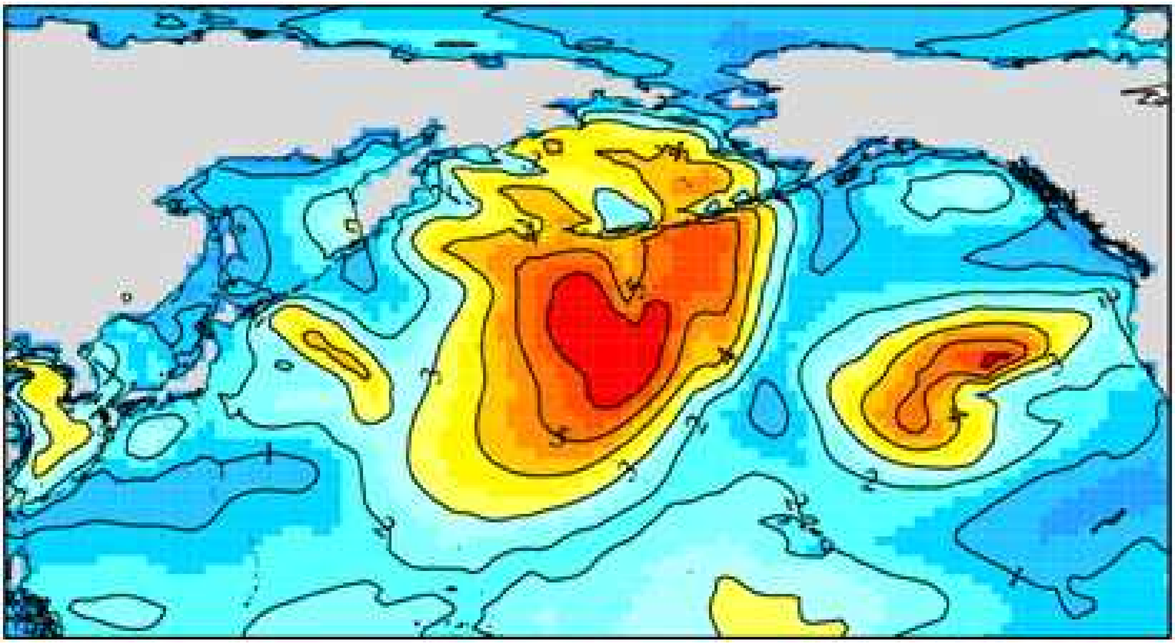
22) The analysis of weather conditions is based on the testimonies of crew, and the flooding and sinking simulation report on the analysis of causes of the sinking accident of 501 Oryong conducted by the Maritime Safety Technology of the Korea Maritime and Ocean University.

3.2.2 At about 06:00, prior to the casualty on the same day, an easterly wind blew at about 10m/s and wave height was about 2m. The weather rapidly deteriorated and by 10:30, the easterly wind was blowing at 18 m/s with wave height reaching about 4m. Waves continued to grow in height.

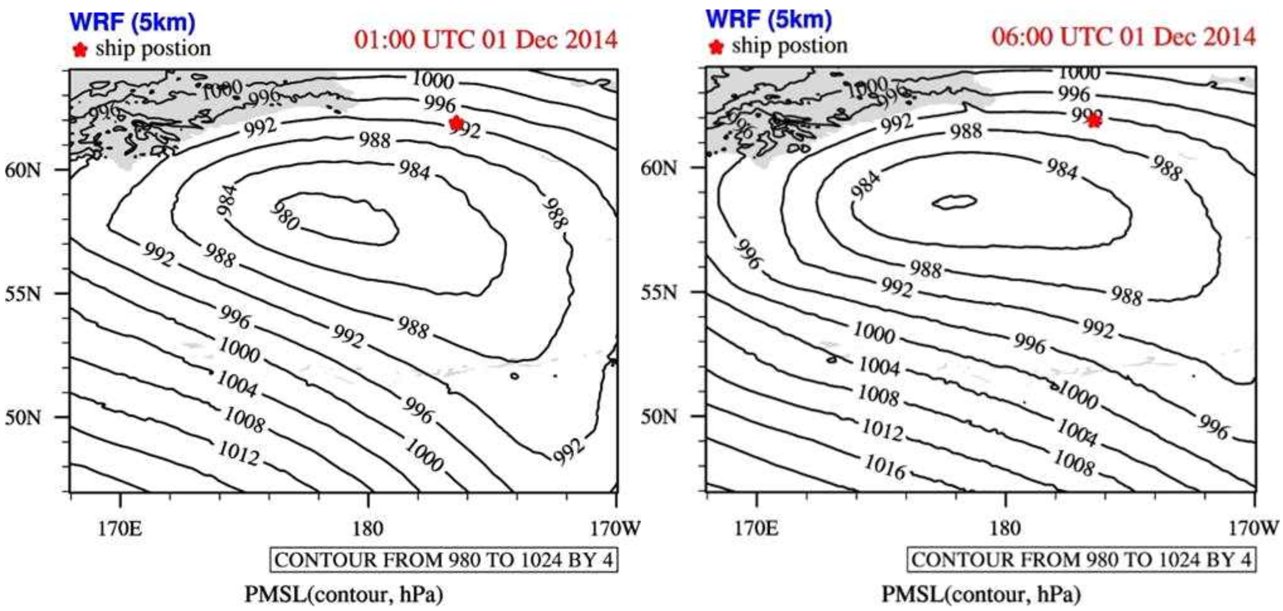
3.2.3 According to WAVEWATCH-III of the U.S. National Oceanic and Atmospheric Administration (NOAA), a model for wave predictions as shown in Image 9, the wave height can be assumed to have been about 4.0-4.5 meters at the casualty site.



[Image 9] Analysis of significant waves at casualty site

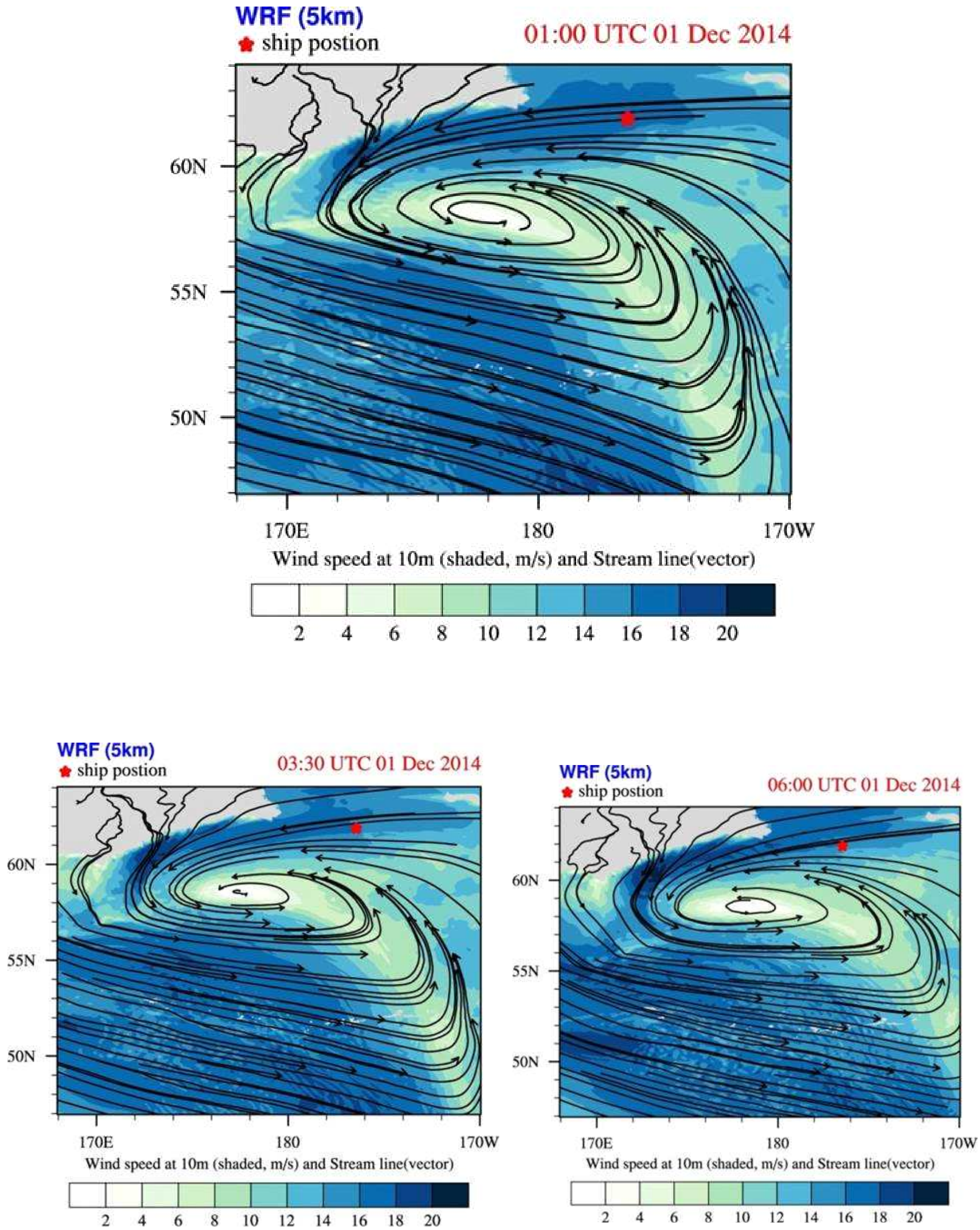


[Image 9-1] Analysis of significant waves at casualty site (casualty site enlarged)

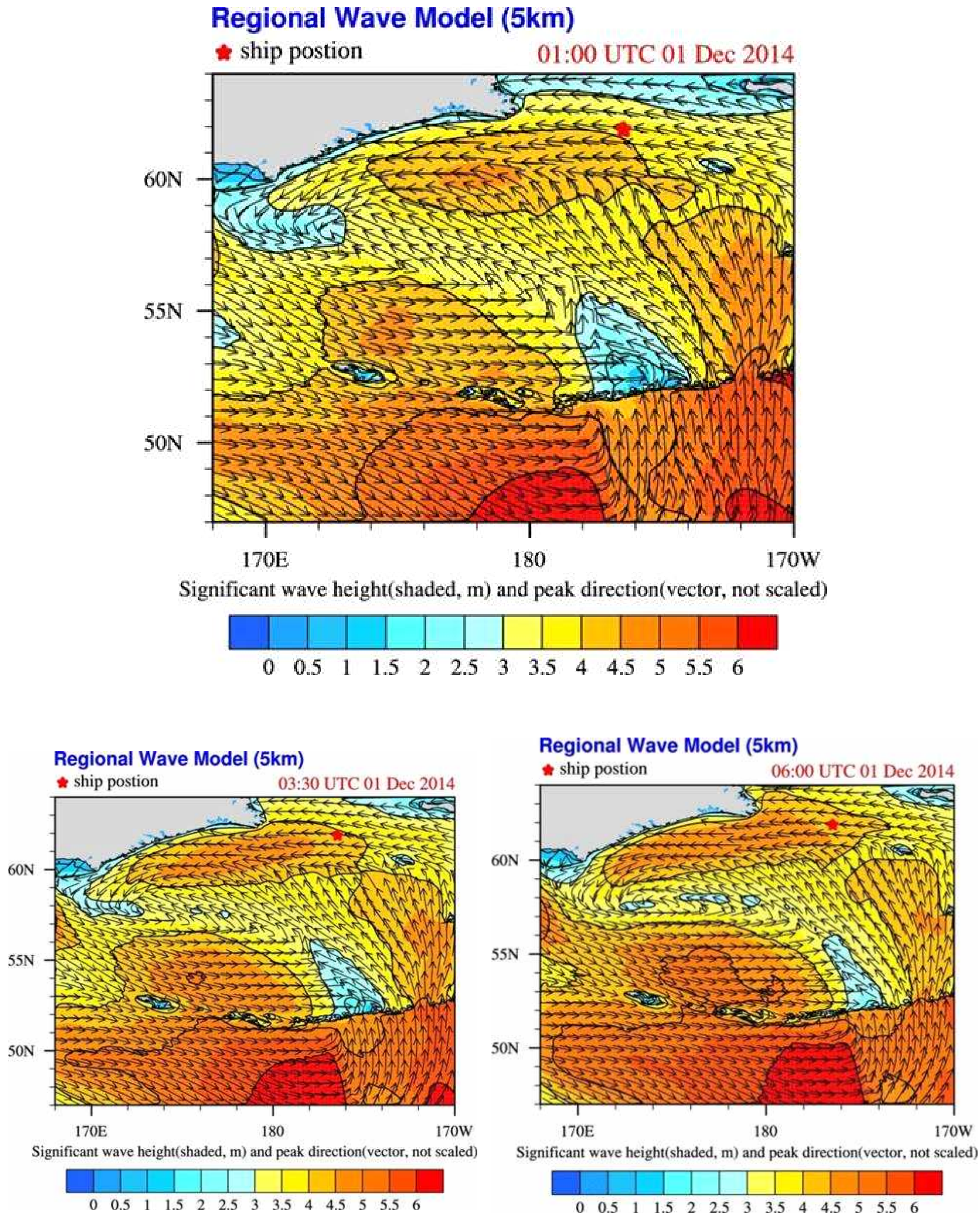


[Image 10] Isallobar at casualty site

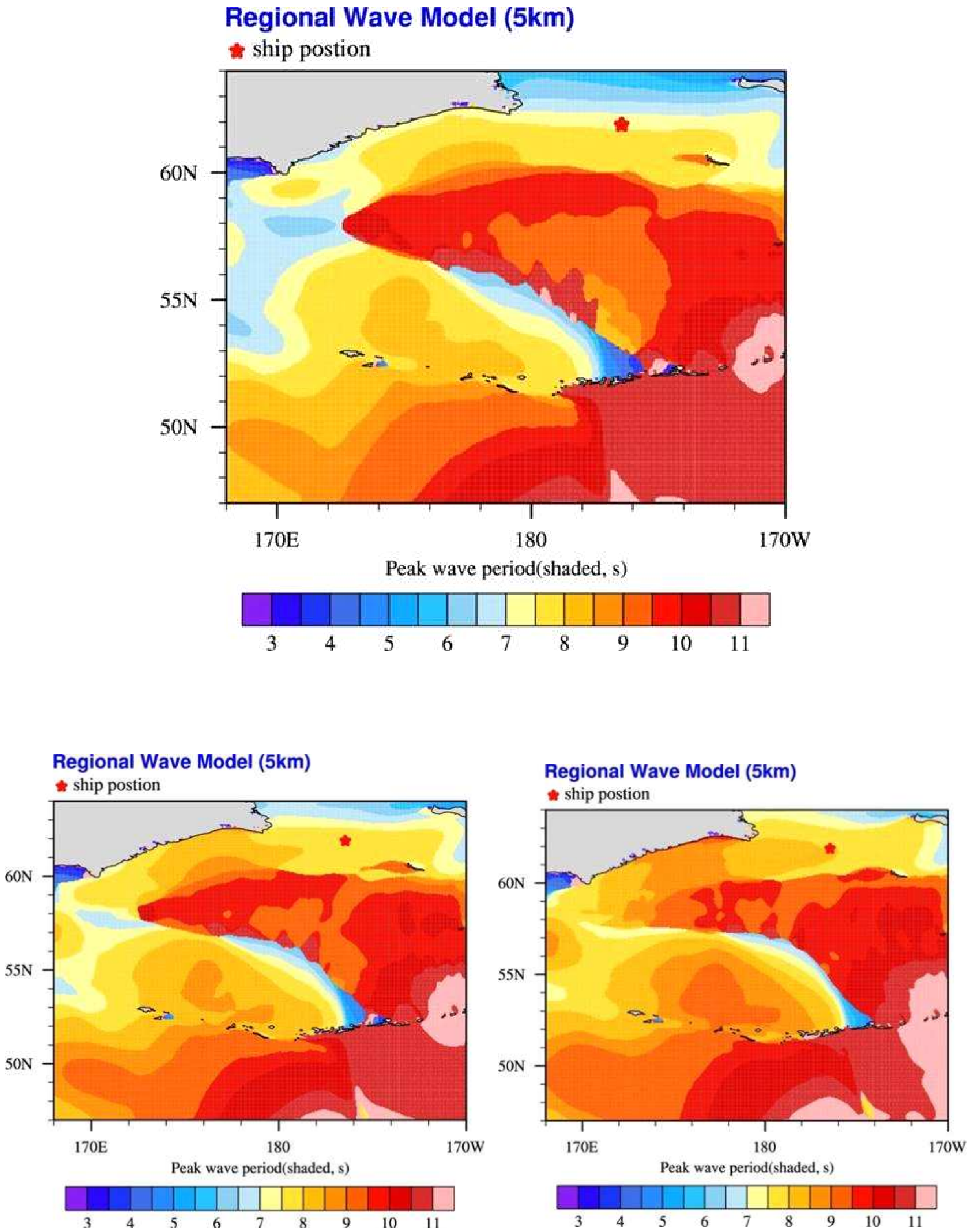
(Local time left: 13:00 Dec. 1, right: 18:00)



[Image 11] Wind direction and power at casualty site by time
{Local time top: 13:00 Dec. 1, left: 15:30, right: 18:00}

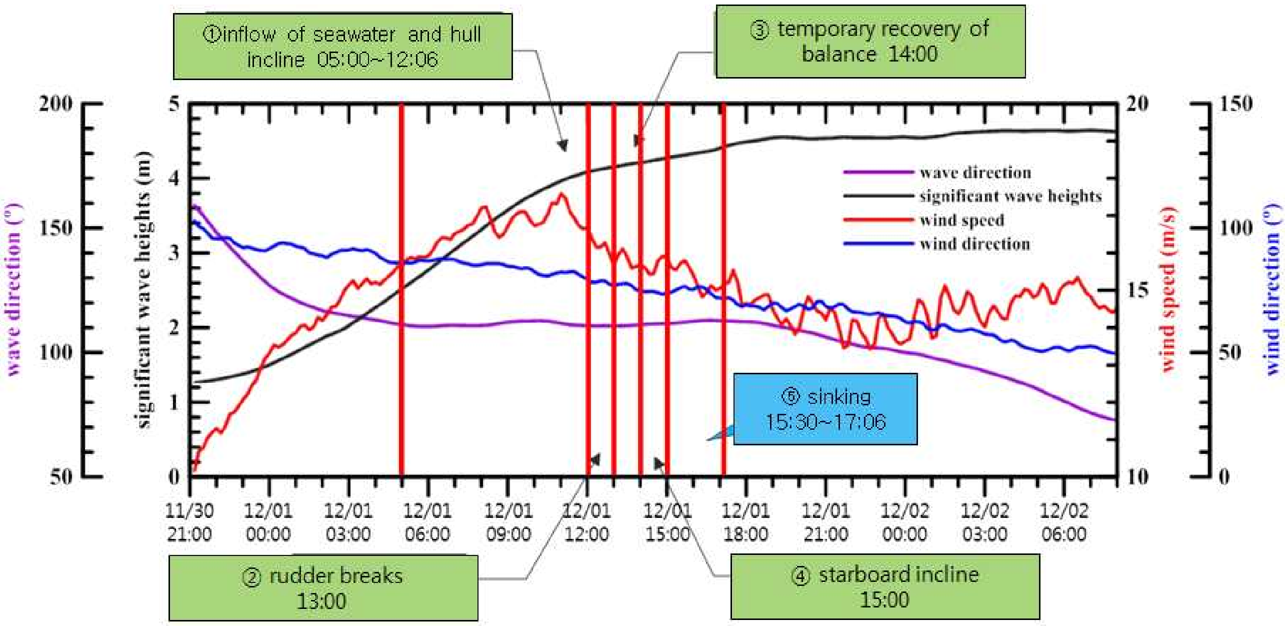


[Image 12] Significant wave height and vector at casualty site by time
(Local time top: 13:00 Dec. 1, left: 15:30, right: 18:00)



[Image 13] Maximum wave period in 10 minutes at casualty site by time (Local time top: 13:00 Dec. 1, left 15:30, right: 18:00)

3.2.4 In analyzing the data above, the weather conditions at the casualty site rapidly deteriorated prior to and after the casualty. As the wave height continued to increase, waves intermittently reached 5m by noon on December 1, 2014.[23] The weather conditions surrounding the vessel's situation can be summarized by time as illustrated in Image 14.



(a) 11.30 21:00 ~ 12.02 07:30

[Image 14] Significant wave height by time period and time-series analysis of wind speed at casualty site

3.3 Circumstances of the Casualty

3.3.1 Pattern of Operation and Captain's Rest prior to the Casualty

3.3.1.1 501 Oryong generally set and hauled its net twice a day, and the operation lasted from 02:00 to 17:00 and 18:00 to 24:00. At each operation, about 10 to 40 tons of pollack were caught, and its areas

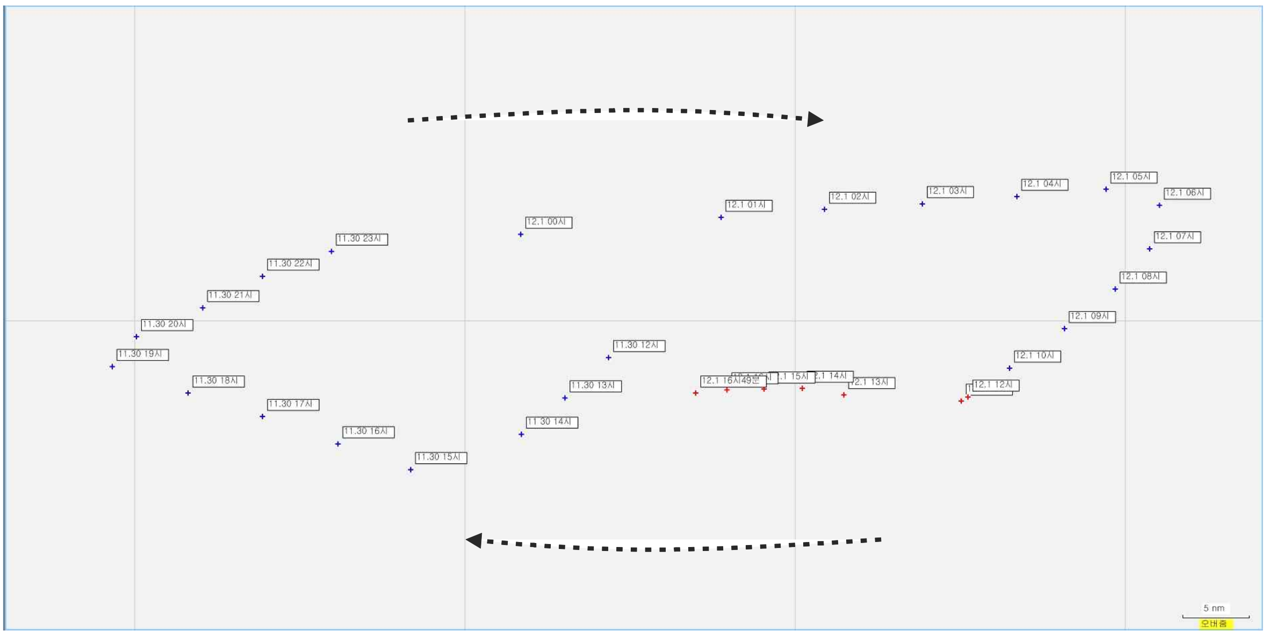
23) Wind wave advisory: when wind speed of over 14m/s continues for more than 3 hours at sea or significant wave height is over 3m
High seas warning: when wind speed of over 21m/s continues for more than 3 hours at sea or significant wave height is over 5m

of fishing operation remained within the boundary of the site of the casualty.

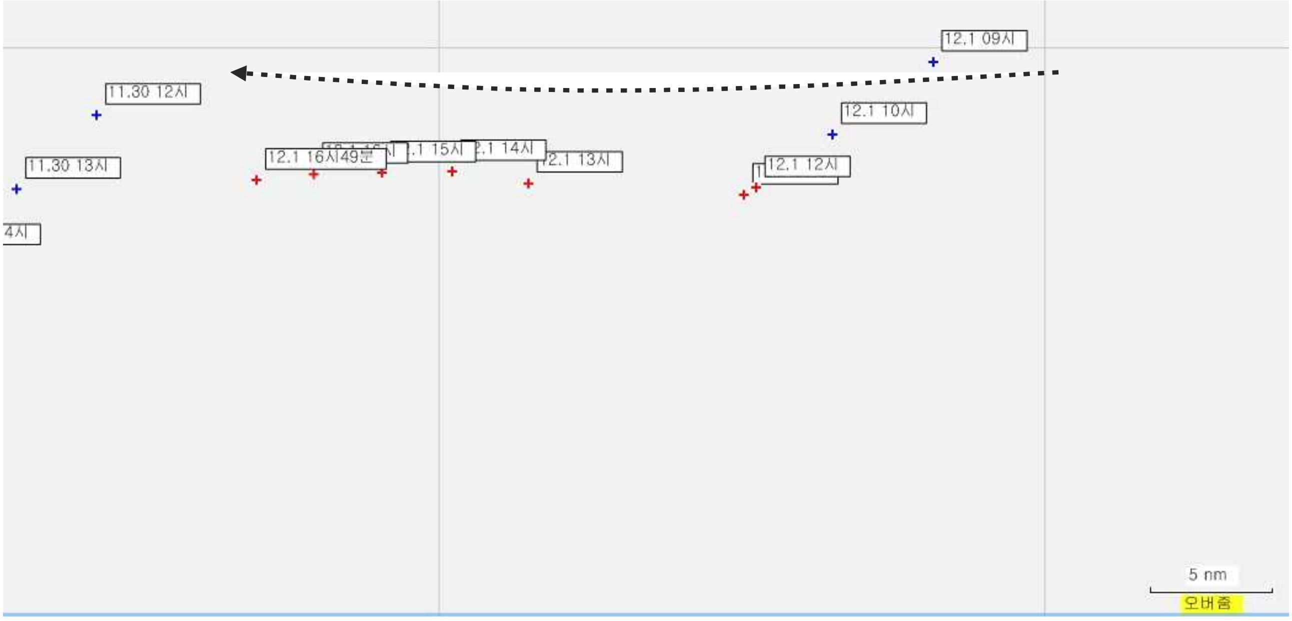
3.3.1.2 The vessel had been receiving updated weather information from a weather chart via weather fax. However, at the time of the casualty, the weather fax was broken and was not in operation. The captain was informed of meteorological information through email or phone calls from the company, and delivered it to other officers at meal time.

3.3.1.3 The captain of the vessel and an Indonesian electrician took rest for an hour from 00:00 to 01:00 on December 1, 2014, the day of the casualty, after sharing a bottle of soju with some peanuts as a snack in the electrician’s’quarters.

3.3.2 Circumstances of the Casualty



[Image 15] Locational changes of 501 Oryong during casualty (GPS)



[Image 15-1] Locational Changes of 501 Oryong during Casualty (enlarged)

[Table 7] Tracking of 501 Oryong (Argos Satellite)

Date (local time)	Latitude	Longitude	Direction (degrees)	Distance (miles)	Distance (kilometers)
14.12.01 05:00	N 62-09-46.80	W 176-31-44.40	082	3.8	7.082
14.12.01 06:00	N 62-08-34.80	W 176-26-52.80	118	2.6	4.759
14.12.01 07:00	N 62-05-20.40	W 176-27-46.80	187	3.3	6.055
14..12.01 08:00	N 62-02-20.40	W 176-30-54.00	206	3.3	6.185
14.12.01 09:00	N 61-59-24.00	W 176-35-31.20	216	3.7	6.770
14.12.01 10:00	N 61-56-27.60	W 176-40-30.00	219	3.8	6.964
14.12.01 11:00	N 61-53-60.00	W 176-44-52.80	220	3.2	5.948
14.12.01 12:00	N 61-54-18.00	W 176-44-16.80	043	0.4	0.7638
14.12.01 13:00	N 61-54-28.80	W 176-55-33.60	272	5.3	9.850
14.12.01 14:00	N 61-54-57.60	W 176-59-20.40	285	1.8	3.416
14.12.01 15:00	N 61-54-54.00	W 177-02-49.20	268	1.6	3.038
14.12.01 16:00	N 61-54-50.40	W 177-06-10.80	268	1.6	2.934
14.12.01 16:49	N 61-54-36.00	W 177-09-00.00	260	1.3	2.500

3.3.2.1 At 05:00 on Monday, December 1, 2014, 501 Oryong set its net over 30 minutes in order to catch pollack amidst easterly winds of 10m/s and wave height of 2m, weather conditions that were similar to usual times.

3.3.2.2 When the vessel was towing the net after completing the setting, weather conditions suddenly deteriorated at around 10:30, with easterly winds blowing at 18m/s and waves reaching 4.0m. The hull shook violently. However, the duty shifts took place as usual within the vessel until this time.

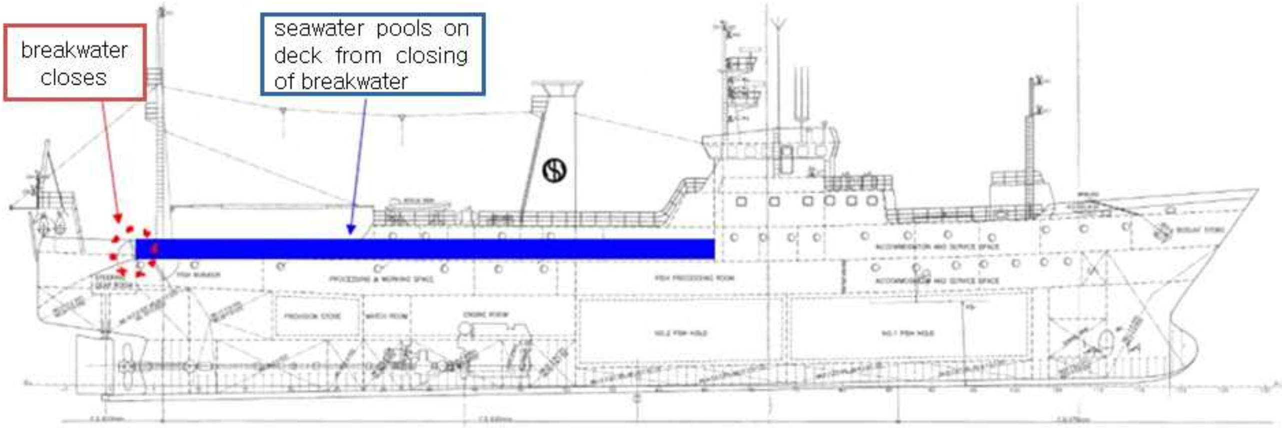
3.3.2.3 The vessel, while towing the net, was hit with easterly winds and waves from the 7:00 position, and sailed on true course of 215° at a speed of about 3.5 knots.

3.3.2.4 In the worsening weather conditions, the captain made an announcement to crew members to prepare for net hauling at 11:00 of the same day.

3.3.2.5 Hauling then proceeded. The stern was hit by strong winds during hauling, and when the net came close to the vessel, the captain turned the boat by 180° and sailed to the northeast direction in order to face the wind and waves with the starboard stern. However, as the weather deteriorated, the captain navigated so that the stern faced the strong wind while the catch was unloaded through the open hatch cover.

3.3.2.6 At around 11:35 on the same day, the breakwater of the stern was closed when the net was lifted on the deck but a large wave climbed over the breakwater and gushed onto the deck. As a result, the square area on deck formed by the breakwater and net guards turned into a water tank where seawater continued to flow in and out from.

3.3.2.7 Even with the seawater rising, the crew members positioned at stern followed the captain's order and prepared to unload the catch into the fish bunker by hanging the net on the gallows[24]. When seawater swelled on deck, crew members found shelter behind nearby structures and came back to finish the work repeatedly.



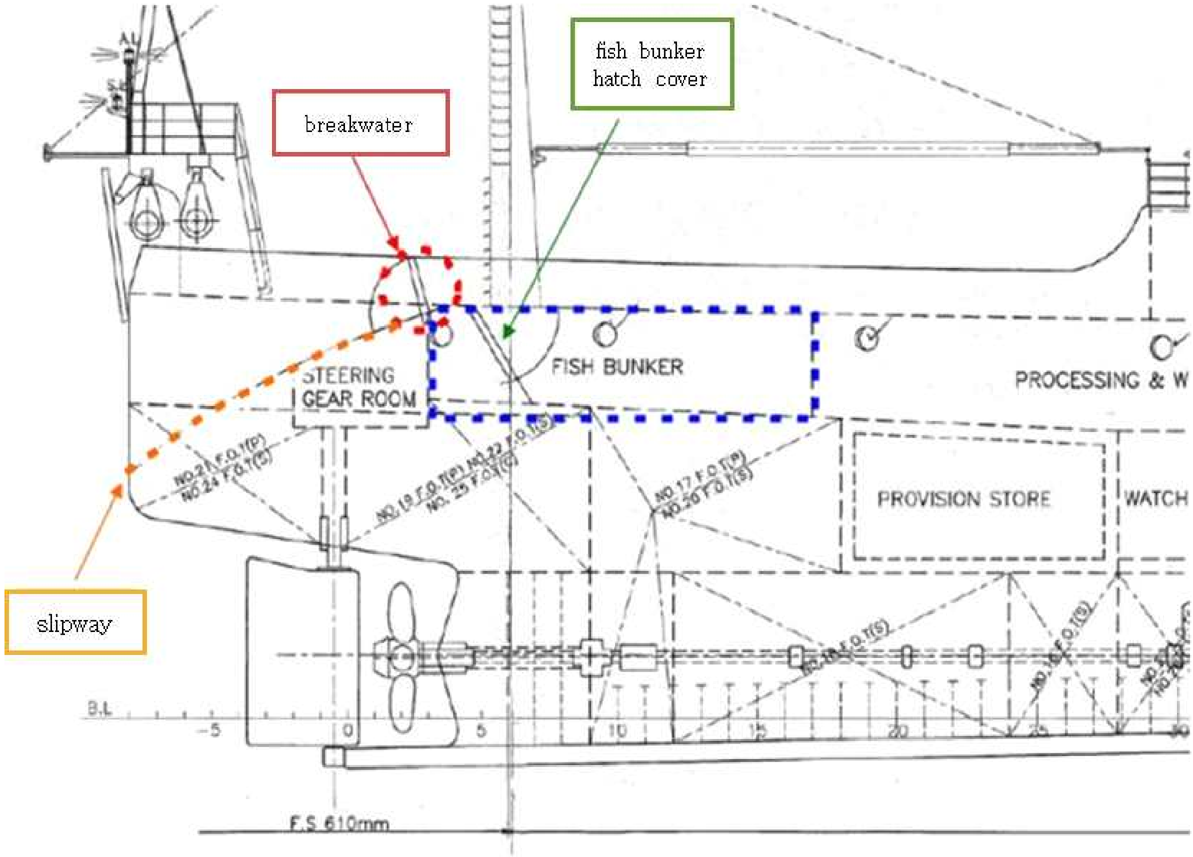
[Image 16] Inflow of seawater onto deck from closing of breakwater

3.3.2.8 The bosun who was directing the work at stern suggested not opening the fish bunker hatch cover as it was very dangerous to do so when seawater was rising on deck. [25]

3.3.2.9 However, the captain ordered the opening of the fish bunker hatch cover. At around 12:00 of the same day, the hatch cover was opened and a significant amount of seawater poured into the fish bunker along with the catch.

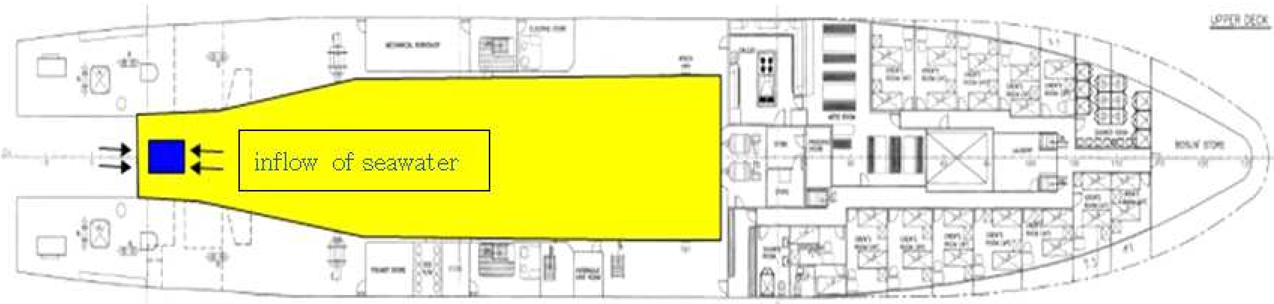
[Image 17] Slipway, breakwater, fish bunker and hatch cover

24) Gallows: a support fixture made with two horizontal poles and transverse board in the upper deck, where the net that has been hauled on deck can be hung.
25) Testimony of a surviving Filipino deck crew (A.J)



3.3.2.10 When seawater continuously flowed in through the open fish bunker hatch cover, the hatch cover was quickly closed from the stern. However, the net, which got pulled into the fish bunker along with the catch, got caught between the hatch cover and the deck, making it impossible to close the hatch cover completely. The gap was about 10cm.

3.3.2.11 From around 12:06 on the same day, when unloading the catch into the fish bunker was completed, 501 Oryong fixed its route towards the west to the Port of Navarin, and began to get underway. All the while, seawater continued to swell onto the deck and flowed in through the gap of the hatch cover.



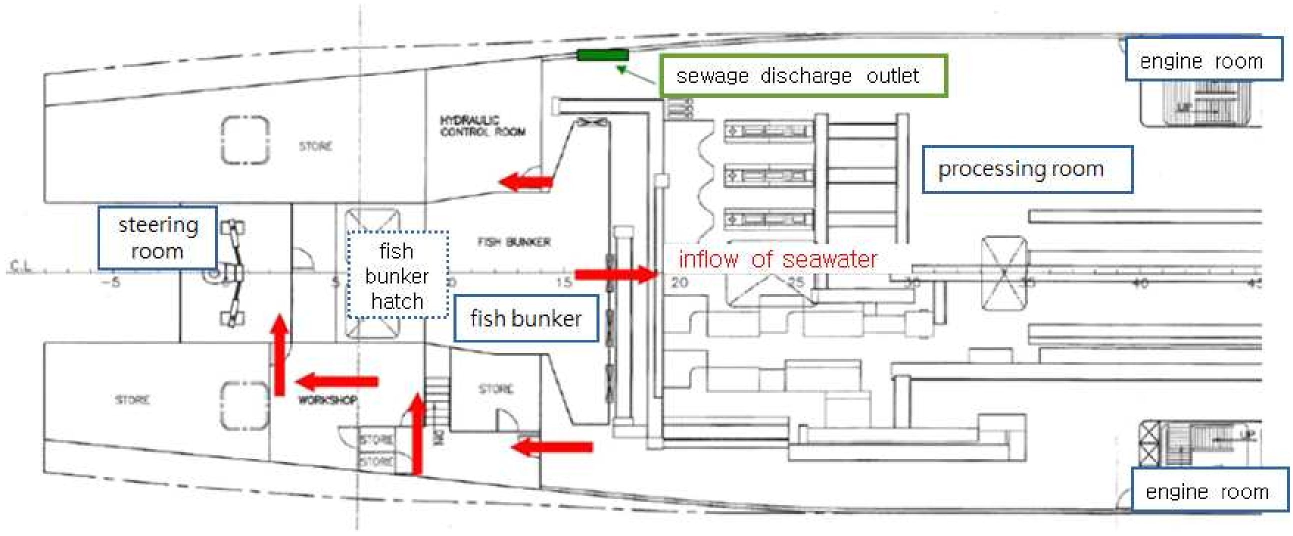
[Image 18] Inflow of seawater into fish bunker through the hatch cover

3.3.2.12 As the amount of fish and seawater in the fish bunker increased, water flowed into the processing room through the gap of the wooden wall that separated the fish bunker from the processing room. As the water flow eventually broke through the wooden wall, seawater and fish gushed into the processing room.

3.3.2.13 Then, due to the continuous inflow of seawater and fish, the stern part of the processing room was flooded as deep as about a meter. Even then, the water continued to flow in from the deck through the fish bunker. Furthermore, with every wave, a significant amount of seawater flowed into the vessel through the sewage discharge outlet on the port side.

3.3.2.14 The inflow of water in the processing room moved past the coaming (door sill, 60cm) of the open door dividing the steering room at the back and flowed into the storage space between the steering room and the processing room. After filling the storage space, the water moved past the coaming (45cm) and flowed into the steering room.

[Image 19] Flow of seawater after entering the fish bunker



3.3.2.15 The fish that poured into the processing room from the fish bunker along with seawater got piled in the bilge well, which blocked the intake entry of the bilge well. This made it difficult to discharge the seawater on the processing room floor with the bilge pump in the engine room.

3.3.2.16 At around 12:30 of the same day, vessel tilted starboard due to waves moving from the port. The seawater and fish that gushed into the processing room also tilted towards the right. As a result, the starboard incline worsened, making the inclination as steep as 30°.

3.3.2.17 At around 12:35 of the same day, the captain contacted Carolina 77, which was towing its net nearby, and hailing for help stating that "water has flowed[26] into the fish pond and into the processing room due to the broken wall. The ship has tilted greatly. Come close quickly and help."

3.3.2.18 Carolina 77 stopped towing after the call for help and hauled its net.

26) Fish pond is another word for fish bunker; it means seawater has filled into the fish bunker.

It started to sail towards 501 Oryong, which was located about 10 miles away, starting 13:10 of the same day.

3.3.2.19 At the time, Zaliv Zabiyaka, which was towing about 13 miles west of 501 Oryong, heard the communication between 501 Oryong and Carolina 77, and confirmed the message by contacting 501 Oryong. It then finished hauling its net at about 13:00 and started to sail towards 501 Oryong at a speed of 4 knots.

3.3.2.20 When the discharge of seawater in the processing room using the bilge pump was insufficient, 501 Oryong started to discharge bilge using 2 portable submersible pumps from 12:30 of the same day. Then, it asked Carolina 77 to lend a portable submersible pump.

3.3.2.21 From around 13:00 of the same day, fuel in the fuel tanks were transferred from starboard to port side under the command of the chief engineer in the engine room, in order to restore the balance of the ship, which was tilting to the right. As for the deck department, products in the fish hold were moved to the port side under the command of the chief officer.

3.3.2.22 At the same time, the steering room was mostly flooded due to a continuous inflow of water, fixing the rudder at hard port. As a result, the vessel lost its ability to keep its course. However, the main engine operated until 15:30 of the same day.

3.3.2.23 The rudder stopped when the main engine was not being used, and so the vessel flowed along the tidal current while tilting starboard.

At around 14:00 of the same day, the hull seemed to be regaining its balance from the transfer of fuel and fish hold products, as well as the discharge of seawater using portable submersible pumps.

3.3.2.24 At around 14:10 of the same day, Carolina approached as close as 200m to the port side of 501 Oryong, which had almost recovered its balance as waves broke into the port side with the bow in the direction of about 200°.

3.3.2.25 From around 14:10 to 14:30 of the same day, Carolina 77 delivered its portable submersible pump to 501 Oryong by tying it to a tow line.

3.3.2.26 Then, Carolina received a message from 501 Oryong that three portable submersible pumps were working well. As it judged that 501 Oryong had recovered to a fair degree, it went on standby nearby without additional action. 501 Oryong, with its bow turned to 200°, was being pushed towards 265° at a speed of 1.8 knots due to waves.

3.3.2.27 At around 15:00, the vessel, which was being pushed to the west,[27] was turned to the port in order to reduce the inflow of seawater through the sewage discharge outlet. The hull shook violently from port to starboard, and suddenly started to tilt towards the port side.

3.3.2.28 Due to the sudden incline to port, the inflow of water through the sewage discharge outlet accelerated, and seawater continued to flow

27) Because the rudder stopped at hard port, if the hull is turned using the main engine only, then the boat turns port.

into the gap of the fish bunker hatch cover. Crew members kept using portable submersible pumps to pump out the seawater but the amount flowing in was too large and the seawater kept rising. Seawater also flowed into the fish hold.

3.3.2.29 At around 15:30 of the same day, the captain, thinking that it would be better to receive the wind and waves from the left side rather than the right as the hull tilted to the left, tried to change the direction of the bow using the main engine. However, when the fluctuations and incline worsened, the captain changed the direction of the bow again and made it so that the vessel received the wind and waves from the right side.

3.3.2.30 At the same time, the Russian inspector who was in the wheelhouse advised the captain to abandon ship when a part of the stern fell below the water level. However, the captain replied “it’s fine”. Not long after using the engine to position the vessel to receive wind and waves from port, the engine room flooded and the engine ceased operating.

3.3.2.31 At about 16:00 of the same day, when the vessel had tilted to port by about 40°, the captain contacted Carolina 77, which had been on standby about 6 miles away, and said “Captain, we need to abandon ship. The vessel has tilted a lot and three life rafts on port have been detached.” Recognizing the urgent situation, Carolina 77 sailed towards the vessel at full speed.

3.3.2.32 At the same time, most equipment on the vessel except for some lighting and communication devices had stopped operating, as much of the engine room was under water. There was also a large inflow of water into the fish hold.

3.3.2.33 At the same time, Zaliv Zabiyaka came as close as 0.5 miles to 501 Oryong and prepared to pass over the portable submersible pump. However, 501 Oryong said "we need to abandon ship" and Zaliv Zabiyaka advised to "turn on as many lights as possible so the crew may be identified."

3.3.2.34 At around 16:10 of the same day, the captain contacted the person in charge of navigation at Sajo Industries and said that "the increase in water level in the processing room from inflow of water from the stern has tilted the boat greatly to a point that balance cannot be restored. We need to abandon ship." The person in charge of navigation replied "then, do as you need to." However, the captain did not make an announcement to abandon ship to the crew.

3.3.2.35 From around 16:30 of the same day, 501 Oryong started to sink from stern, and about 30-40 crew members gathered at the wheelhouse and the deck to the right of the wheelhouse and took actions to abandon ship, such as dropping life rafts.

3.3.2.36 At around 16:50 of the same day, when the wheelhouse also was also submerged, some lives were lost as crew who had been hanging on to structures on the vessel got swept away by waves.

3.3.2.37 Meanwhile, the vessel's ARGOS satellite signal ceased transmitting at around 16:49 of the same day, and as the vessel fully submerged, the Emergency Position Indicating Radio Beacon (EPIRB) began to operate from 17:06 of the same day at N61° 54' 36" W177° 09' 00".

3.3.3 Ship Abandonment and Rescue Operation

3.3.3.1 From around 16:00 to 16:10 of the same day, the captain of 501 Oryong contacted the main office of Sajo Industries and nearby vessels and conveyed his decision to abandon ship. However, the announcement for ship abandonment was not made and around 16:00, as the port side went under water, 3 life rafts became detached from the vessel.

3.3.3.2 At around 16:30 of the same day, the stern of the vessel had become completely submerged and the incline to the left was more than 60°. Crew members who had been pumping water out from the processing room under the command of the chief officer, the officer in charge of processing, and the boatswain felt danger when the boat tilted. Spontaneously, 10 crew gathered at starboard wing bridge)[28] and 20-30 crew members gathered behind the starboard wheelhouse. At the time, the captain sat with his head dropped in the wheelhouse.

3.3.3.3 From around 16:30 of the same day, crew members who had gathered around the wheelhouse connected the four life rafts on the starboard side with a rope under the instructions of the boatswain. Then, they were dropped into the water to be inflated. While one raft inflated immediately, others inflated later.

28) Open area to the side of the wheelhouse

3.3.3.4 From around 16:40 of the same day, the central part of the hull had began to sink, and the starboard wing bridge repeatedly bobbed under the water. At this point, crew members started jumping into the sea. Although most crew were only wearing life jackets, the Russian inspector and the Korean officer in charge of processing were wearing wetsuits.

3.3.3.5 N, an Indonesian crew member from the processing room, came up to the wheelhouse after pumping water out of the processing room and crawled from the starboard wing bridge towards life rafts, then boarded the life raft that had inflated. Afterwards, N helped five other crew board the raft, including the Russian inspector, S, a Filipino crew from the engineering department, 2 Korean engineer officers, and 2 Indonesian crew members.

3.3.3.6 The Russian inspector jumped into the water from the wing bridge to the right of the wheelhouse with a rope tied around a Korean crew. The Russian inspector had swam for a while to get away from the vessel before approaching the life raft, and then got lifted by other crew who were on the raft, but the Korean crew to whom he had been tied to had disappeared as the rope had untied.

3.3.3.7 S, the Filipino crew from the engineering department, had been taking a rest in his quarters when he noticed that the vessel was not restoring its balance after starting to tilt toward the port at around 16:00. He then layered on winter clothes and went up to the wheelhouse while wearing a life vest. He had been at the starboard wing bridge when he saw another crew who had seen the stern sink below the water jump into the sea. He also jumped into the water and after floating for about 20 minutes, he found the life raft and climbed on to it.

3.3.3.8 T, a Filipino crew from the processing room, had been in the processing room at 16:30, and after putting on winter clothes and a life jacket, he climbed up to the wheelhouse. When the wheelhouse was sinking under water, the vessel having sunk from its stern, he had been holding onto the fender near the bow. When the vessel started to sink, he began to swim away. Then, he tried to climb up to the inflated life raft, but as it flipped, he was on top of the bottom surface of the life raft.

3.3.3.9 W, an Indonesian crew from the deck department, was working in the fish hold and the processing room when he put on a life jacket and moved up to the wheelhouse. As the left side of the wheelhouse sank, he held on to a structure on the right side of the wheelhouse. Then, he was hit by a wave and fell into the sea. He swam away from the vessel and found a crew member on top of the upturned life raft. He tried to pull himself up but did not have enough strength, so instead he held on to the rope.

3.3.3.10 Carolina found four life rafts that were connected by rope as it approached 501 Oryong at around 16:50. It was too heavy to lift up so it checked each raft one by one. Then, it rescued the Filipino crew, T, who was on the upturned life raft, and W, the Indonesian crew from the deck department, who was holding on to the rope in the water.

3.3.3.11 Then, Carolina 77 found six crew on one life raft and rescued N, an

Indonesian crew from the processing room, the Russian inspector, a Korean 2nd engineer, and S, a Filipino crew from the engineering department, but two Indonesian crew could not be saved as they lost footing during rescue.

3.3.3.12 After the lights went out, the Indonesian electrician ran through the vessel, including the quarters, calling for all crew members to move up to the wheelhouse. Then at around 16:40 of the same day, he put on a life jacket in the quarters and moved up to the wheelhouse. After holding on for some time to the hand rail of the starboard deck of the wheelhouse, he jumped into the sea. After swimming for a bit, he found a 20-liter plastic bin and held onto it.

3.3.3.13 R, a Filipino crew from the deck department, had been working with other crew in the processing room to pump out water when he heard instructions from the boatswain. He went to his quarters and put on the life jacket. At around 16:30 of the same day, he moved up to the wheelhouse. Then, after getting swept by a wave, he fell into the sea. He found a wooden pallet that was floating on the sea and held onto it.

3.3.3.14 Zaliv Zabiyaka situated itself leeward from 501 Oryong and rescued the Indonesian electrician and R, the Filipino deck crew, who floated down from the upwind side.

3.3.3.15 Survivors abandoned the ship from around 16:40. Nearby vessels Zaliv Zabiyaka and Carolina 77, rescued 2 crew (1 Indonesian, 1 Filipino) and 6 crew (1 Korean, 2 Filipinos, 2 Indonesians, 1

Russian), respectively, but the Korean crew died.

3.3.3.16 As a result of the casualty, of 60 crew members (11 Koreans, 1 Russian, 13 Filipino, 35 Indonesians), seven (1 Russian, 3 Filipinos, 3 Indonesians) were rescued, 27 died, and 26 went missing.

3.3.4 Search Operations after the Casualty

3.3.4.1 Carolina 77 and Zaliv Zabiyaka, Korea-Russia joint fishing vessels, arrived at the casualty site immediately before the casualty on December 1, 2014, and continued to undertake search operations after rescuing a total of 8 crew members.

3.3.4.2 They undertook visual searches using radar and the naked eye but as the time of the sun set on the day of the casualty was around 14:33, the civil twilight[29)] was 15:33, making it dark and difficult to continue the search with the naked eye.

3.3.4.3 Then, VLADMIR BRODYUK (gross tonnage of 3,816 tons), a Korea-Russia joint fishing vessel, PELAGIAL and ASTRONAVT, Russian vessels, that were operating nearby, joined in the search operation, and on the 3rd of the same month, the U.S. Coast Guard sent an aircraft to assist in the search. On the 3rd of the same month, 11 dead bodies were collected by fishing vessels that were on search.

29) Civil twilight: twilight refers to the time period immediately before sunrise or after sunset when it is hazy. It can be either civil twilight or nautical twilight. For civil twilight, it is possible to distinguish objects with the naked eye and engage in outdoor activities without lights. It occurs within one hour prior to sunrise or after sunset.

3.3.4.4 On the night of the 3rd of the same month, 7 deep-sea fishing vessels that were operating in the Bering Sea arrived at the casualty site and joined in the search operation. On the 4th of the same month, MUNRO, U.S. search and rescue vessel equipped with a helicopter, also arrived at the scene and began to search.

3.3.4.5 On the 4th of the same month, 8 dead bodies were collected. One Russian aircraft also joined in the search. On the 5th of the same month, seven dead bodies were collected. On the 6th of the same month, ALEX HALEY, a U.S. search and rescue vessel, joined in the search.

3.3.4.6 On the 5th of the same month, the Korea Coast Guard sent out a patrol boat to the casualty site, as well as two patrol planes on the 6th of the same month to join in the search operation. Since th 7th of the same month, vessels repeatedly took shelter and resumed operation due to factors such as bad weather and finished the search on January 3, 2015. The final search results are as shown on Table 8.

[Table 8] Final Rescue Results

Category	Total	Korean	Foreigner		
			Russian	Filipino	Indonesian
On board	60	11	1	13	35
Rescued	7	-	1	3	3
Dead	27	6	-	5	16
Missing	26	5	-	5	16

3.3.5 Timeline of Messages Exchanged with Nearby Ships

3.3.5.1 The captain of 501 Oryong contacted Oyang 96, Carolina 77, and Zaliv Zabiyaka which were operating nearby on the day of the casualty, as well as the navigation team of the main office of Sajo Industries.

3.3.5.2 At around 07:30 on December 1, 2014, Oyang 96, which was towing its net, immediately hauled its net when maritime conditions deteriorated and began to get underway with a course pointing to 320° and a speed of 9.0 knots. At around 08:00 of the same day, the captain of this vessel said to the captain of 501 Oryong, "it looks like the weather conditions will deteriorate, would it not be better to make the decision to get underway quickly?" and the captain of 501 Oryong replied that "the net will be hauled in."

3.3.5.3 At around 12:30 of the same day, the captain of Zaliv Zabiyaka replied "we will head over there" to the call for help by the captain of 501 Oryong stating that "the water that flowed into the processing room cannot be pumped out, and the hull is tilting to port. We are trying to stabilize it as much as possible, but come close as the situation does not look good." Thus, he hauled in the net at about 13:00 and started sailing toward 501 Oryong. Then, 501 Oryong reported that "water continues flowing in through the sewage discharge outlet."

3.3.5.4 At around 12:35 of the same day, the captain of Carolina 77 received a call for help from the captain of 501 Oryong, saying "water has flowed into the fish pond and into the processing room due to the broken wall. The ship has tilted greatly. Come close quickly and help." It then hauled in its net and started to sail towards 501 Oryong, which was located about 10 miles away, around 13:10.

3.3.5.5 The captain of Carolina 77, after being informed that "seawater continues to flow in through the sewage drainage[30] in the processing room as the vessel is tilting", advised the captain of 501 Oryong to "use the mattress to block the inflow." Then, when the captain of 501 Oryong said that "the rudder has stopped at hard port as the steering room has flooded", the captain of Carolina 77 advised to "stop the engine." Then, in response to the request that stating that "the two pumps are being used to pump out water but it is not working well due to fish. Support us with as many portable discharge pumps available", the captain of Carolina 77 advised to "respond calmly as the situation is not so dangerous." Then, it sent out requests for assistance in search operation to nearby vessels through the VHF and the SSB.

3.3.5.6 At around 14:00 of the same day, the captain of Zaliv Zabiyaka heard from the captain of 501 Oryong that "work is being undertaken to transfer the catch stored on the starboard side to port as the ship had tilted to the right at first" and that "the large inflow of water into the processing room moved to the steering room, and the rudder stopped as the ship, overall, is underwater."

3.3.5.7 At around 14:00 of the same day, the captain of Oyang 96 was notified by the captain of 501 Oryong that "it seems everything will be fine as stability has been restored and more than half the water inflow has been discharged" who responded by saying "good job,

30) It is assessed to refer to the sewage discharge outlet at port side.

calmly encourage the crew, wrap up operations well, and move to Navarin quickly." Then, in relief, he continued to get underway.

3.3.5.8 Carolina 77 approached 501 Oryong and delivered a portable submersible pump to 501 Oryong from 14:10 to 14:30, and asked the status of the vessel and pumps. 501 Oryong responded that "the inflow of seawater has reduced by half, and three pumps, including the one that was delivered, are working fine."

3.3.5.9 At around 14:30 of the same day, the captain of Zaliv Zabiyaka was notified by the captain of 501 Oryong that "the ship has almost restored its balance and the water level in the processing room has decreased a lot after Carolina 77 delivered its portable submersible pump." But not long after, it was notified that "the water level is rising again."

3.3.5.10 At around 15:00 of the same day, the captain of 501 Oryong said to the captain of Oyang 96 that "water is filling up in the fish pond again. I turned the vessel to place the discharge outlet on the port side at leeward but the ship started to sink so I am moving it back."

3.3.5.11 At around 15:30 of the same day, the captain of Zaliv Zabiyaka, after being notified by the captain of 501 Oryong that "the boat should be turned so that the port receive the wind because the situation is worsening with the wind hitting starboard", responded "make a careful judgement." Then, not long after, he heard "The situation has worsened after turning the boat. I am turning it back."

3.3.5.12 At around 16:00, the captain of Zaliv Zabiyaka was notified by the captain of 501 Oryong that “swelling seawater that did not get discharged from the processing room moved into the steering room and stopped the rudder at hard port. Because the waves are high and the ship continues to turn toward port, water is being pumped out without operating the engine but this is not enough. I ask for assistance with pumps.” He responded by advising “Block the inflow of seawater as much as possible and keep pumping out the water.”

3.3.5.13 At around 16:10 of the same day, the captain of Carolina 77 heard the captain of 501 Oryong saying “captain, the ship needs to be abandoned. 3 life rafts have become detached as the ship has tilted a lot to port.” Then, Carolina 77 sailed at full speed towards 501 Oryong.

3.3.5.14 At about 16:10 of the same day, the navigation team of Sajo Industries, after being notified by the captain of 501 Oryong that “we need to abandon ship”, asked “how is the situation?” The captain responded “the inflow of seawater at stern has filled water in the processing room and the increase in the water level has tilted the boat to a degree that cannot be restored.” The team replied “then, do as you need.”

3.3.5.15 At around 16:30 of the same day, the captain of Zaliv Zabiyaka heard from the captain of 501 Oryong that “the ship needs to be abandoned” and advised to “turn as many lights possible on as possible in order to identify the the crew.” Then, it heard that “a life raft at port side burst underwater.”

3.3.5.16 After being notified by Carolina 77 that "the ship is moving towards 501 Oryong as the order for ship abandonment has been made", the captain of Oyang 96 called 501 Oryong at about 16:30 of the same day. The captain of 501 Oryong said "I should say my last words of goodbye to you, my big brother" and the captain of Oyang 96 replied "Don't do that. Get the crew off the boat safely and make it off yourself, too."

3.3.5.17 After 16:30 of the same day, 501 Oryong ceased communication with all other vessels, and the lights of the ship went off. The messages communicated between 501 Oryong and nearby vessels are as summarized on Table 9.

[Table 9] Summary of Communication between 501 Oryong and Nearby Vessels

Time	Vessel	Contents
12.1 07:30	Oyang 96	Weather conditions worsening. Better to make decision to get underway.
	501 Oryong	We will haul the net
12:30	501 Oryong	Inflow of seawater into the processing room during net-hauling causes vessel to tilt towards port; trying to stabilize the hull. Situation is bad, requests approach for assistance / water continues to flow in through the sewage discharge outlet
	Zaliv Zabiyaka	Heading that direction (begins to sail at 13:00 after net-hauling)
12:35	501 Oryong	Inflow of seawater in the fish pond; 20 tons of fish pours into the processing room Diagonal incline; requests approach for assistance
	Carolina 77	(Begins sailing at 13:10 after net-hauling)
12:35 -14:00	501 Oryong	Inflow of seawater continues through the discharge outlet of the tilted processing room
	Carolina 77	Block water with mattress
	501 Oryong	Steering room submerged; rudder stops at hard port
	Carolina 77	Stop the engine
	501 Oryong	Working with two pumps but not going well; requests for pump assistance
	Carolina 77	Respond calmly as it is not a dangerous situation
14:00	501 Oryong	Starboard incline; processing room, then steering room sinks

		underwater while transferring fish stored starboard to port; stops using rudder
	Zaliv Zabiyaka	(Received)
14:00	501 Oryong	Recovered stability; more than half the water discharged; will be fine
	Oyang 96	Good; encourage crew; move quickly to Navarin
14:10 -14:30	Carolina 77	(Delivers a pump) asks about vessel status and operation of pump
	501 Oryong	Level of seawater reduced by half; three pumps working fine
14:30	501 Oryong	Returns pump to Carolina 77, stability fine; lowered water level in processing room / water level rises again
	Oyang 96	(Received)
15:00	501 Oryong	Water filled up in fish pond again Turned the boat to place the discharge outlet leeway but moved it back
	Oyang 96	(Received)
15:30	501 Oryong	I will turn the boat to receive wind on port side since wind at starboard is strong Situation is worse after turning the boat; I will turn it back
	Zaliv Zabiyaka	(Received)
16:00	501 Oryong	Rudder stopped at hard port; pumping insufficient; request for pump assistance
	Zaliv Zabiyaka	Continue pumping to limit the inflow as much as possible
16:10	501 Oryong	Situation calls for ship abandonment; three life rafts at port detached
	Carolina 77	(Sails to 501 Oryong at full speed)
16:10	501 Oryong	Situation calls for ship abandonment; diagonal incline of the processing room toward stern
	Navigation Team, Sajo Industries	Do as you need to
16:30	501 Oryong	We will abandon ship
	Zaliv Zabiyaka	Put on as many lights as you can to identify crew
16:30	501 Oryong	Farewell
	Oyang 96	Get crew off the boat and get out

4. Casualty Analysis

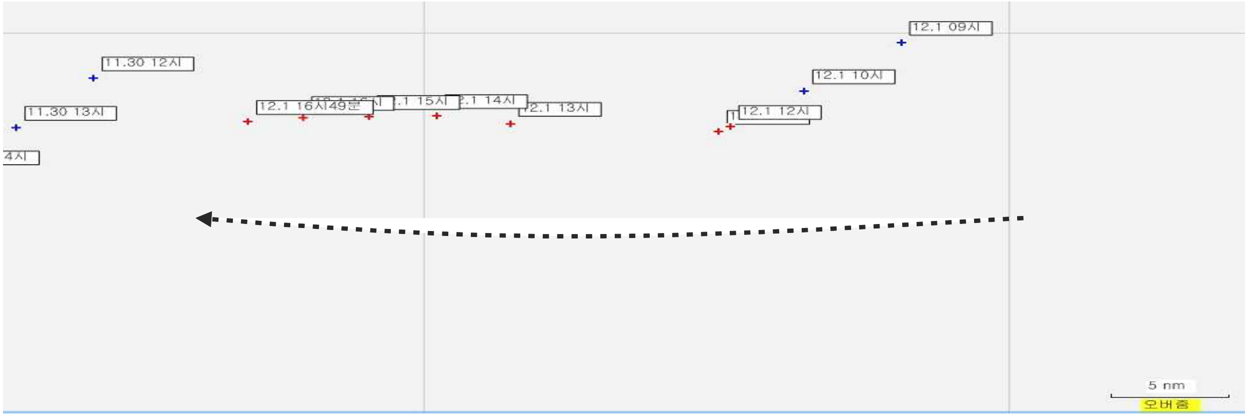
4.1 Site and Time of the Marine Casualty

4.1.1 It is reasonable to say that the casualty of 501 Oryong is not a capsizing casualty resulting from excessive transverse incline of the hull, but rather a sinking[31] casualty that was caused by loss of buoyancy from a large inflow of seawater through the fish bunker hatch cover on the upper deck and the sewage discharge outlet installed on the port side of the hull.

4.1.2 With regard to the time of the casualty, there could be different views but as the vessel sank from stern, with the bow going underwater last, it is reasonable to consider the time at which the bow sank underwater as the time of the casualty.

4.1.3 The track of the vessel at the time of the casualty based on the satellite records (Argos) of 501 Oryong is as shown in Image 20.

31) According to Article 13 (type of accident) Section 1(1) of the Management Guidelines for the Act on the Investigation of and Inquiry into Marine Accidents, a capsize is when the vessel turns upside down (except when caused by a crash, stranding, fire or explosion) and sinking is defined as when the vessel goes down underwater as a result of bad weather or flooding from a crack, hole or fracture in the outer surface (except when caused by a crash, stranding, fire or explosion).



[Image 20] Track of 501 Oryong (Argos Satellite)

4.1.4 As can be seen in the track illustrated in 4.1.3, the time and location at which 501 Oryong sent out its final signal is 16:49 on December 1, 2014, at N61° 54' 36", W177° 09' 00".

4.1.5 However, in comprehensively analyzing the testimonies of crew and the location and time of the EPIRB signal, it is assessed that the vessel started to sink at the above location at around 17:06 of the same day and completely sank to bow.

4.1.6 The location the vessel sank is about 107 miles away from the Port of Navarin in Russia, at a direction 102°, where the depth of water is 108m.

4.2 Changes in Displacement and Simulation Analysis on Stability[32)]

4.2.1 Changes in Displacement from Departure to Casualty

4.2.1.1 501 Oryong departed from Gamcheon Port in Busan on July 10, 2014, carrying 55 crew members. With 670.8 tons of marine gas oil (MGO), 14.7 tons of lubricating oil (LO), and about 259.2 tons of other items such as freshwater, it departed with an assumed displacement of 3,431.84 tons and an assumed draft of 6.39m.

4.2.1.2 Based on the assumed displacement at the time of departure, the changes in displacement are as shown on Table 10 when adjusting for the catch of fish and remaining fuel that were reported. At the time of departure, with an assumed displacement of 3,431.84 tons (full load displacement 3,398.490 tons), it exceeded the full load displacement by 33.35 tons and the full load draft[33)] (6.35m) by 4cm.

[Table 10] Displacement of 501 Oryong on Key Dates since Departure

Date	MGO	LO	Remaining Products	Other Items	DWT	Displacement	Assumed Draft	Notes
7.10	670.8	14.7	-	259.2	944.70	3,431.84	6.39	At departure

32) The stability simulation analysis referred to the results of the “flooding and sinking simulation report on the analysis of causes of the sinking accident of 501 Oryong” by the Maritime Safety Technology of the Korea Maritime and Ocean University, and the simulation used the KST SHIP Program of the Korea Ship Safety Technology Authority to calculate stability.

33) The full load draft line is the draft line at which a vessel can sail safely with an appropriate load. It indicates the maximum limit for carrying passengers or cargo while sailing safely.

7.22	554.8	14.0	-	194	762.80	3,249.94	6.17	Arrived at fishing ground
7.27	500.9	13.7	391.3	194	1,099.90	3,587.04	6.58	
8.1	445.7	13.4	811.4	194	1,464.51	3,951.65	7.01	Day before transfer
8.3						Complete transfer and received 200kl of MGO		
8.4	593.9	9.54	5.6	194	803.04	3,290.18	6.22	After transfer
8.5	582.9	13.1	87.3	194	877.30	3,364.44	6.31	
8.6	571.8	13.1	170.7	194	949.60	3,436.74	6.39	Exceeds full load draft
8.14	468.3	12.5	824.3	194	1,499.10	3,986.24	7.05	
8.16	451.9	12.3	7.3	194	665.50	3,152.64	6.05	After transfer
						Continues same pattern of work		
11.25	586.9	5.6	64.5	194	851.00	3,338.14	6.28	
11.26	575.9	5.5	104.5	194	879.90	3,367.04	6.31	
11.27	566.1	5.4	150.5	194	916.00	3,403.14	6.36	Exceeds full load draft
11.30	537.3	5.2	275.2	194	1,011.70	3,498.84	6.47	
12.1	527.7	5.1	315.2	194	1,042.10	3,529.24	6.51	

※ It is considered to be overloaded if the water line exceeds the full load draft (6.35m)

4.2.1.3 In undertaking fishing operations at the fishing ground after departure, the vessel periodically exceeded the full load draft as the catch of fish increased. The displacement of 3,986 tons on August 14th of the same year exceeded the full load displacement by about 587 tons and thus, the average draft exceeded the full load draft by 70cm.

4.2.1.4 On December 1st of the same year, the day of the casualty, the displacement, excluding the day's catch, was about 3,529 tons, which is about 131 tons over the full load displacement. The average draft was about 16cm over the full load draft.

4.2.2 Vessel Stability Standards

4.2.2.1 The term “stability” refers to the nature of a vessel floating upright in water to return to its original state after being tilted to a side by an external force such as waves or wind. It is the nature of a vessel that was floating upright in water to return to its original state when external factors disappear after being disturbed by them.[34)]

4.2.2.2 Such stability changes even under the same external factors depending on the vessel shape and loading conditions including people, cargo, and ballast water.

4.2.2.3 According to the Fishing Vessel Stability and Load Line Standards (Ministry of Oceans and Fisheries, no. 2013-164, 2013.6.17., partial revision) based on Article 3 of the Fishing Vessels Act, fishing vessels

34) Article 2(8) of the Ship Safety Act, the Society of Naval Architects of Korea, 「Naval Architectural Calculation」 (Textbooks), page 48 etc.

of length greater than 24m and fishing vessels (built after July 30, 2002) whose maximum number of allowable persons on board is more than 13 based on the Charter Fishing Business Act, must get their stability data regarding the adequacy of vessel stability approved by the vessel inspection organization and comply with the standards.

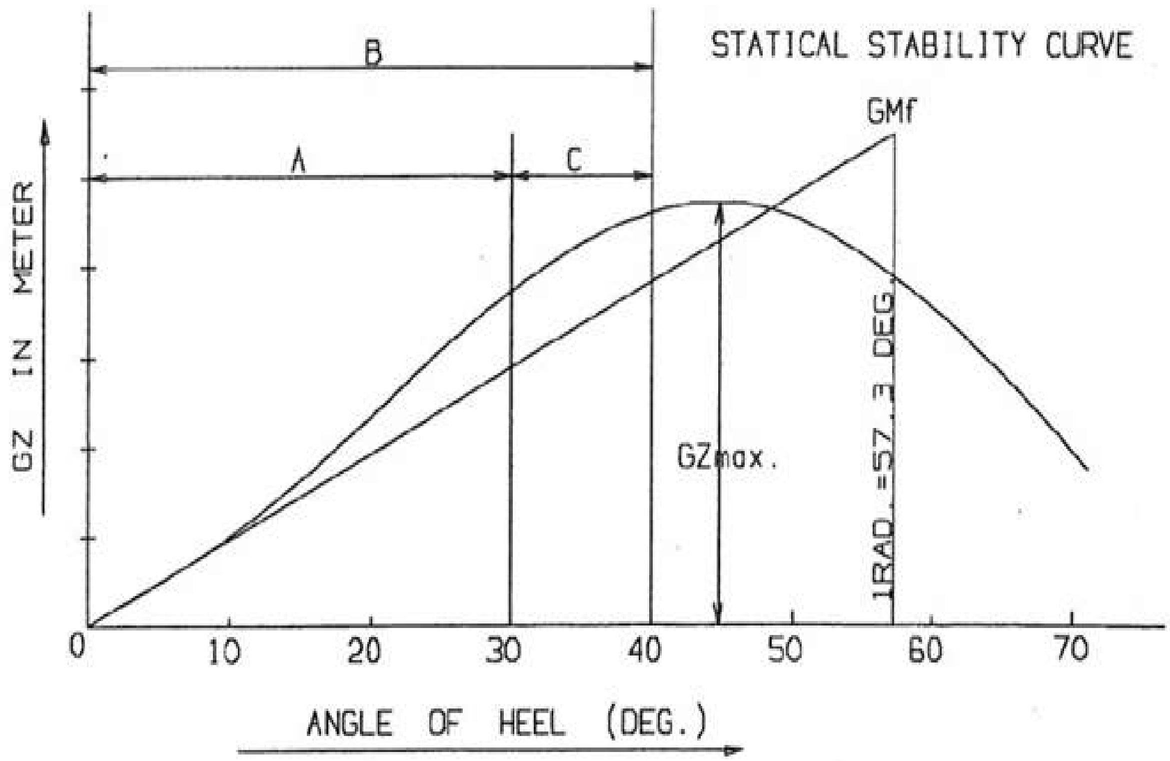
4.2.2.4 The stability standards are applied differently depending on the type of the vessel, which can be categorized as a liner, fishing vessel, and other vessels. Fishing vessels of length greater than 40m must meet the following stability standards.

A. For fishing vessels with a complete superstructure or a length greater than 70m, the GoM must be more than 0.15m.

B. The area surrounded by the transverse axis and the stability curve must be more than the value on Table 11.

[Table 11] Standard for Minimum Area of Stability Curve based on Stability Standards

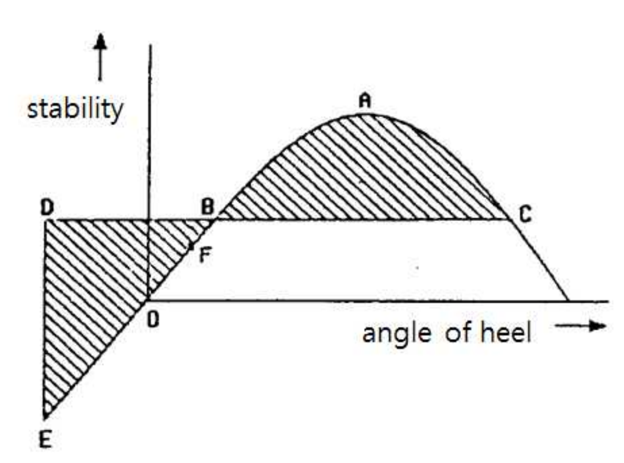
Angle of Heel	Area (meter · radian)
From 0 – 30° (Picture A)	0.055
From 0 - 40° or up to small angle of inflow angle (θf) (Picture B)	0.090
From 30 - 40° or up to small angle of inflow angle (θf) (Picture C)	0.030



[Image 21] Stability curve based on stability standard

C. The maximum value of stability is at a heel angle greater than 25° and stability for a heel angle greater than 30° should be more than 0.2m.

D. In considering the incline caused by severe wind and rolling from waves, the area ABC on the stability curve of Image 22 must be bigger than the area BDE.



※ The line segment DBC is the value that gets subtracted from the stability value depending on the wind in accordance with a set equation.

[Image 22] Stability standard on wind and waves

4.2.2.5 The stability of a vessel is generally calculated then approved by first undertaking an incline test to find the center of gravity of a vessel at ballast condition without any cargo or fuel. Based on this, the extent to which the vessel fulfills the stability standard at departure and entry in different load status of various cargo and fuel is checked.

4.2.2.6 In other words, the vessel stability data is approved by the vessel inspection organization based on the average load rather than its actual state. Therefore, when the load status is significantly different from the condition in the stability data or when there are doubts as to the fulfillment of requirement of stability standards, it is necessary to check the stability directly.

4.2.3 Stability at Departure from Gamcheon Port in Busan (Jul. 10)

4.2.3.1 The stability of the vessel at the time of departure from Gamcheon Port in Busan is as shown in Table 12 through Table 12-3.

[Table 12] Fluid Statistics Characteristic Value by Weight on July 10, date of departure from Gamcheon Port

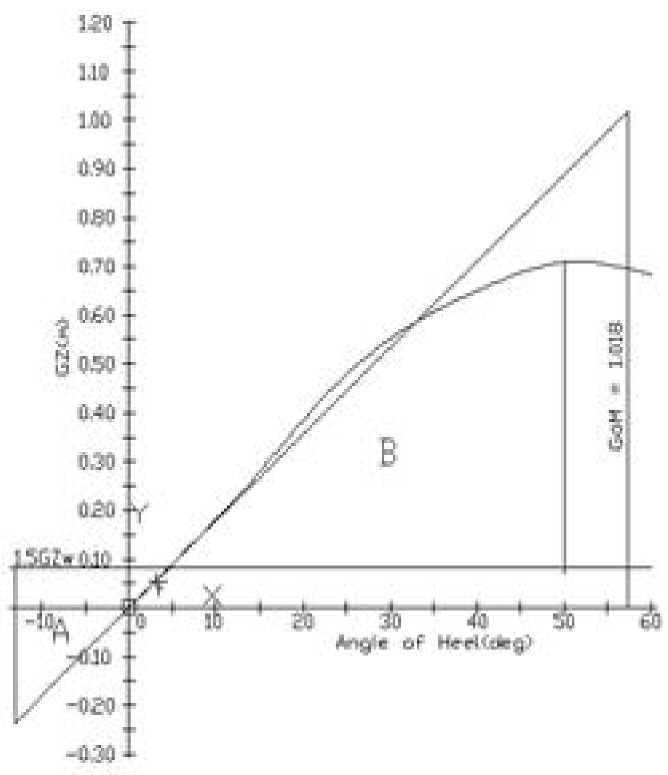
Items	Weight [ton]	L.C.G. [m]	L-Moment [ton*m]	V.C.G. [m]	V-Moment [ton*m]	F.S.M. [ton*m]
Constant Weight	90.83	-11.14	-1,012.34	7.33	666.03	8.61
Sub Total	90.83	-11.14	-1,012.34	7.33	666.03	8.61
F.O.T	670.81	-9.56	-6,577.72	3.13	2,152.56	0.37
L.O.T	14.9	-17.58	-262.47	2.24	33.48	6.99
F.W.T	163.01	-9.550	-1,328.67	1.99	277.07	0.00
Paper Box & Vinyl	4.00	2.20	8.80	2.87	11.48	0.00
FISH HOLD	0.00	0.00	0.00	0.00	0.00	0.00
Sub Total	852.76	-9.811	-8,366.37	2.92	2,489.24	7.36
Dead Weight	943.89	-9.94	-9,378.71	3.34	3,155.28	15.97
Light Weight	2,487.00	-3.88	-9,649.56	5.87	14,898.69	0.00
Displacement	3,430.59	-5.55	-19,028.27	5.17	17,753.96	15.97

[Table 12-1] Fluid Statistics Characteristic Value on July 10, date of departure from Gamcheon Port

Draft Equivalent(Ext.)	6.388 m	Transverse Metacenter (KMT)	6.198 m
Draft(B.L.)	5.738 m		
Total Trim by Stern	-2.472 m	Vertical Center of Gravity (KG)	5.175 m
Draft Forward	4.956m	Metacentric Height (GM)	1.022 m
Draft Aft	7.428m	Free Surface Correction (GG')	0.005 m
Draft Mean	6.192m	Correction Metacentric Height (G'M)	1.018 m
L.C.B.	-2.542 m	M.T.C.	41.683 m*ton
L.C.F.	-5.787 m	T.P.C.	8.247 mt/cm

[Table 12-2] Righting Arm (GZ) by Transverse Slope on July 10, date of departure from Gamcheon Port

Angle [degree]	KN [m]	KG*SIN [m]	GZ [m]	AREA [m*rad]
5	0.541	0.451	0.089	0.004
10	1.080	0.899	0.181	0.016
15	1.619	1.341	0.279	0.036
20	2.156	1.772	0.384	0.065
30	3.141	2.590	0.551	0.147
40	3.979	3.330	0.649	0.253
50	4.676	3.968	0.708	0.372
60	5.171	4.486	0.685	0.495



[Image 23] Stability curve on July 10, date of departure from Gamcheon Port

[Table 12-3] Stability Assessment Criteria on July 10, date of departure from Gamcheon Port

Stability criteria	KST-SHIP	Criterion (>=)	judgement
GoM (m):	1.018	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.147	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	0.105	0.030	GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.253	0.090	GOOD
GZ at 30 deg (m):	0.551	0.200	GOOD
Angle of Max. GZ occurs at (deg):	51.5	25.000	GOOD
Angle of down-flooding(deg):	53.7	-	
Area A (m-rad)	0.048	-	
Area B (m-rad)	0.304	-	
Area Ratio B/A	6.269	1	GOOD

4.2.3.2 At the time of departure from Gamcheon Port, the vessel exceeded the full load draft by about 4cm but satisfied the stability assessment criteria. Because the sewage discharge outlet at port of this vessel was in normal condition, the conditions for seawater inflow angle was the same as that for the seawater inflow angle on the stability report.

4.2.4 Stability during Fishing Operation (Aug. 14)

4.2.4.1 The review results of stability on August 14th of the same year, when the vessel exceeded its full load displacement by maximum degree, are as shown in Table 13 through Table 13-3.

4.2.4.2 The results show that the vessel satisfied the stability assessment criteria as it had at the time of departure. The sewage discharge outlet was also in normal condition at the time.

[Table 13] Fluid Statistics Characteristic Value by Weight on August 14, during fishing operation

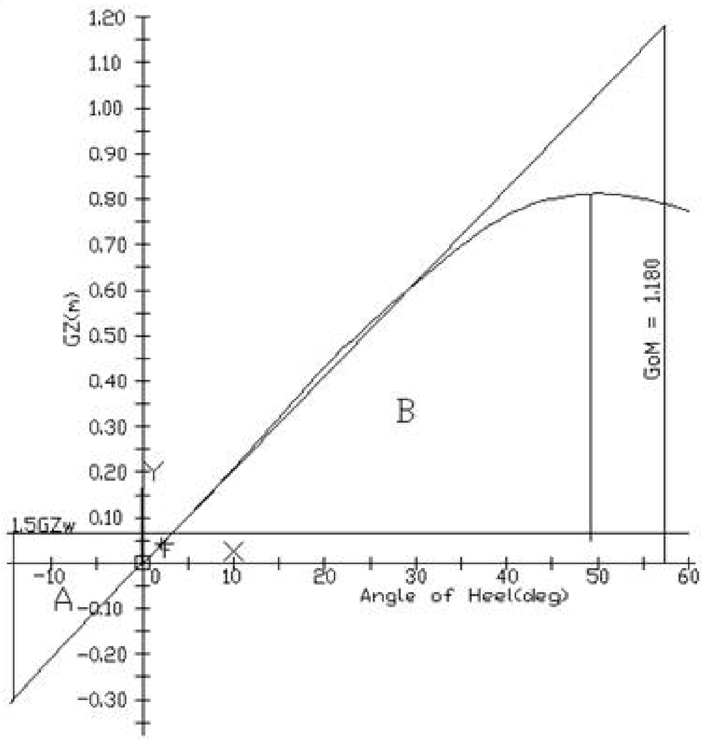
Items	Weight [ton]	L.C.G. [m]	L-Moment [ton*m]	V.C.G. [m]	V-Moment [ton*m]	F.S.M. [ton*m]
Constant Weight	90.83	-11.14	-1,012.34	7.33	666.03	8.61
Sub Total	90.83	-11.14	-1,012.34	7.33	666.03	8.61
F.O.T	468.10	-12.05	-5,851.55	2.88	1,349.31	650.98
L.O.T	12.44	-17.57	-218.58	2.10	26.19	5.63
F.W.T	100.18	-9.518	-953.50	1.65	165.49	60.31
Paper Box & Vinyl	4.00	2.20	8.80	2.87	11.48	0.00
FISH HOLD	824.73	9.02	7,440.38	3.17	2,614.54	0.00
Sub Total	1,409.45	0.30	425.55	2.95	4,167.01	716.92
Dead Weight	1500.28	-0.39	-586.79	3.22	4,833.04	725.53
Light Weight	2,487.00	-3.88	-9,649.56	5.87	14,898.69	0.00
Displacement	3,987.28	-2.57	-10,236.35	4.87	19,431.73	725.53

[Table 13-1] Fluid Statistics Characteristic Value on August 14, during fishing operation

Draft Equivalent	7.049 m	Transverse Metacenter (KMT)	6.236 m
Draft (B.L.)	6.399 m		
Total Trim by Stern	-0.366 m	Vertical Center of Gravity (KG)	7.873 m
Draft Forward	7.261 m	Metacentric Height (GM)	1.362 m
Draft Aft	6.894 m	Free Surface Correction (GG')	0.182 m
Draft Mean	7.078 m	Correction Metacentric Height (G'M)	1.180 m
L.C.B.	-2.987 m	M.T.C.	45.693 m*ton
L.C.F.	-5.665 m	T.P.C.	8.584 mt/cm

[Table 13-2] Righting Arm (GZ) by Transverse Slope on August 14, during fishing operation

Angle [degree]	KN [m]	KG*SIN [m]	GZ [m]	AREA [m*rad]
5	0.544	0.441	0.103	0.005
10	1.086	0.878	0.209	0.018
15	1.627	1.308	0.318	0.041
20	2.159	1.729	0.430	0.074
30	3.144	2.528	0.616	0.166
40	4.012	3.250	0.763	0.287
50	4.685	3.873	0.812	0.426
60	5.154	4.378	0.775	0.566



[Image 24] Stability curve on August 14, during fishing operation

[Table 13-3] Stability Assessment Criteria on August 14, during fishing operation

Stability criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	1.180	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.166	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	0.121	0.030	GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.287	0.090	GOOD
GZ at 30 deg (m):	0.616	0.200	GOOD
Angle of Max. GZ occurs at (deg):	49.6	25.000	GOOD
Angle of down-flooding (deg):	49.2	-	
Area A (m-rad)	0.054	-	
Area B (m-rad)	0.361	-	
Area Ratio B/A	6.654	1	GOOD

4.2.5 Stability on the Morning (before casualty) of the Casualty (Dec. 1)

4.2.5.1 The vessel continued to engage in fishing operations without repairing the shutter of the sewage discharge outlet at port side which became detached mid-September of the same year. Therefore, on December 1st, the day of the casualty, it is appropriate to review the vessel stability based on an inflow angle that is in line with the base line of 6.4m from the upper surface of the sewage discharge outlet (Image 7: refer to the installation status of sewage discharge outlet)

4.2.5.2 Therefore, the review of vessel stability on the day of the casualty, while taking into account the upper surface of the sewage discharge outlet as the inflow angle, is as shown in Table 14 through Table 14-3.

[Table 14] Fluid Statistics Characteristic Value by Weight on Dec. 1, on the morning of the casualty

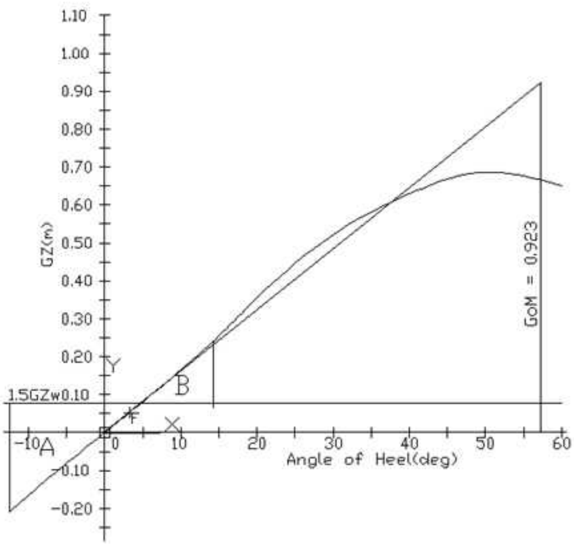
Items	Weight [ton]	L.C.G. [m]	L-Moment [ton*m]	V.C.G. [m]	V-Moment [ton*m]	F.S.M. [ton*m]
Constant Weight	90.83	-11.14	-1,012.34	7.33	666.03	8.61
Sub Total	90.83	-11.14	-1,012.34	7.33	666.03	8.61
F.O.T	527.16	-12.25	-6,458.76	2.96	1,559.63	707.49
L.O.T	5.14	-17.50	-89.94	1.60	8.21	1.79
F.W.T	100.18	-9.518	-953.50	1.65	165.49	60.31
Paper Box & Vinyl	4.00	2.20	8.80	2.87	11.48	0.00
FISH HOLD	315.69	9.00	2,842.03	2.15	678.64	0.00
Sub Total	952.17	-4.88	-4,651.37	2.54	2,423.45	769.59
Dead Weight	1043.00	-5.43	-5,663.70	2.96	3,089.48	778.20
Light Weight	2,487.00	-3.88	-9,649.56	5.87	14,898.69	0.00
Displacement	3,530.00	-4.34	-15,313.26	5.01	17,688.17	778.20

[Table 14-1] Fluid Statistics Characteristic Value on Dec. 1, on the morning of the casualty

Draft Equivalent	6.508 m	Transverse Metacenter (KMT)	6.154 m
Draft (B.L.)	5.858 m		
Total Trim by Stern	-1.415 m	Vertical Center of Gravity (KG)	5.011 m
Draft Forward	5.688 m	Metacentric Height (GM)	1.143 m
Draft Aft	7.103 m	Free Surface Correction (GG')	0.220 m
Draft Mean	6.395 m	Correction Metacentric Height (G'M)	0.923 m
L.C.B.	-2.634 m	M.T.C.	42.496 m*ton
L.C.F.	-5.803 m	T.P.C.	8.318 mt/cm

[Table 14-2] Righting Arm (GZ) by Transverse Slope on Dec. 1, on the morning of the casualty

Angle [degree]	KN [m]	KG*SIN [m]	GZ [m]	AREA [m*rad]
5	0.537	0.456	0.081	0.004
10	1.073	0.908	0.164	0.014
15	1.608	1.354	0.255	0.032
20	2.144	1.789	0.355	0.059
30	3.137	2.616	0.522	0.136
40	3.992	3.363	0.629	0.238
50	4.694	4.007	0.687	0.353
60	5.181	4.530	0.650	0.471



[Image 25] Stability curve on Dec. 1, on the morning of the casualty

[Table 14-3] Stability Assessment Criteria on Dec. 1, on the morning of the casualty

Stability criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.923	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.136	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	-0.104	0.030	NOT GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.029	0.090	NOT GOOD
GZ at 30 deg (m):	0.522	0.200	GOOD
Angle of Max. GZ occurs at (deg):	50.7	25.000	GOOD
Angle of down-flooding(deg):	14.3	-	
Area A (m-rad)	0.043	-	
Area B (m-rad)	0.013	-	
Area Ratio B/A	0.307	1	NOT GOOD

4.2.5.3 The stability review report, as detailed in Table 14-3, shows that the stability fell short of the stability assessment criteria, and the area ratio was also very small compared to that on July 10, at departure, and August 14, during fishing operation due to rough waves and wind pressure.

4.2.6 Stability Immediately Before the Casualty (loaded 20 tons of catch on upper deck)

4.2.6.1 Just before the casualty, the vessel hauled in its net and placed 20 tons of catch on the stern deck. The stability of the vessel, taking into account the catch of fish, is as shown in Table 15 through Table 15-3.

[Table 15] Fluid Statistics Characteristic Value by Weight Dec. 1, immediately before the casualty

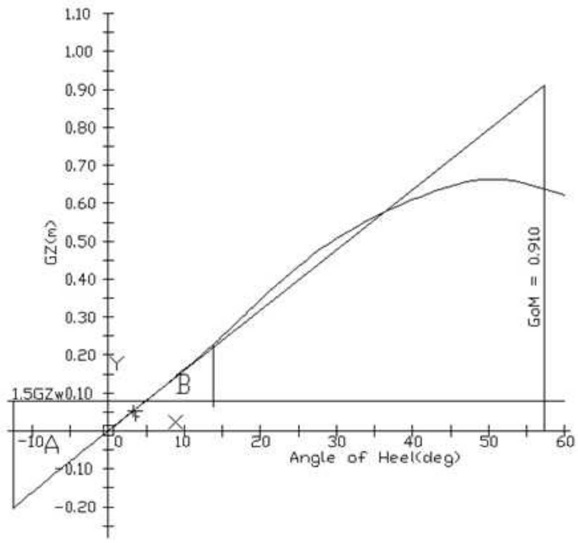
Items	Weight [ton]	L.C.G. [m]	L-Moment [ton*m]	V.C.G. [m]	V-Moment [ton*m]	F.S.M. [ton*m]
Constant Weight	90.83	-11.14	-1,012.34	7.33	666.03	8.61
Sub Total	90.83	-11.14	-1,012.34	7.33	666.03	8.61
F.O.T	527.16	-12.25	-6,458.76	2.96	1,559.63	707.49
L.O.T	5.14	-17.50	-89.94	1.60	8.21	1.79
F.W.T	100.18	-9.518	-953.50	1.65	165.49	60.31
Paper Box & Vinyl	4.00	2.20	8.80	2.87	11.48	0.00
FISH HOLD	315.69	9.00	2,842.03	2.15	678.64	0.00
Taken Fish	20.00	-28.00	-560.00	9.60	192.00	0.00
Sub Total	972.17	-5.36	-5,211.37	2.69	2,615.45	769.59
Dead Weight	1063.00	-5.85	-6,223.70	3.09	3,281.48	778.20
Light Weight	2,487.00	-3.88	-9,649.56	5.87	14,898.69	0.00
Displacement	3,550.00	-4.47	-15,873.26	5.04	17,880.17	778.20

[Table 15-1] Fluid Statistics Characteristic Value on Dec. 1, immediately before the casualty

Draft Equivalent	6.532 m	Transverse Metacenter (KMT)	6.166 m
Draft(B.L.)	5.882 m		
Total Trim by Stern	-1.514 m	Vertical Center of Gravity (KG)	5.037 m
Draft Forward	5.655 m	Metacentric Height (GM)	1.129 m
Draft Aft	7.169 m	Free Surface Correction (GG')	0.219 m
Draft Mean	6.412 m	Correction Metacentric Height (G'M)	0.910 m
L.C.B.	-2.652 m	M.T.C.	42.659 m*ton
L.C.F.	-5.806 m	T.P.C.	8.333 mt/cm

[Table 15-2] Righting Arm (GZ) by Transverse Slope on Dec. 1, immediately before the casualty

Angle [degree]	KN [m]	KG*SIN [m]	GZ [m]	AREA [m*rad]
5	0.538	0.458	0.080	0.003
10	1.075	0.913	0.162	0.014
15	1.610	1.360	0.250	0.032
20	2.143	1.798	0.346	0.058
30	3.136	2.628	0.508	0.133
40	3.987	3.378	0.609	0.231
50	4.689	4.026	0.663	0.343
60	5.174	4.552	0.622	0.457



[Image 26] Stability curve on Dec. 1, immediately before the casualty

[Table 15-3] Stability Assessment Criteria on Dec. 1, immediately before the casualty

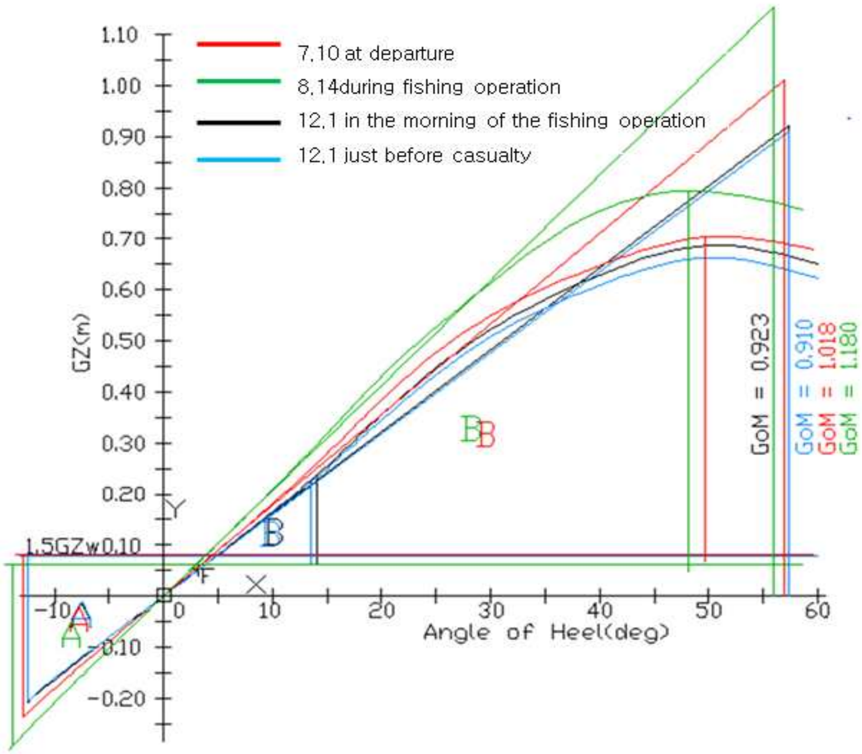
Stability criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.910	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.133	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	-0.101	0.030	NOT GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.027	0.090	NOT GOOD
GZ at 30 deg (m):	0.508	0.200	GOOD
Angle of Max. GZ occurs at (deg):	50.4	25.000	GOOD
Angle of down-flooding (deg):	13.7	-	
Area A (m-rad)	0.042	-	
Area B (m-rad)	0.011	-	
Area Ratio B/A	0.270	1	NOT GOOD

4.2.6.2 According to the review results, the same items that did not meet the stability criteria in the morning of the casualty fell short of the stability standard. The value for each item worsened.

4.2.6.3 The results of the stability review reports for the morning of the casualty and immediately before the casualty failed to satisfy standards because the shutter of the sewage discharge outlet of the vessel had been destroyed in mid-September. This changed the opening for seawater inflow from below the chimney to the upper surface of the sewage discharge outlet, and thus greatly reduced the size of the inflow angle.

4.2.7 Comparison with Stability Expected of Normal Sewage Discharge Outlet

4.2.7.1 The vessel stability from July 10th of the same year, at departure from Gamcheon Port, to immediately before the casualty, as reviewed earlier, can be comprehensively analyzed as follows.



[Image 27] Comparison of stability curve based on displacement (Jul.10-Dec.1)

[Table 16] Comparison of Stability Criteria based on Displacement (Jul.10-Dec.1)

Stability criteria	At Departure from Gamcheon (7.10)	Fishing Operation (8.14)	Day of Casualty (12.1 morning)	Immediately before Casualty (12.1)	Criterion
GoM (m):	1.018	1.180	0.923	0.910	0.150
GZ Curve Area between 0-30 deg (m-rad):	0.147	0.166	0.136	0.133	0.055
GZ Curve Area between 30-40/SWI deg (m-rad):	0.105	0.121	-0.104	-0.101	0.030
GZ Curve Area between 0-40/SWI	0.253	0.287	0.029	0.027	0.090

deg (m-rad):					
GZ at 30 deg (m):	0.551	0.616	0.522	0.508	0.200
Angle of Max. GZ occurs at (deg):	51.5	49.6	50.7	50.4	25.000
Angle of down-flooding (deg):	53.7	49.2	14.3	13.7	
Area A (m-rad)	0.048	0.054	0.043	0.042	-
Area B (m-rad)	0.304	0.361	0.013	0.011	-
Area Ratio B/A (>=1)	6.269	6.654	0.307	0.270	1

4.2.7.2 According to Table 16 above, there had not been any issues with stability until mid-September when the sewage discharge outlet had been normal, but after its detachment, the issue of stability persisted.

4.2.7.3 In order to clarify the stability issue as a result of the damage in the sewage discharge outlet, Table 17 compares the stability with what is presumed it should have been had the discharge outlet not been damaged until the casualty.

[Table 17] Comparison of Stability Criteria with Assumption of Undamaged Sewage Discharge Outlet

Stability Criteria	Day of Casualty (12.1 morning)	Day of Casualty (12.1 morning) undamaged sewage discharge outlet	Immediately Before Casualty (12.1)	Immediately Before Casualty (12.1) undamaged sewage discharge outlet	Criterion
GoM (m):	0.923	0.923	0.910	0.910	0.150
GZ Curve Area between 0-30 deg (m-rad):	0.136	0.136	0.133	0.133	0.055
GZ Curve Area between 30-40/SWI deg (m-rad):	-0.104	0.101	-0.101	0.098	0.030
GZ Curve Area between 0-40/SWI deg (m-rad):	0.029	0.238	0.027	0.231	0.090
GZ at 30 deg (m):	0.522	0.522	0.508	0.508	0.200
Angle of Max. GZ occurs at (deg):	50.7	50.7	50.4	50.4	25.000

Angle of down-flooding(deg):	14.3	53.3	13.7	53.0	-
Area A (m-rad)	0.013	0.043	0.011	0.042	-
Area B (m-rad)	0.307	0.288	0.270	0.279	-
Area Ratio B/A (>=1)	0.002	6.745	0.00	6.635	1

4.2.7.4 Based on the comparison in Table 17 above, the stability in the presumed situation of undamaged sewage discharge outlet meets standards. It can be seen that the stability criteria could not be satisfied as a result of the damage to the sewage discharge outlet.

4.2.8 Review of Stability during the Occurrence of Casualty

4.2.8.1 This casualty began with the inflow of seawater through the hatch cover on the upper deck and was exacerbated with the continuous inflow of seawater through the hatch cover and the sewage discharge outlet below the upper deck. Therefore, calculating stability during the casualty should involve calculating damage stability.

4.2.8.2 However, because such a deep-sea fishing vessel is not subjected to damage stability review, there is no object of comparison. The comparison was made with the intact stability as it was deemed to be more effective in assessing the stability capacity underwater.

4.2.8.3 In conducting the vessel sinking simulation using the fluid-structure interaction method, stability during the process of the casualty was divided broadly into cases of starboard incline (Case 1) and port incline (Case 2) for calculations.

4.2.9 Stability from Starboard Incline during the Casualty (Case 1)

4.2.9.1 In the early stage of the casualty, there was a transverse slope to starboard as a result of transverse wave at port side. The situation of the starboard transverse incline is Case 1 and it is divided into three situations of Case 1-1 (starboard incline 0°), Case 1-2 (starboard incline 25°) and Case 1-3 (starboard incline 35°) in order to calculate the damage stability.

4.2.9.2 The Case 1-1 scenario is when fish and seawater have poured into the fish bunker through the hatch cover, with some flowing into the processing room, but without any incline. The stability in this situation is as follows.

[Table 18] Damaged Compartments and Permeability in Case 1-1 (0˚)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	-
NO.2 Fish Hold	-
Engine Room	-
Process Room	3.3
Fish Bunker	51.0

[Table 18-1] Stability and Area in Case 1-1 (0˚)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.458	0.073	0.003
10	0.912	0.159	0.013
15	1.360	0.253	0.031
20	1.797	0.352	0.057
25	2.220	0.417	0.091
30	2.627	0.469	0.130
35	3.013	0.509	0.173
40	3.377	0.545	0.219
45	3.714	0.575	0.268
50	4.024	0.595	0.319
55	4.303	0.596	0.371
60	4.549	0.576	0.422

[Table 18-2] Stability Criteria in Case 1-1 (0˚)

Stability Criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.834	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.130	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	0.089	0.030	GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.219	0.090	GOOD
GZ at 30 deg (m):	0.469	0.200	GOOD
Angle of down-flooding (deg):	14.3	-	
Area A (m-rad)	0.024	-	
Area B (m-rad)	0.028	-	
Area Ratio B/A	1.167	1	GOOD

4.2.9.3 As a result of calculations for Case 1-1 (starboard incline 0°), the stability criteria were all met, and the area ratio from waves and wind pressure were good.

4.2.9.4 In Case 1-2 (starboard incline 25°), the destruction of the wooden wall in the fish bunker resulted in a large inflow of seawater and fish into the fish processing room, and seawater continuously flowed into the vessel through the fish bunker hatch cover that was not shut completely. As a result, the vessel inclined to starboard by 25° and its stability at this status is as follows.

[Table 19] Damaged Compartments and Permeability in Case 1-1 (starboard incline 25°)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	5.0
NO.2 Fish Hold	4.0
Engine Room	-
Process Room	34.0
Fish Bunker	27.0

[Table 19-1] Stability and Area in Case 1-1 (starboard incline 25°)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.458	-0.310	-0.014
10	0.912	-0.227	-0.037
15	1.360	-0.142	-0.053
20	1.797	-0.064	-0.062
25	2.220	-0.001	-0.065
30	2.627	0.058	-0.063
35	3.013	0.120	-0.055
40	3.377	0.184	-0.042
45	3.714	0.237	-0.024
50	4.024	0.278	-0.002
55	4.303	0.307	0.024
60	4.549	0.328	0.052

[Table 19-2] Stability Criteria in Case 1-1 (starboard incline 25°)

Stability Criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.696	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	-0.063	0.055	N.G
GZ Curve Area between 30-40/SWI deg (m-rad):	0.021	0.030	N.G
GZ Curve Area between 0-40/SWI deg (m-rad):	-0.042	0.090	N.G
GZ at 30 deg (m):	0.058	0.200	N.G
Angle of down-flooding (deg):	14.3	-	
Area A (m-rad)	0.018	-	
Area B (m-rad)	-	-	
Area Ratio B/A	-	1	N.G

4.2.9.5 In Case 1-2 (starboard incline 25°), the vessel's stability did not satisfy the stability criteria except the GoM and GZ curve area between 30-40˚, and failed to meet the area ratio from wind pressure. As transverse incline has taken place due to flooding, the stabilizing force is only generated when the incline is greater than 25°. It shows that the vessel lacks the dynamic stability energy needed for the stabilizing force.

4.2.9.6 In Case 1-3 (starboard incline 35°), the continuous inflow of seawater through the hatch cover and the sewage discharge outlet has caused an incline of 35° to starboard. The vessel stability in this situation is as follows.

[Table 20] Damaged Compartments and Permeability in Case 1-3 (starboard incline 35°)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	7.0
NO.2 Fish Hold	8.0
Engine Room	-
Process Room	47.9
Fish Bunker	65.3

[Table 20-1] Stability and area in Case 1-3 (starboard incline 35°)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.458	-0.340	-0.013
10	0.912	-0.277	-0.036
15	1.360	-0.201	-0.054
20	1.797	-0.155	-0.067
25	2.220	-0.105	-0.076
30	2.627	-0.053	-0.082
35	3.013	0.004	-0.085
40	3.377	0.060	-0.084
45	3.714	0.112	-0.080
50	4.024	0.150	-0.074
55	4.303	0.184	-0.066
60	4.549	0.206	-0.056

[Table 20-2] Stability Criteria in Case 1-3 (starboard incline 35°)

Stability criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.647	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	-0.097	0.055	N.G
GZ Curve Area between 30-40/SWI deg (m-rad):	-0.001	0.030	N.G
GZ Curve Area between 0-40/SWI deg (m-rad):	-0.096	0.090	N.G
GZ at 30 deg (m):	-0.053	0.200	N.G
Angle of down-flooding (deg):	14.3	-	
Area A (m-rad)	0.023	-	
Area B (m-rad)	-	-	
Area Ratio B/A	-	1	N.G

4.2.9.7 As can be assessed with the above data, Case 1-3 (starboard incline 35°) did not satisfy any criteria except GoM. As was the case of Case 1-2 (starboard incline 25°), flooding from damage has caused a transverse incline, and since the stabilizing force is only generated after an incline greater than 35°, there was not enough stabilizing force.

4.2.10 Stability from Port Incline during Casualty (Case 2)

4.2.10.1 The vessel temporarily restored its equilibrium from starboard incline after moving the catch of fish and fuel to the port. However, it then tilted to port. The situation of the port transverse incline is Case 2 and it is divided into three situations, Case 2-1 (port incline 0°), Case 2-2 (port incline 25°) and Case 2-3 (port incline 35°) to calculate the damage stability.

4.2.10.2 In Case 2-1 (port incline 0°), the vessel had temporarily reached an equilibrium by transferring the catch of fish and fuel on board to port side, and pumping out seawater. The results of stability calculations are as follows.

[Table 21] Damaged Compartments and Permeability in Case 2-1 (0˚)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	7.0
NO.2 Fish Hold	8.0
Engine Room	-
Process Room	13.0
Fish Bunker	36.0

[Table 21-1] Stability and Area in Case 2-1 (0˚)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.457	0.128	0.006
10	0.911	0.269	0.023
15	1.358	0.398	0.052
20	1.795	0.491	0.091
25	2.217	0.560	0.137
30	2.624	0.614	0.188
35	3.010	0.643	0.243
40	3.373	0.659	0.300
45	3.710	0.657	0.357
50	4.019	0.643	0.414
55	4.298	0.625	0.469
60	4.544	0.604	0.523

[Table 21-2] Stability Criteria in Case 2-1 (0˚)

Stability Criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	1.774	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	0.188	0.055	GOOD
GZ Curve Area between 30-40/SWI deg (m-rad):	0.112	0.030	GOOD
GZ Curve Area between 0-40/SWI deg (m-rad):	0.300	0.090	GOOD
GZ at 30 deg (m):	0.614	0.200	GOOD
Angle of down-flooding (deg):	12.9	-	
Area A (m-rad)	0.065	-	
Area B (m-rad)	0.027	-	
Area Ratio B/A	0.415	1	NOT GOOD

4.2.10.3 The results in Case 2-1 (port incline 0°) meet the criteria for dynamic stability force but as the inflow angle was lowered due to the inflow of seawater through the sewage discharge rate, it does not satisfy the area ratio from severe wave and wind pressure.

4.2.10.4 This means that the vessel did not have sufficient stability force to respond to severe wind and waves as a result of the continuous inflow of seawater through the sewage discharge outlet and flooding of damaged compartments, albeit in a temporary state of equilibrium.

4.2.10.5 In Case 2-2 (port incline 30°), the vessel had been in an equilibrium state when it was hit by an external force from starboard which caused it to tilt to port by 30°. As a result, seawater gushed into the engine room and the fish hold. The results of stability calculations in this situation are as follows.

[Table 22] Damaged Compartments and Permeability in Case 2-2 (port incline 30°)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	18.0
NO.2 Fish Hold	19.0
Engine Room	24.0
Process Room	35.0
Fish Bunker	69.0

[Table 22-1] Stability and Area in Case 2-2 (port incline 30°)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.457	-0.372	-0.016
10	0.911	-0.285	-0.045
15	1.358	-0.193	-0.066
20	1.795	-0.121	-0.080
25	2.217	-0.062	-0.088
30	2.624	-0.002	-0.091
35	3.010	0.063	-0.088
40	3.373	0.131	-0.080
45	3.710	0.185	-0.066
50	4.019	0.231	-0.048
55	4.298	0.264	-0.026
60	4.544	0.290	-0.002

[Table 22-2] Stability Criteria in Case 2-2 (port incline 30°)

Stability criteria	KST-SHIP	Criterion (>=)	judgement
GoM (m):	0.719	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	-0.091	0.055	N.G
GZ Curve Area between 30-40/SWI deg (m-rad):	0.011	0.030	N.G
GZ Curve Area between 0-40/SWI deg (m-rad):	-0.080	0.090	N.G
GZ at 30 deg (m):	0.002	0.200	N.G
Angle of down-flooding (deg):	12.9	-	
Area A (m-rad)	0.015	-	
Area B (m-rad)	-	-	
Area Ratio B/A	-	1	N.G

4.2.10.6 The results of Case 2-2 (port incline 30°) show that the vessel did not satisfy the criteria for dynamic stability force except for the GoM standard. As it also failed to meet the criteria for area ratio from severe wind and waves, it can be inferred that the vessel was in a state in which it could not regain its equilibrium.

4.2.10.7 Case 2-3 (port incline 45°) is when 70% of the engine room is flooded and 23-24% of each fish hold is flooded, with the vessel steadily sinking. The stability of the vessel in this situation is calculated as follows.

[Table 23] Damaged Compartments and Permeability in Case 2-3 (port incline 45°)

Damaged Compartments	Permeability(%)
NO.1 Fish Hold	24.0
NO.2 Fish Hold	23.0
Engine Room	68.0
Process Room	44.0
Fish Bunker	92.0

[Table 23-1] Stability and area in Case 2-3 (port incline 45°)

Angle [Degree]	K.Go*sinθ [m]	GZ [m]	AREA [m*rad]
0	0.000	0.000	0.000
5	0.457	-0.472	-0.021
10	0.911	-0.396	-0.059
15	1.358	-0.338	-0.091
20	1.795	-0.290	-0.118
25	2.217	-0.244	-0.141
30	2.624	-0.187	-0.160
35	3.010	-0.122	-0.173
40	3.373	-0.059	-0.181
45	3.710	-0.001	-0.184
50	4.019	0.048	-0.182
55	4.298	0.093	-0.176
60	4.544	0.129	-0.166

[Table 23-2] Stability Criteria in Case 2-3 (port incline 45°)

Stability Criteria	KST-SHIP	Criterion (>=)	Judgement
GoM (m):	0.608	0.150	GOOD
GZ Curve Area between 0-30 deg (m-rad):	-0.160	0.055	N.G
GZ Curve Area between 30-40/SWI deg (m-rad):	-0.021	0.030	N.G
GZ Curve Area between 0-40/SWI deg (m-rad):	-0.181	0.090	N.G
GZ at 30 deg (m):	-0.187	0.200	N.G
Angle of down-flooding(deg):	12.9	-	
Area A (m-rad)	0.003	-	
Area B (m-rad)	-	-	
Area Ratio B/A	-	1	N.G

4.2.10.8 In Case 2-3 (port incline 45°), the results show that the vessel, as in the case of port incline of 30°, did not meet stability criteria other than the GoM standard, including the area ratio from severe wave and wind pressure. The situation worsened from the case of a 30° port incline, indicating that the sinking of the vessel was accelerated.

4.2.11 Sub-conclusion

4.2.11.1 The most fundamental principle of fishing vessel stability is that the restoring energy must be greater than the capsizing energy derived from climate conditions including wind and waves encountered during fishing operations or navigation.

4.2.11.2 Factors that have an impact on such stability include the weight of load in each compartment, impact of circulating fluid if the load is fluid, vessel structure, and the location of openings for inflow of seawater, which are comprehensively taken into account in the calculation.

4.2.11.3 After calculating the vessel stability for each part of the vessel from departure to the point of sinking, there was no issue with stability in the scenario of normal operation.

4.2.11.4 However, as the location of the opening allowing inflow of seawater changed as a result of the damaged sewage discharge outlet located below the upper deck, the inflow angle changed. When taking this into account, problems with vessel stability emerged.

4.2.11.5 As such, the fact that the vessel operated for a long time with the damaged sewage discharge outlet means that the dangerous state at which the vessel is not seaworthy continued for an extended period of time. It is assessed that the negative impact on restoring force resulting from the inflow of seawater through the sewage discharge outlet at the outbreak of the casualty was a contributing factor in the sinking of the vessel.

4.3 Analysis of Sinking Ship Simulation Using Fluid-Structure Interaction

4.3.1 Background of Simulation

4.3.1.1 The Korean Maritime Safety Tribunal requested the Maritime Safety Technology of the Korea Maritime and Ocean University to conduct a simulation in order to objectively prove the process of the vessel's sinking from flooding based using confirmed data on the vessel's fuel and cargo load.

4.3.1.2 This simulation used Weather Research Forecasting (WRF), a U.S. [35] model for predicting regional weather conditions, to analyze the climate conditions and maritime conditions of the West Bering Sea, where the casualty occurred. It produced local climate data for every 10 minutes, and by using WAVEWATCH-III, a wave predicting model of developed by the US NOAA[36], it analyzed the waves.

4.3.1.3 Furthermore, by using the Modeling & Simulation (M&S) system for interpreting the Fluid-Structure Interaction (FSI), a simulation was generated for the rough maritime conditions including tidal waves.

4.3.1.4 Also, the simulation was conducted by analyzing and modeling the vessel shape and structure. In addition, by considering factors such as circulating fluid and arrangement of fish on board, the vessel stability for each stage of the casualty was calculated.

35) National Center for Environmental Prediction (NCEP) in the U.S.
36) National Oceanic and Atmospheric Administration (NOAA) in the U.S.

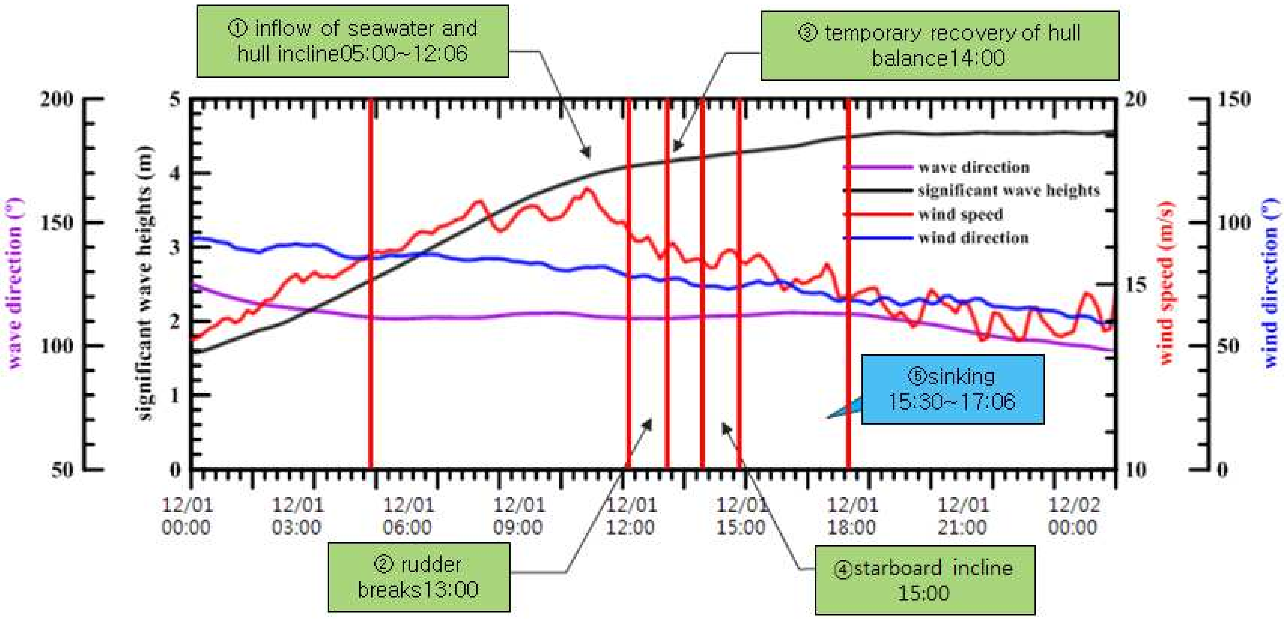
4.3.1.5 The sinking and flooding scenario used in the simulation is based on the data (crew testimonies, radio messages, etc.) collected by the Safety Investigation Team of the Korean Maritime Safety Tribunal, and is listed in Table 24.

[Table 24] Flooding and Sinking Scenario

Scenario	Situation		
	Description	Hull Incline	Wave Direction
CASE 1-0 (presuming a situation different from 1-1)	- Gets underway without a fully closed hatch cover *inflow of seawater when pouring the catch into the fish bunker	-	Starboard bow 20°
CASE 1-1	- Pours the catch into the fish bunker, closes the hatch cover incompletely - Seawater starts flowing in through the hatch cover	10° to starboard	Stern port 20°
CASE 1-2	- Hatch cover closed incompletely - Large inflow of seawater into the fish processing room and steering room from broken wooden wall -Rudder out of control	20° to starboard	Stern port 20°
CASE 1-3	- Ship unable to maintain course - Wave direction changes to 725° at stern port	25-30° to starboard	Stern port 72.5°
CASE 1-4	- Starboard incline stopped at 35° due to water discharge using pump	35° to starboard	Stern port 72.5°
CASE 2-0	- Transfers some fuel and fish to port - Discharges seawater using pump	Temporary equilibrium, then 5° to starboard	Stern port 72.5°
CASE 2-1	- Hull is rotated left to change the wave direction form 725° stern port to 725° stern starboard	10° to port	Stern starboard 72.5°
CASE 2-2	- Seawater inflow continues at transverse wave hitting starboard - Stern sinks	Steep incline of 30-35° to port	Stern starboard 72.5°
CASE 2-3	- Inflow of seawater continues, stern sinking exacerbates	45-50° to port	Stern starboard 72.5°
CASE 2-4	- Large inflow of seawater - Steep port incline and sinking from stern	More than 65° to port	Stern starboard 72.5°
CASE 2-5	- Large inflow of seawater, complete sinking of hull	More than 80° to port	Stern starboard 72.5°

4.3.2 Analysis of Maritime Conditions during Casualty and Simulation

4.3.2.1 The time-series data of significant wave height, wave direction, wind speed, and direction at the casualty site (N61° 54′, W177° 09′) of 501 Oryong analyzed using the WRF model and WAVEWATCH-III are as shown as a graph in Image 28.



[Image 28] Time-series data of sea-level pressure, Significant wave height and wind speed (partially enlarged) at 177.09W, 61.54N

4.3.2.2 Furthermore, a summary of the wave period for each time period on the day of the casualty is as shown in Table 25.

[Table 25] Significant Wave Height and Wind Speed by Time at Casualty Site

Time	Situation	Significant Wave Height	Wave Direction	Wave Period	Wind Speed	Wind Direction	Sea-level Pressure
12/1 05:00	sets net	2.6m	111.5°	5.6s	16.3m/s	86.1°	998.0 hPa
11:00	hauls net	4.0m	112.0°	7.4s	17.5m/s	82.2°	991.8hPa
12:00	incomplete closing of hatch cover	4.1m	111.2°	7.6s	16.4m/s	78.3°	991.0hPa
12:06	starts taking shelter	4.1m	111.2°	7.6s	16.2m/s	78.3°	990.7hPa
13:00	rudder out of control	4.2m	111.2°	7.7s	16.0m/s	77.5°	990.5hPa
14:00	temporary balance of hull	4.2m	111.9°	7.8s	15.6m/s	74.5°	989.7hPa
15:00	rapid incline to starboard	4.3m	112.3°	7.9s	15.6m/s	74.3°	991.2hPa
15:30	starts sinking from stern	4.3m	112.7°	8.0s	15.8m/s	76.7°	990.9hPa
16:49	loses VMS signal	4.4m	113.3°	8.1s	15.1m/s	71.9°	989.8hPa
17:06	hull sinks completely	4.4m	113.2°	8.1s	15.2m/s	72.0°	989.6hPa

※ Standard for wind wave special alert (Korea Meteorological Administration)

☞ Wind wave advisory: when wind speed of over 14m/s continues for more than 3 hours at sea, or significant wave height is over 3m

☞ High seas warning: when wind speed of over 21m/s continues for more than 3 hours at sea, or significant wave height is over 5m

※ Standard for controlling vessel departure based on the Maritime Safety

Act

☞ Wind wave advisory: domestic vessels of less than 250 tons in gross tonnage that has a length less than 35m

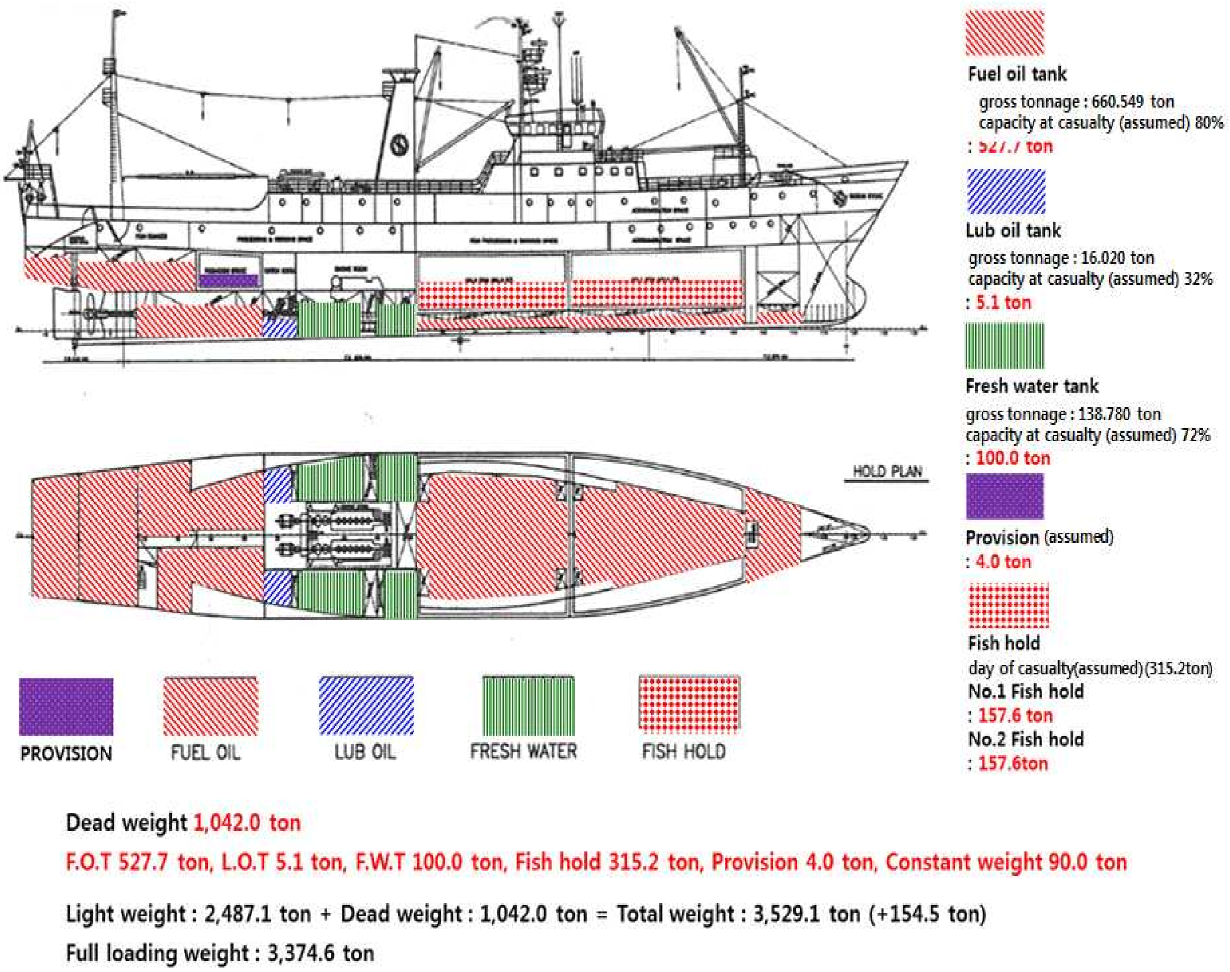
☞ High seas warning : domestic vessel of less than 1,000 tons in gross tonnage that has a length less than 63m

4.3.2.3 In conclusion, the significant wave height in the waters near the site of the casualty of 501 Oryong was about 4.0-4.5m, with wave period of about 8 seconds at a true bearing of about 110°. It can also be observed that the wind continued to blow at a speed of 15m/s at a true bearing of about 75°.

4.3.3 Analysis of Vessel Model and Structure and Simulation Modeling

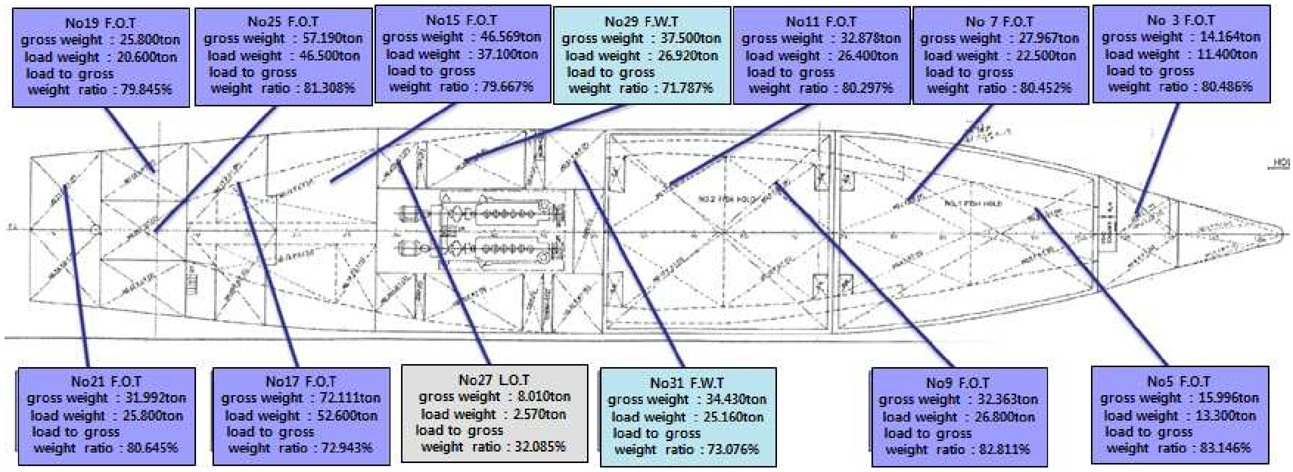
4.3.3.1 For vessel shape and weight distribution of 501 Oryong, floor plans such as the general layout and stability calculations were taken into account, and the vessel structure and layout was identified by visiting vessels of similar and same type as 501 Oryong.

4.3.3.2 Image 29 shows the total load capacity and weight distribution at the time of the casualty, and due to the remaining catch of 315 tons, fuel of 527 tons and lubricating oil of 5.1 tons, it is presumed that the vessel had loaded about 131 tons over its maximum capacity compared to the full load displacement.

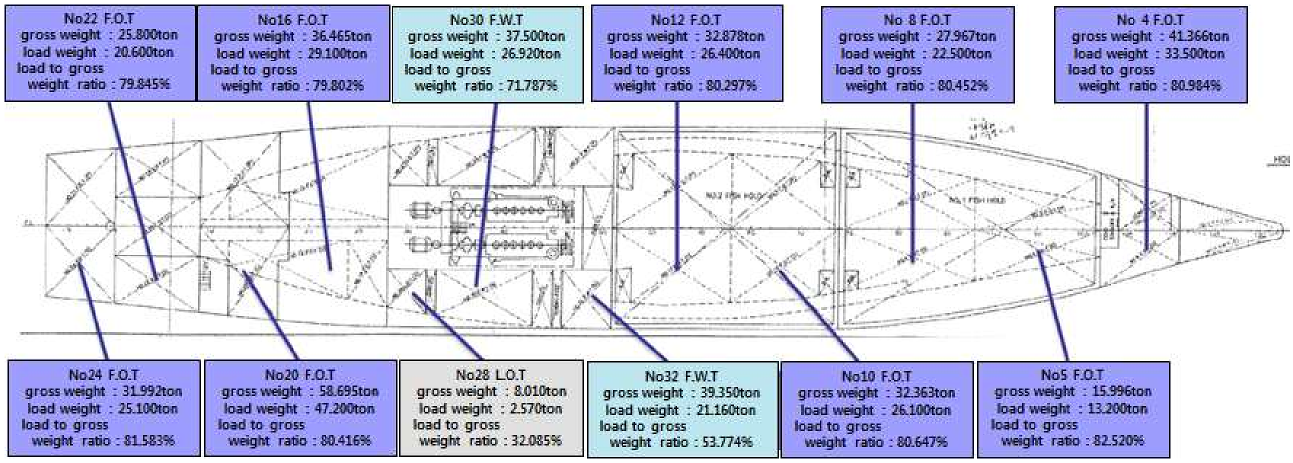


[Image 29] Distribution of deadweight at the time of casualty (fish, fuel etc.)

4.3.3.3 Image 30 and Image 31 show the total load capacity of the main tank and the weight distribution on the day of the casualty. Because there are no exact records, it has been assumed that the load has been stocked evenly, in general.

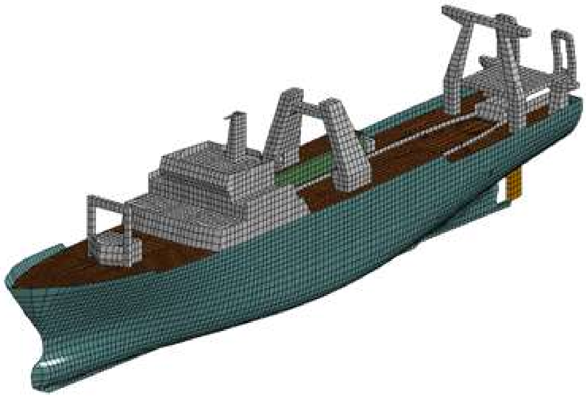
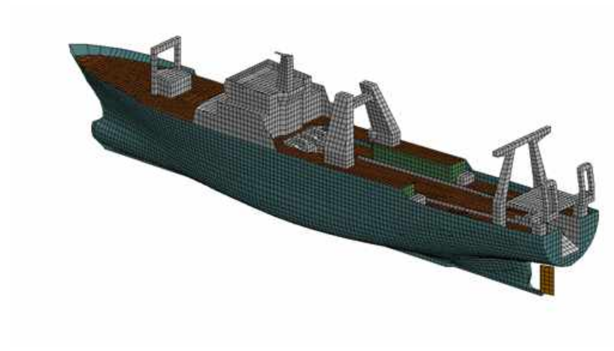
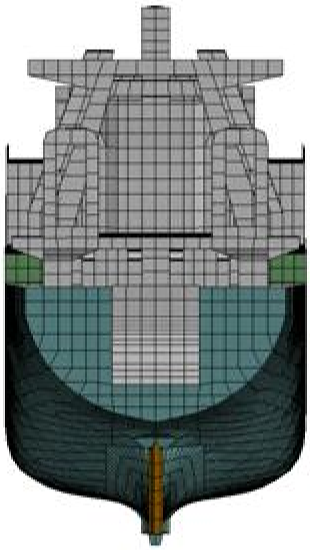
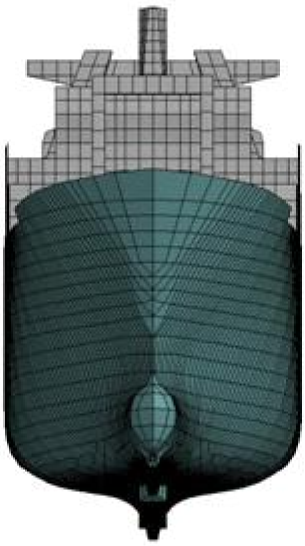
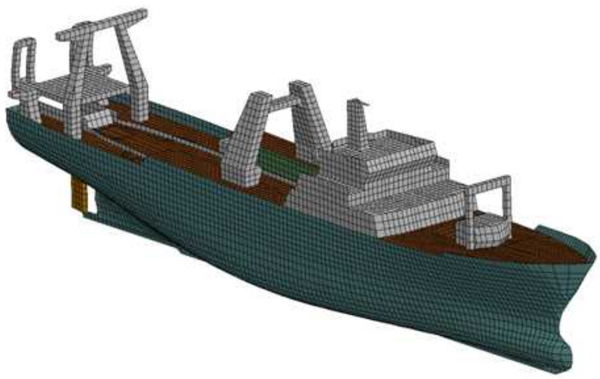
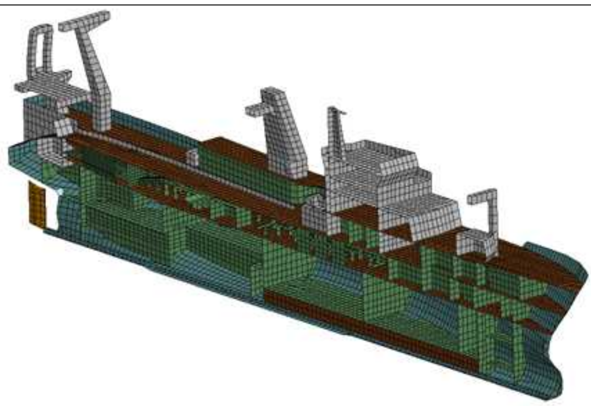


[Image 30] Distribution of tank weight at the time of casualty (port)

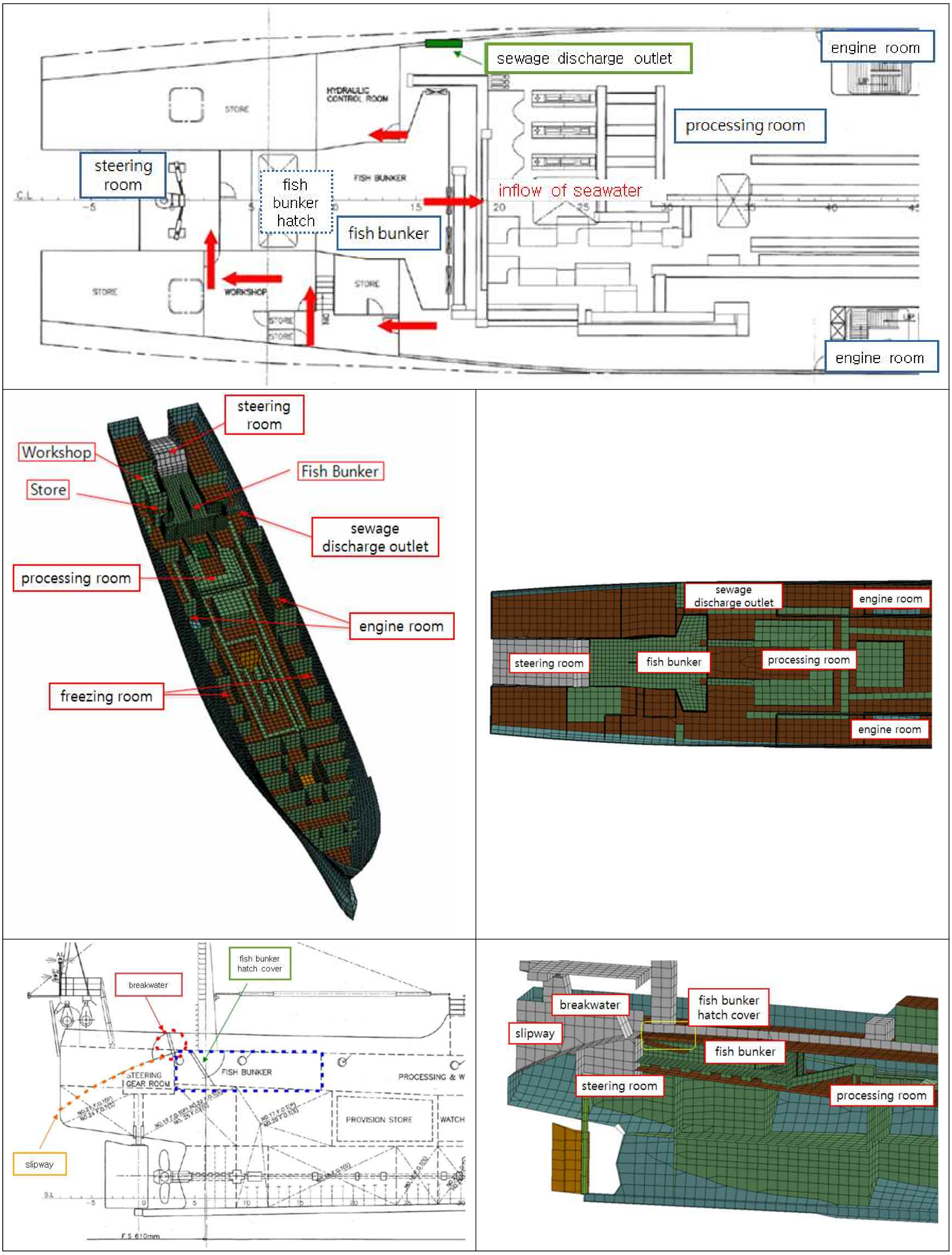


[Image 31] Distribution of tank weight at the time of casualty (starboard)

4.3.3.4 The whole-ship modeling for the sinking and flooding simulation was conducted by analyzing the volume of each tank based on the overall vessel shape, weight distribution at light load, and stability calculations, and by sufficiently identifying seawater floods and flows in the interior structure. Image 32 shows the cross-section modeling of the vessel by each direction, and Image 33 shows the interior structural modeling.

	
Side-view from port bow	Side-view from port stern
	
Stern	Bow
	
Side-view from starboard bow	Inner structure from starboard bow

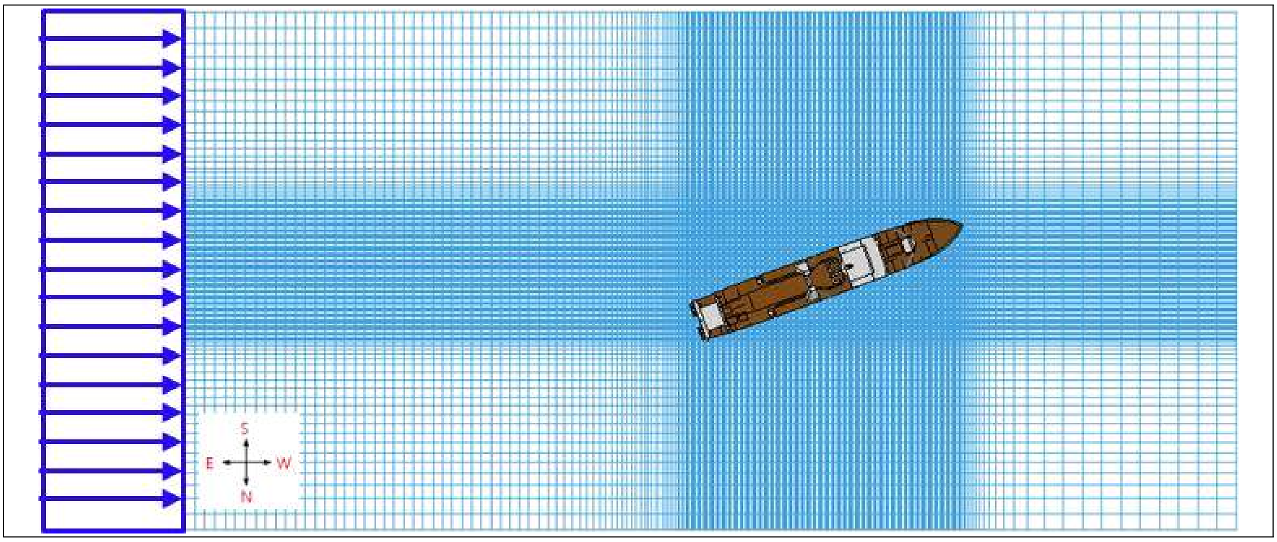
[Image 32] Cross-section view by direction



[Image 33] Interior modeling

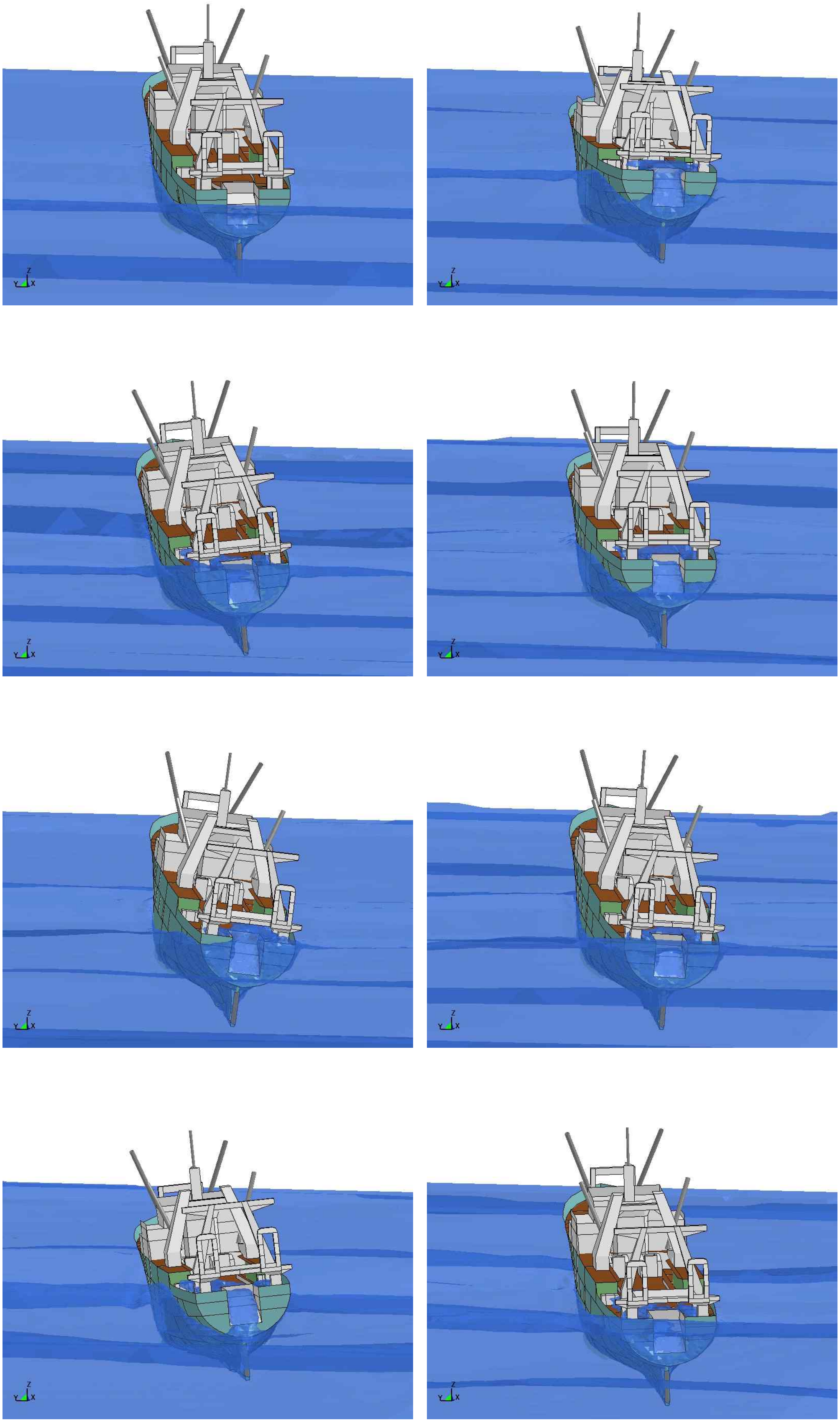
4.3.4 Simulation of Ship-sinking Using Fluid-Structure Interaction

4.3.4.1 In Case 1-1 (starboard incline of 10° after getting underway), in addition to the 80 tons of seawater that was poured into the fish bunker along with the catch of fish, about 170 tons of seawater entered the ship, flooding the floor of the fish processing room. Without a fully closed hatch cover, the vessel had set its course towards the west while receiving waves from port stern at 20°, as shown in Image 34.



[Image 34] Direction of waves in Case 1-1

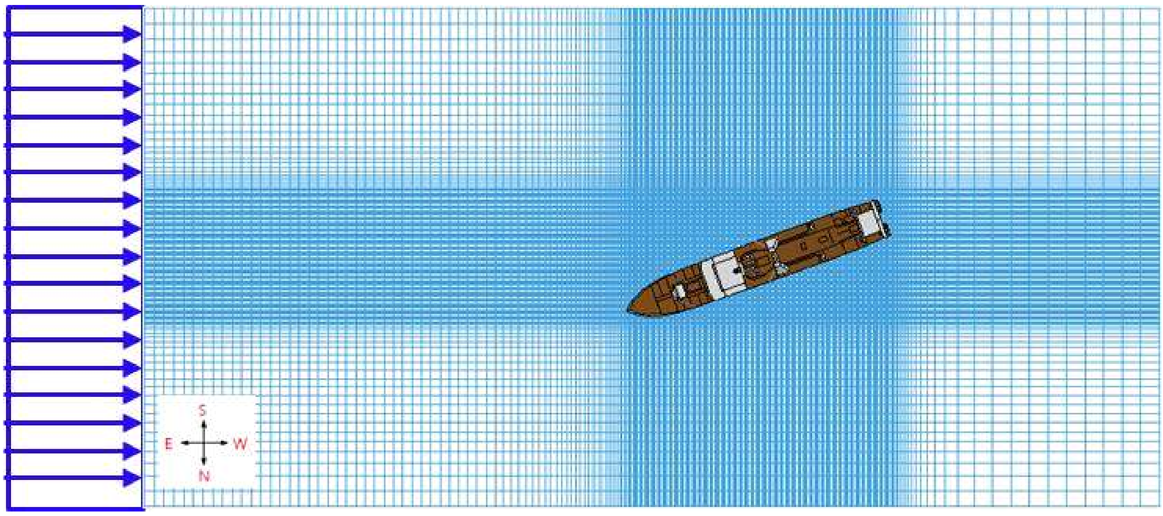
4.3.4.2 At the time, a part of the starboard stern had sunk underwater and waves were swelling over the stern deck. The sewage discharge outlet at stern port was located relatively higher than the water level as the hull had been tilted starboard, but there was still some inflow of seawater as the port stern periodically sank underwater as waves rolled onto the hull at a sharp angle.



[Image 34-1] Movement in Case 1-1 (waves, stern port 20°)

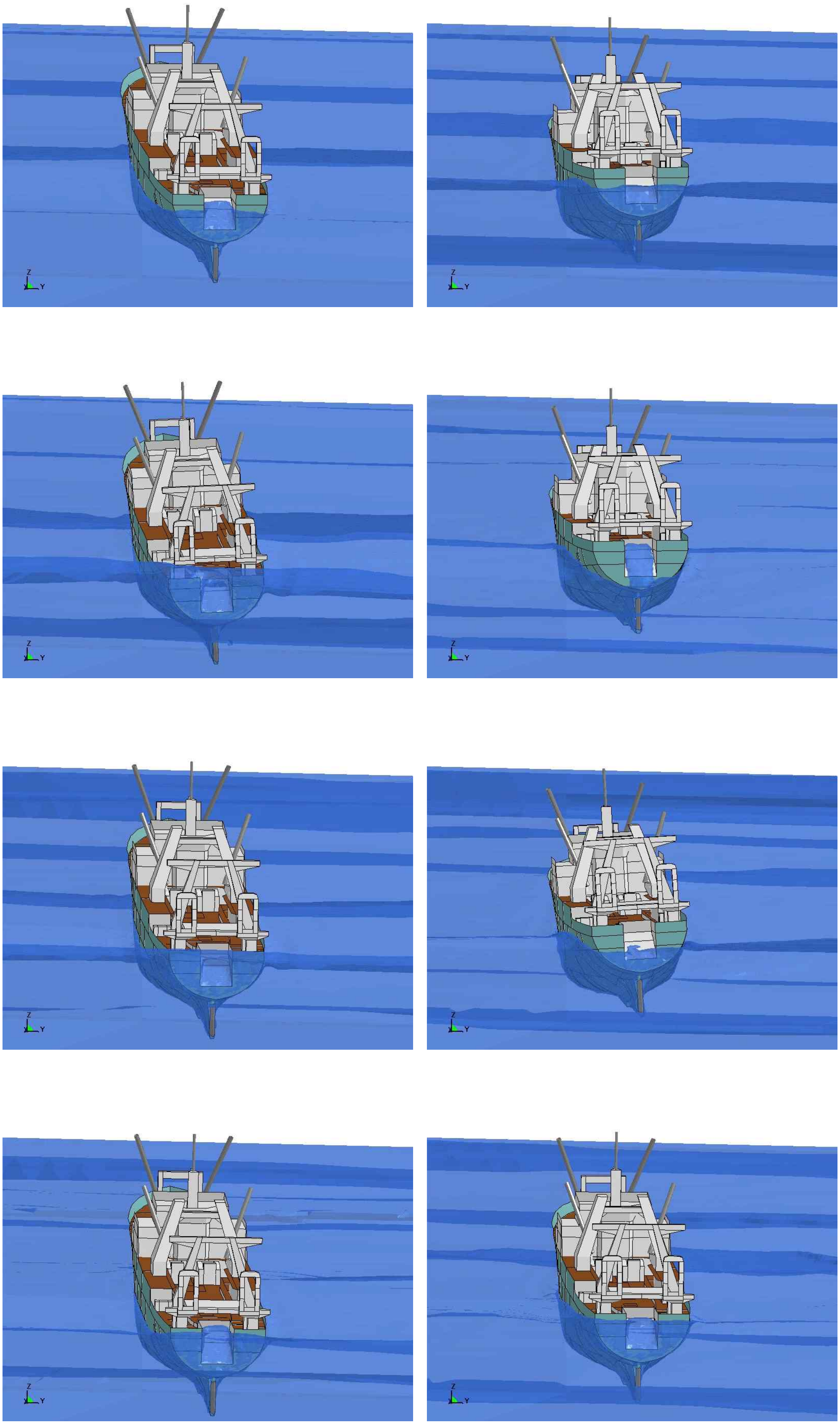
observed from stern

4.3.4.3 In Case 1-0 (presuming a different situation to that of Case 1-1, receiving waves with starboard bow at a 20° angle), it is presumed that a significant amount of seawater has entered the fish bunker while releasing the catch of fish. In addition, it is presumed that the vessel had set sail with no hull incline after changing its course without a fully closed hatch cover, while receiving waves with starboard bow at an a 20° angle. There was no increase in the inflow of seawater except the 80 tons that were poured into the fish bunker along with the catch of fish.



[Image 35] Direction of waves in Case 1-0

4.3.4.4 According to the simulation result of Case 1-0, despite the small angles of pitching and rolling, waves did not swell over the upper deck and no additional seawater flowed through the hatch cover or the sewage discharge outlet. The results are as shown in Image 35-1.

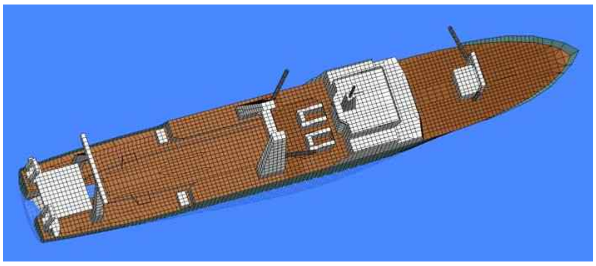


[Image 35-1] Movement in Case 1-0
(waves, starboard bow 0°) observed at stern

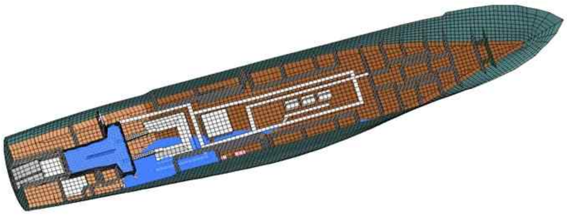
4.3.4.5 From the results of the simulation, it could be confirmed that if the vessel had turned its position so that the bow faced the waves before pouring the catch of fish through the open hatch cover of the fish bunker, as in case 1-0, the casualty would not have taken place, as waves would not have swelled over the upper deck.

4.3.4.6 Furthermore, even if water had continued to flow in through the hatch cover after it set sail, the vessel could have been turned so the bow faces the waves, which would have prevented waves from swelling over the upper deck. Then, after closing the hatch cover properly with sufficient time, the ship could have continued to get underway by resetting the course. In this case, the casualty would not have taken place.

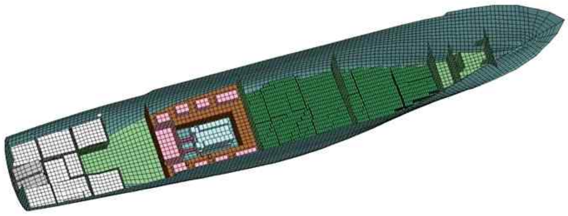
4.3.4.7 In Case 1-2 (starboard incline by 20° due to transverse waves at port), waves are crashing into port stern at 20° and 290 tons of seawater have flowed in through the hatch cover and the sewage discharge outlet. This has caused the hull to tilt to starboard by 20° as the water starts to flood the fish processing room and the steering room.



(a) Overall View of the Ship



(b) Fish Processing Room



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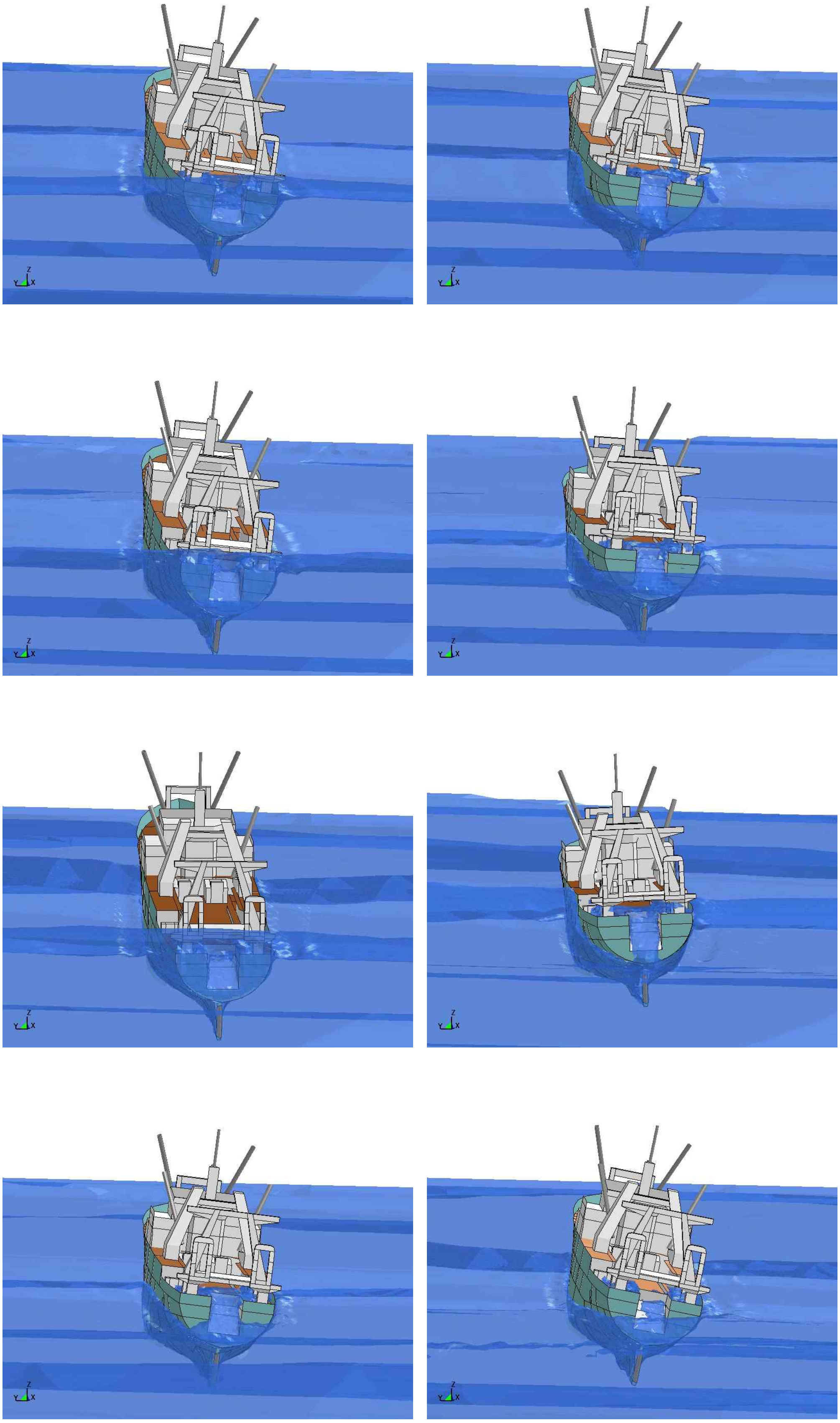
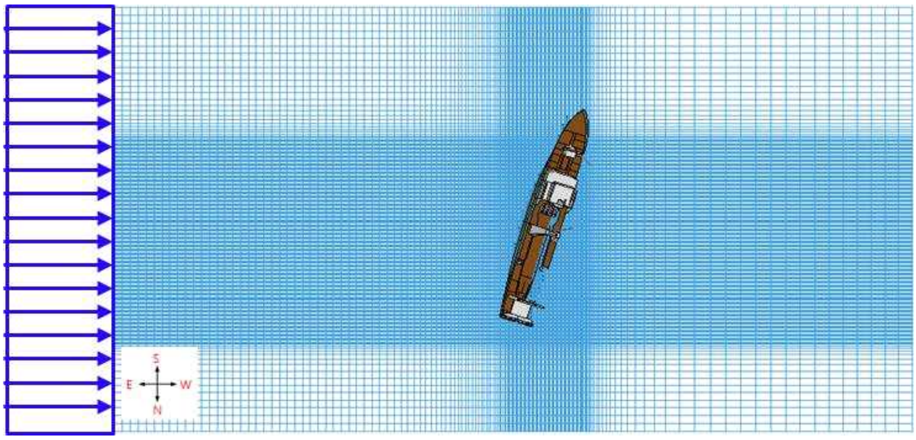
[Image 36] Status of seawater inflow in Case 1-2

4.3.4.8 The continuous inflow of seawater and the large incline towards starboard caused part of the starboard stern to sink from due to the pitching and rolling of the vessel. As a large amount of water flowed into the steering room, 70% of the steering room gets flooded and the rudder stops at hard port.



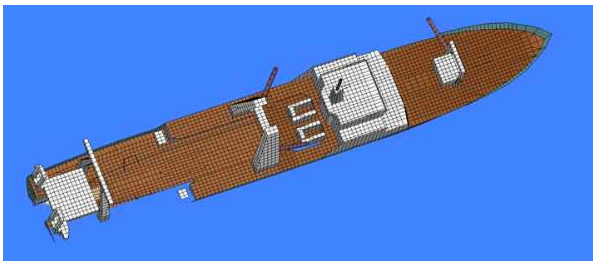
[Image 36-1] Movement in Case 1-2 (waves, port stern 20°) observed from stern

4.3.4.9 In Case 1-3 (rudder out of control, starboard incline by 25-30°), the in operable status of the rudder in Case 1-2 continued and as the hull was hit by waves from the stern port side at a 72.5° angle, the hull tilted significantly starboard and the slope increased to 25-30°.

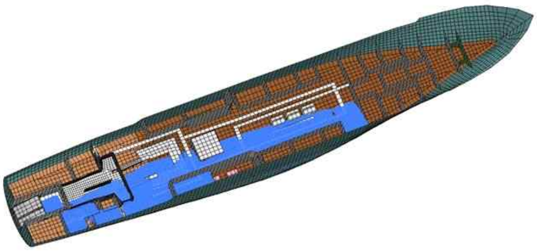


[Image 37] Direction of waves in Case 1-3

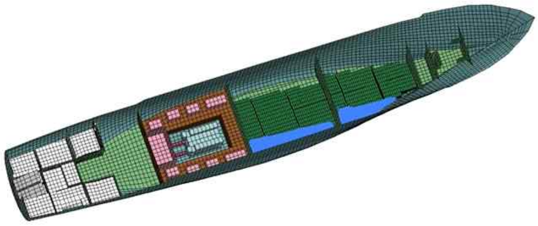
4.3.4.10 With the hull tilted 25° to starboard, waves rolled into the port stern at an angle of 72.5°, which caused seawater amounting to 471 tons to continue flowing in through the hatch cover and the sewage discharge outlet. The seawater flowed into fish holds 1 and 2 and filled up the lower part (6% of the entire area) of the fish hold.



(a) Overall View of the Ship

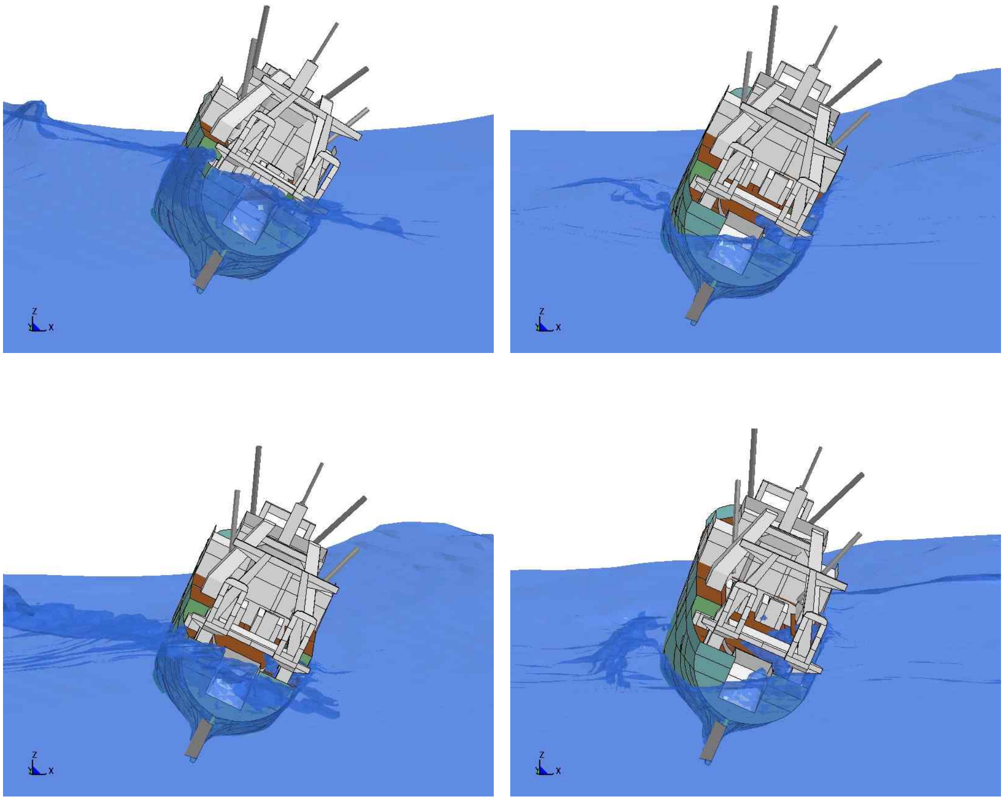


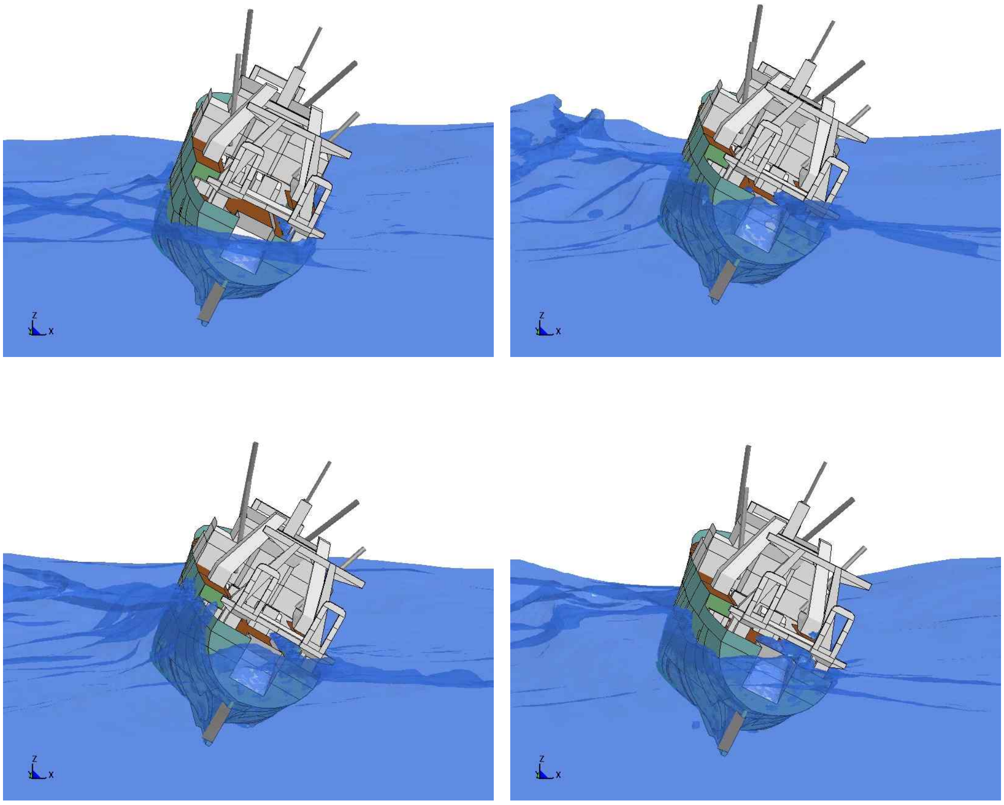
(b) Fish Processing Room



© Engine Room and Fish Hold

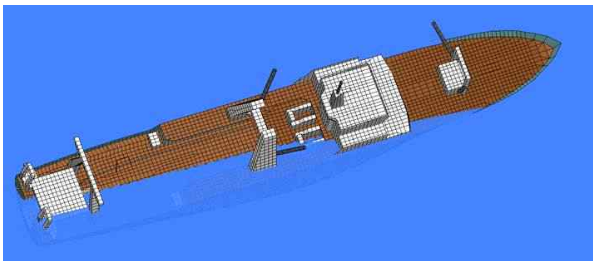
[Image 37-1] Status of Seawater Inflow in Case 1-3



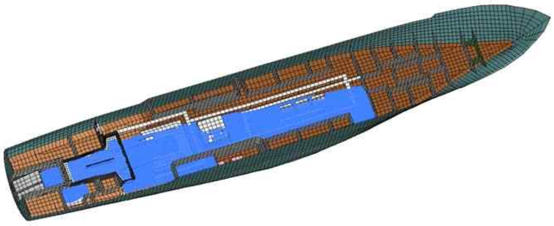


[Image 37-2] Movement in Case 1-3 (starboard incline 30°) observed at stern

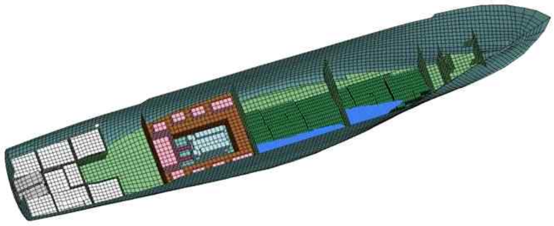
4.3.4.11 Case 1-4 (stopped at starboard incline of 35°) is a continuation of Case 1-3, where the stern port is being hit by waves at an angle of 72.5° and the hull is tilted starboard by 35°. Although the seawater inflow amounts to 588 tons, the use of 2 pumps on board prevented the hull from further tilting starboard.



(a) Overall View of the Ship



(b) Fish Processing Room



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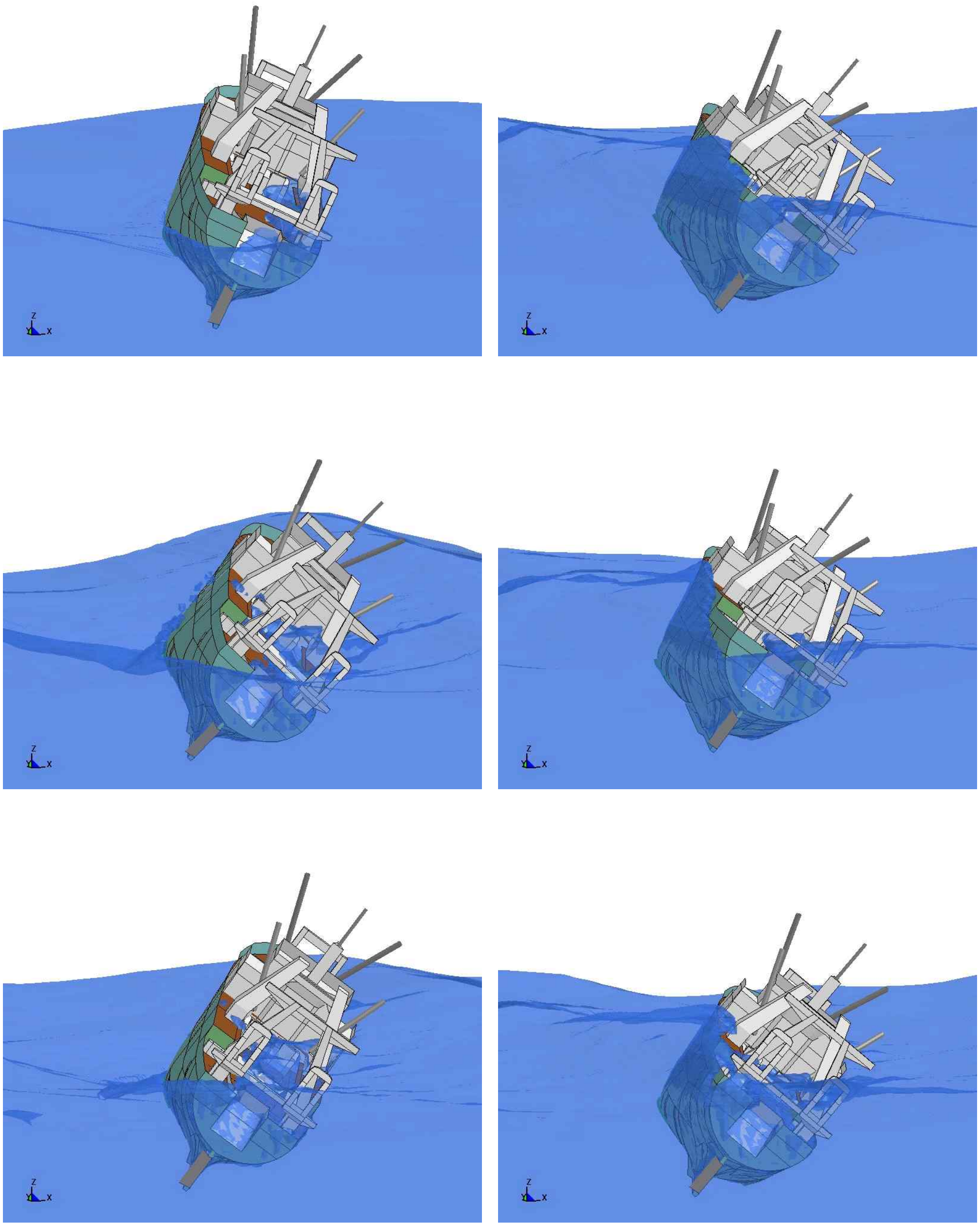
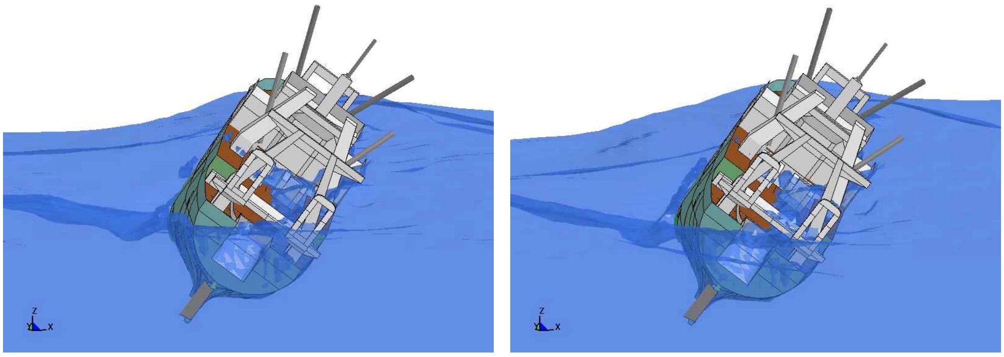
[Image 38] Status of seawater inflow in Case 1-4

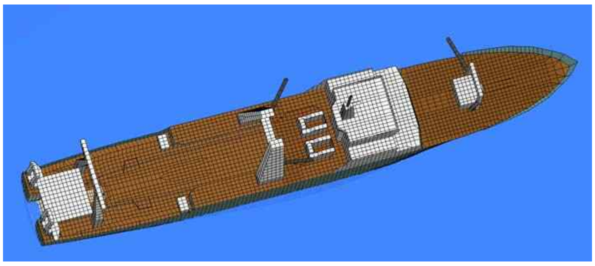




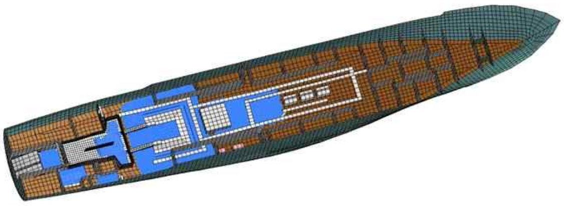
[Image 38-1] Movement in Case 1-4 observed at stern

4.3.4.12 In Case 2-0 (temporary equilibrium in transverse waves at port due to transfer of load to port side), about 30 tons of fish in the fish hold and about 48 tons of fuel have been transferred from starboard to port when the hull inclined to starboard greatly from Case 1-4.

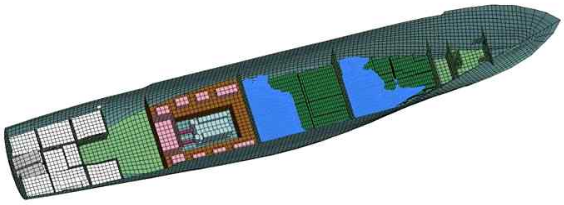
4.3.4.13 By continuing to pump out water while transferring fish and fuel load, the crew managed to discharge a significant amount of seawater in the fish processing room. The amount of water decreased to about 225 tons, and the vessel maintained its equilibrium temporarily while the port stern faced waves at a 72.5° angle. Then, as the amount of water increased to 273 tons due to a continuous inflow through the sewage discharge outlet at port side, the vessel began to tilt to starboard by about 5°.



(a) Overall View of the Ship



(b) Fish Processing Room



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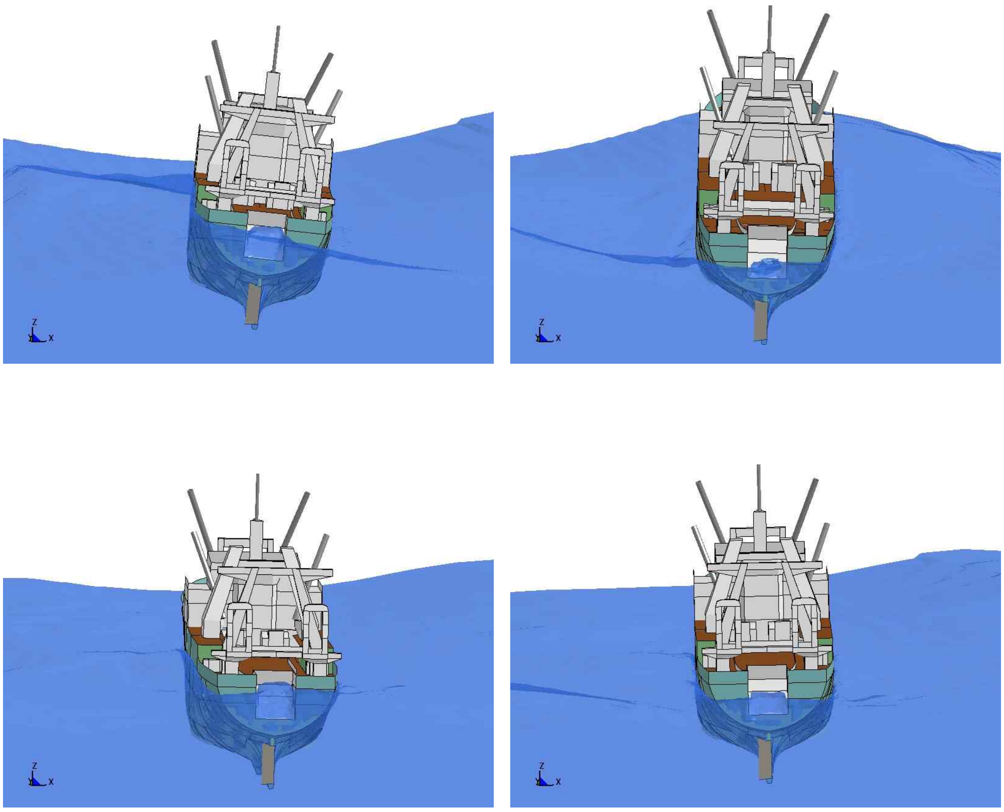
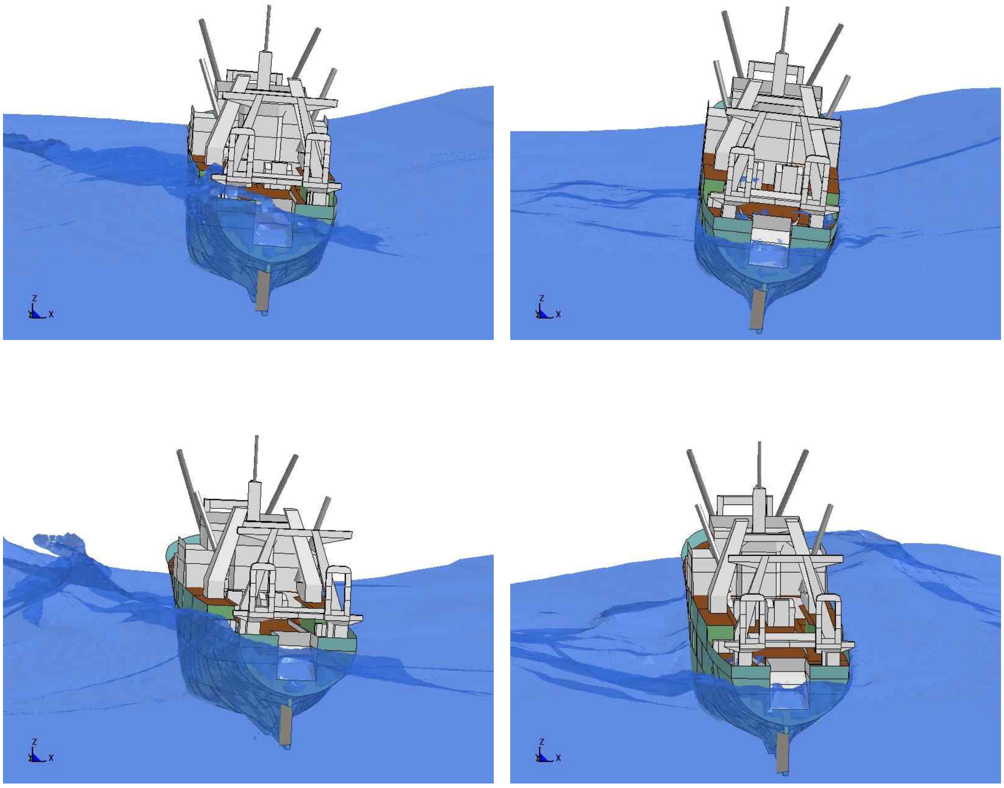
[Image 39] Status of seawater inflow in Case 2-0

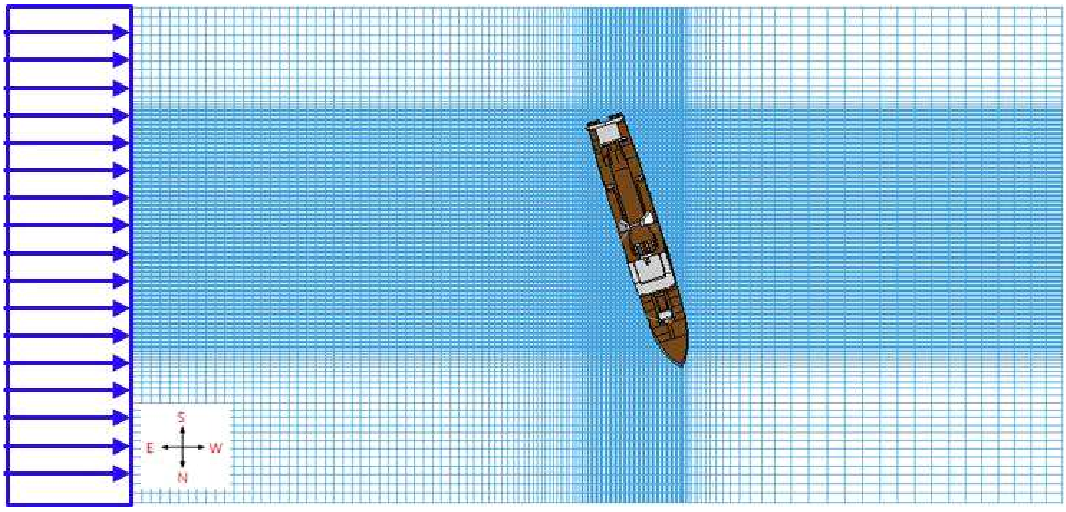




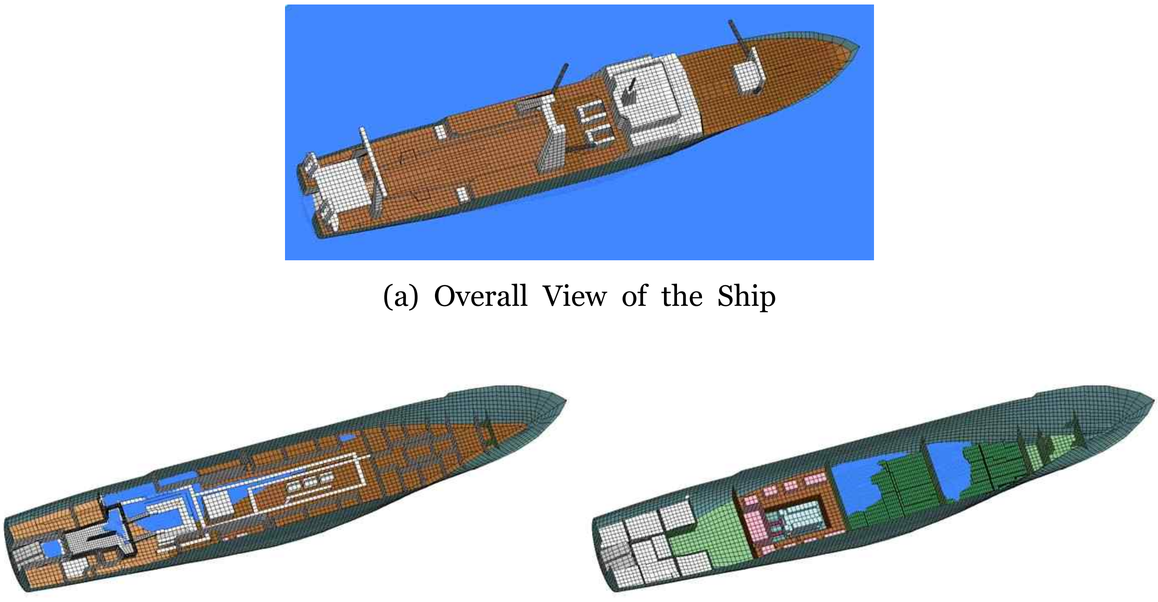
[Image 39-1] Movement in Case 2-0 observed at stern

4.3.4.14 In Case 2-1 (port incline of 10° in transverse waves at starboard after transferring weight to port side), the vessel temporarily maintained its equilibrium but when water continued to flow in through the sewage discharge outlet at port due to waves hitting the port side, the boat was turned so that the starboard faces the waves in an attempt to reduce the amount of inflow into the vessel by using the engine only as the rudder was stopped. As in Image 40, when the vessel receives winds at starboard stern from an angle of 72.5°, the vessel tilts to port by 10° and the inflow of seawater amounts to 358 tons. [37)]

37) In practice, when the port incline worsened by turning the vessel to make the starboard face the waves, the vessel was turned again to causing the waves hit



[Image 40] Direction of waves in Case 2-1

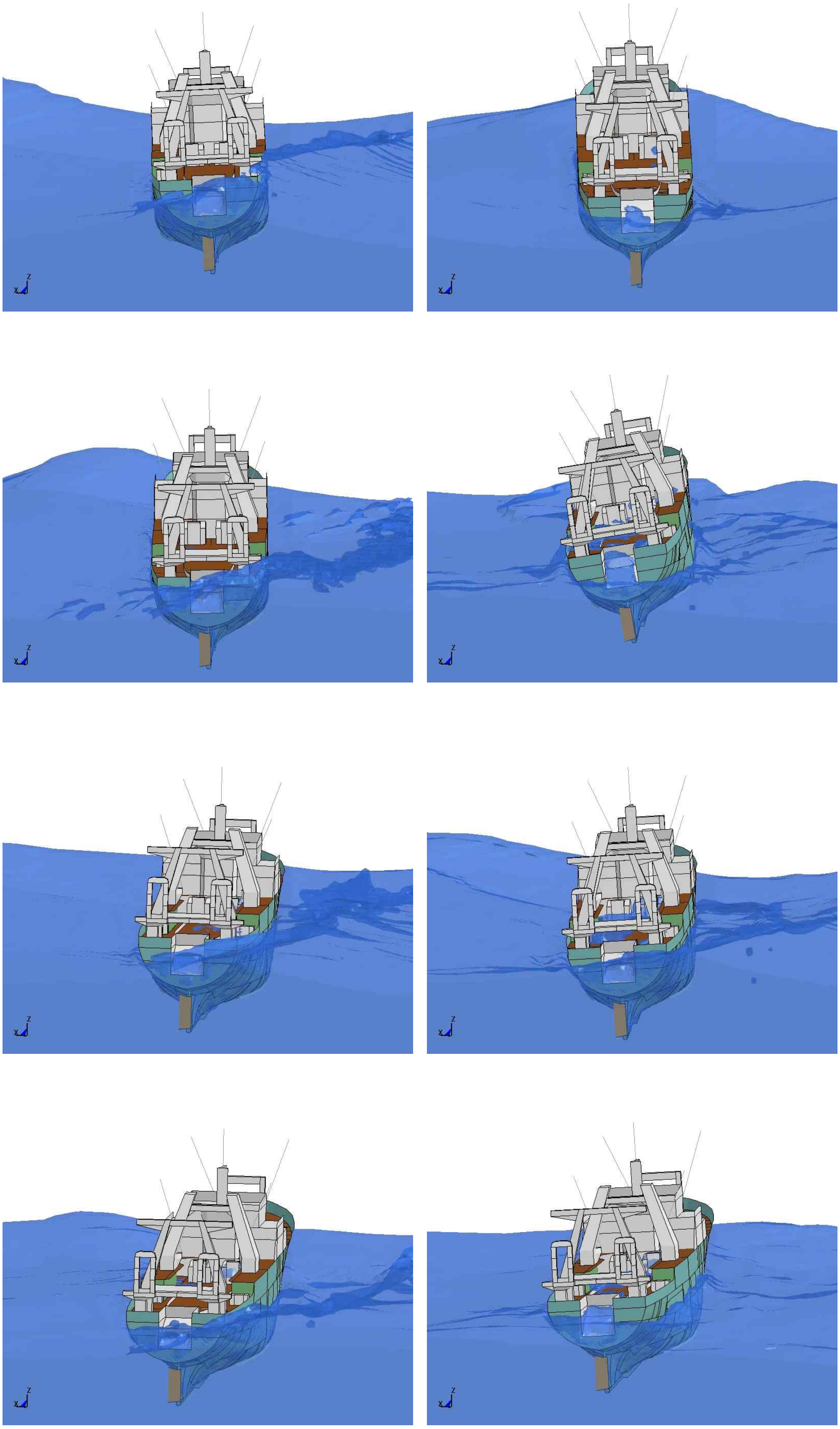


(a) Overall View of the Ship

(b) Fish Processing Room   © Engine Room and Fish Hold

[Image 40-1] Status of Seawater Inflow in Case 2-1

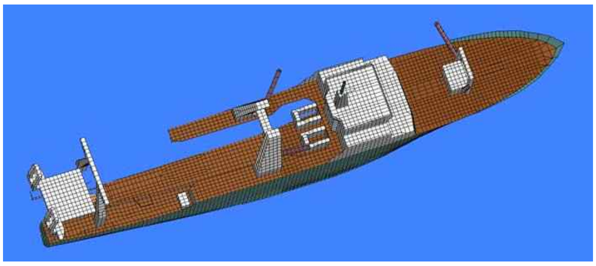
the port. But as the situation worsened, the vessel was turned once more to making the waves hit the starboard side.



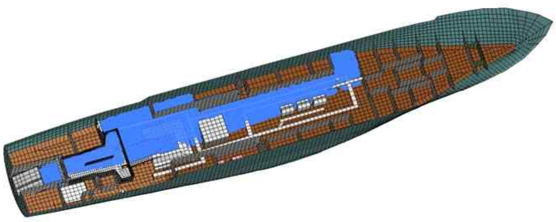
[Image 40-2] Movement in Case 2-1 observed at stern

4.3.4.15 In case 2-2 (continuous inflow of seawater, stern sinking, port incline of 30-35°), a large amount of water continuously flowed into the vessel, with waves rolling into starboard at an angle of 72.5°, and caused the hull to tilt steeply towards port by 30-35°.

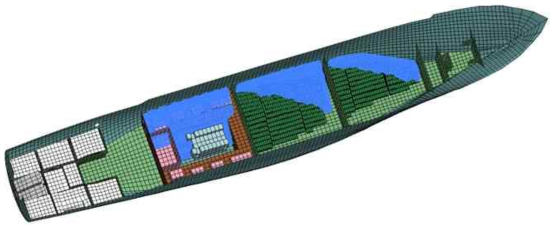
4.3.4.16 In particular, as the port stern periodically sank underwater, the inflow of seawater through the sewage discharge outlet at port greatly increased, and the port inflow angle became larger. The amount of water on board reached 723 tons and water seeped into the engine room as well.



(a) Overall View of the Ship



(b) Fish Processing Room



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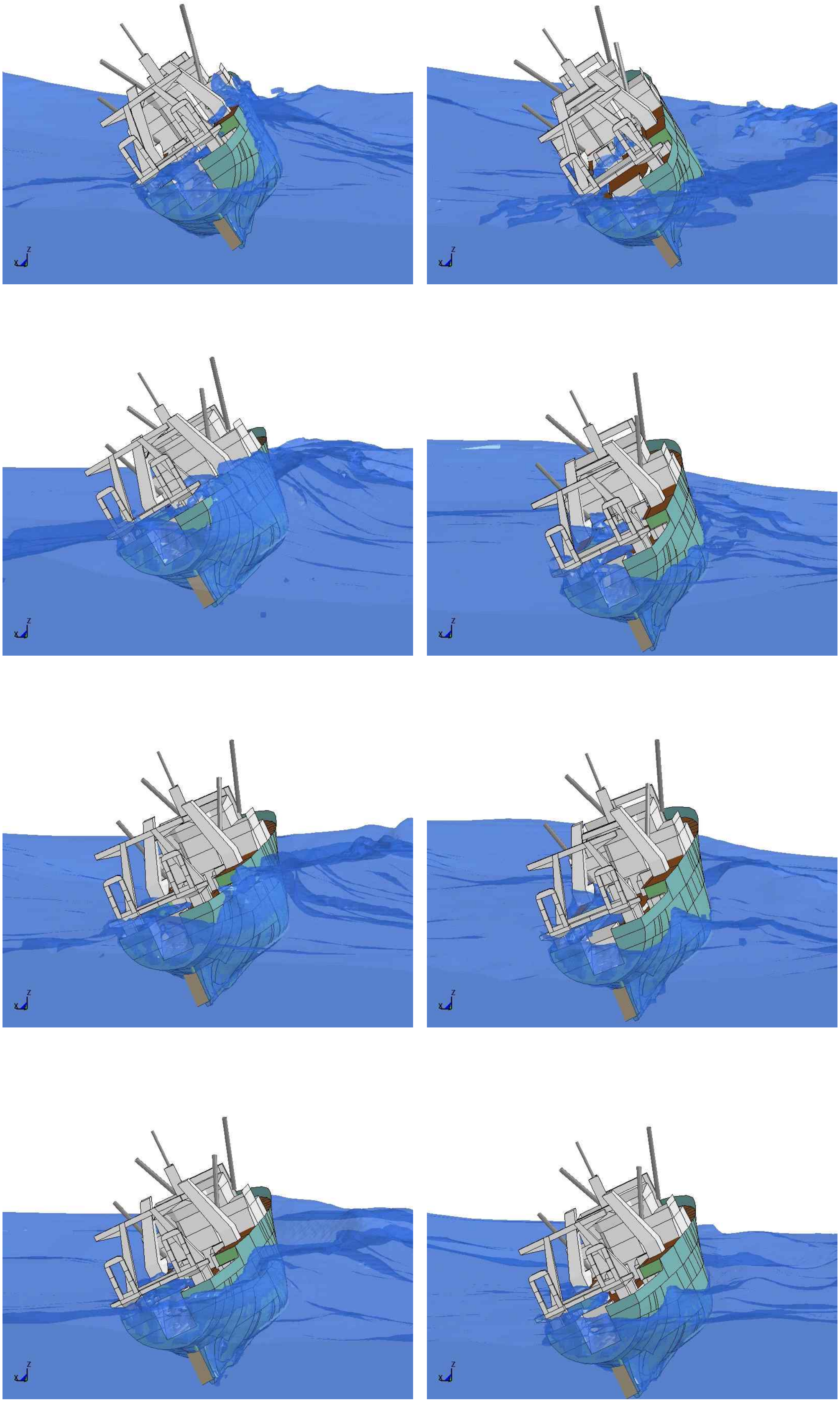
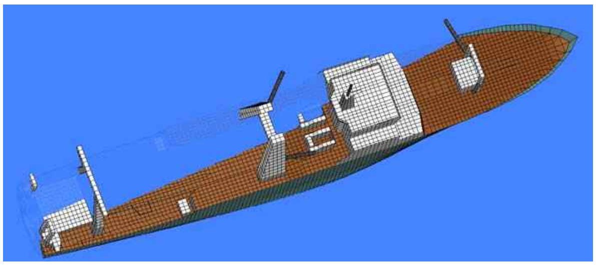
[Image 41] Status of seawater inflow in Case 2-2



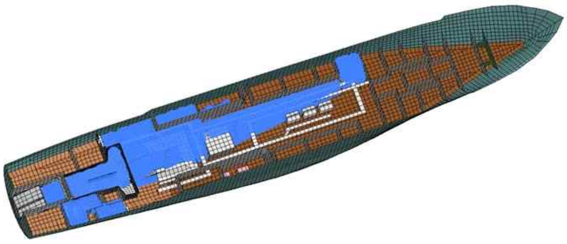
[Image 41-1] Movement in Case 2-2 observed at stern

4.3.4.17 In Case 2-3 (stern sinking accelerates, port incline of 45-50°), waves continue to strike the starboard side at an angle of 72.5°. As the inflow of seawater increases, the hull steeply tilts to port by more than 45°. With water flowing into the engine room and the fish hold, the stern of the vessel continues to sink.

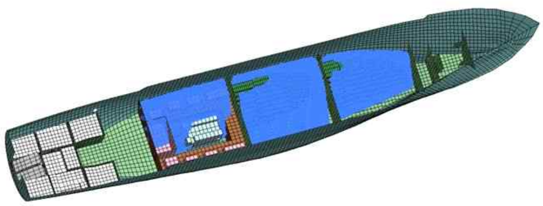
4.3.4.18 At the time, as a result of the increase in inflow of seawater in the engine room, about 67% of the engine room was flooded and the engine stopped. The overall inflow of seawater amounted to 1,056 tons.



(a) Overall View of the Ship

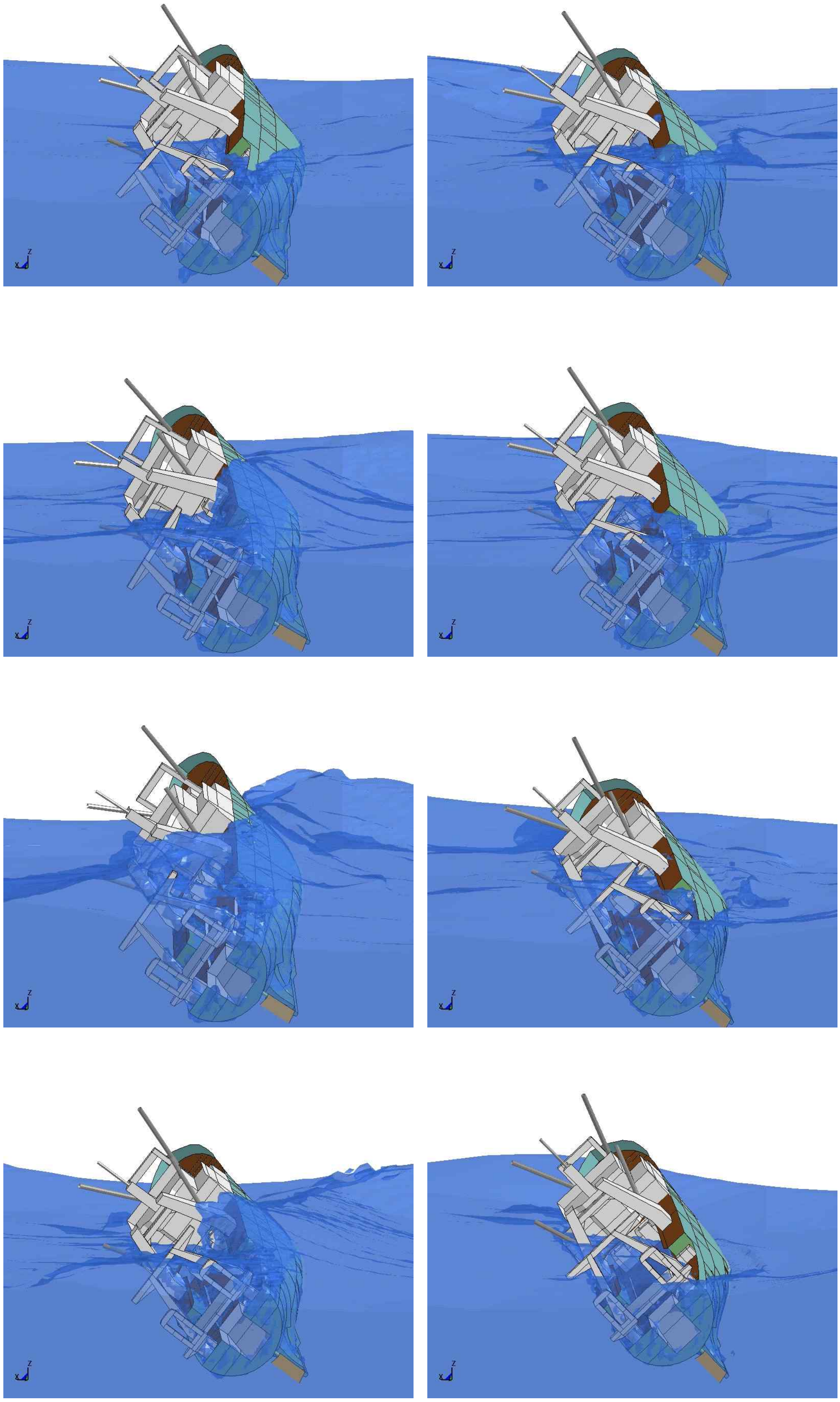


(b) Fish Processing Room



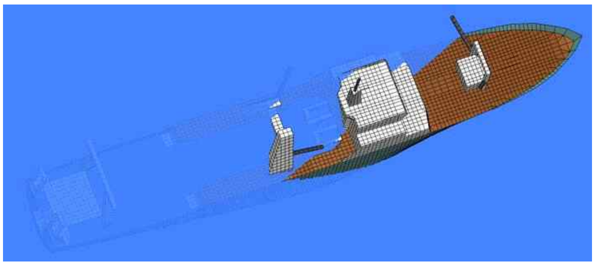
c) Engine Room and Fish Hold

[Image 42] Status of seawater inflow in Case 2-3

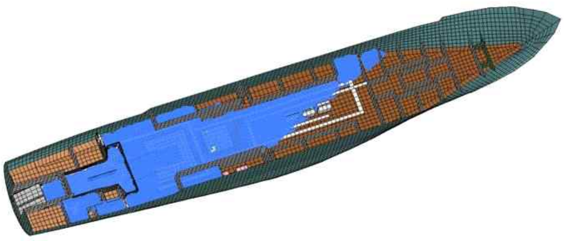


[Image 42-1] Movement in Case 2-3 observed at stern

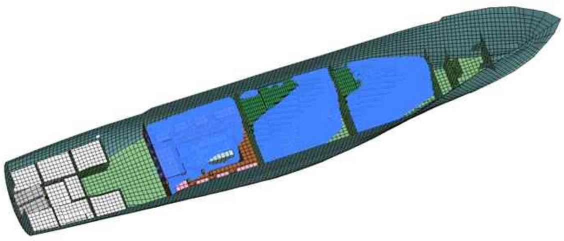
4.3.4.19 In Case 2-4 (sinking from stern, port incline greater than 65°), with waves continuing to roll into the starboard side at an angle of 72.5°, it was verified that water was flowing in through various openings of the vessel. As the vessel tilted to port by more than 65°, it lost buoyancy. The vessel steadily sank from stern, and the amount of inflow into the vessel amounted to 1,540 tons.



(a) Overall View of the Ship



(b) Fish Processing Room



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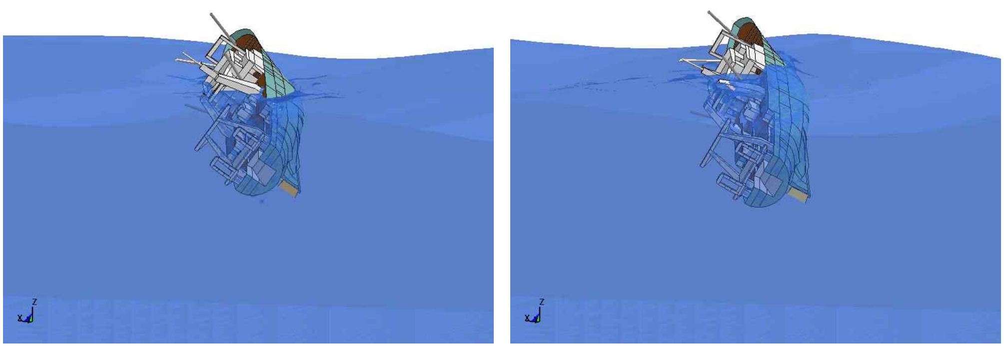
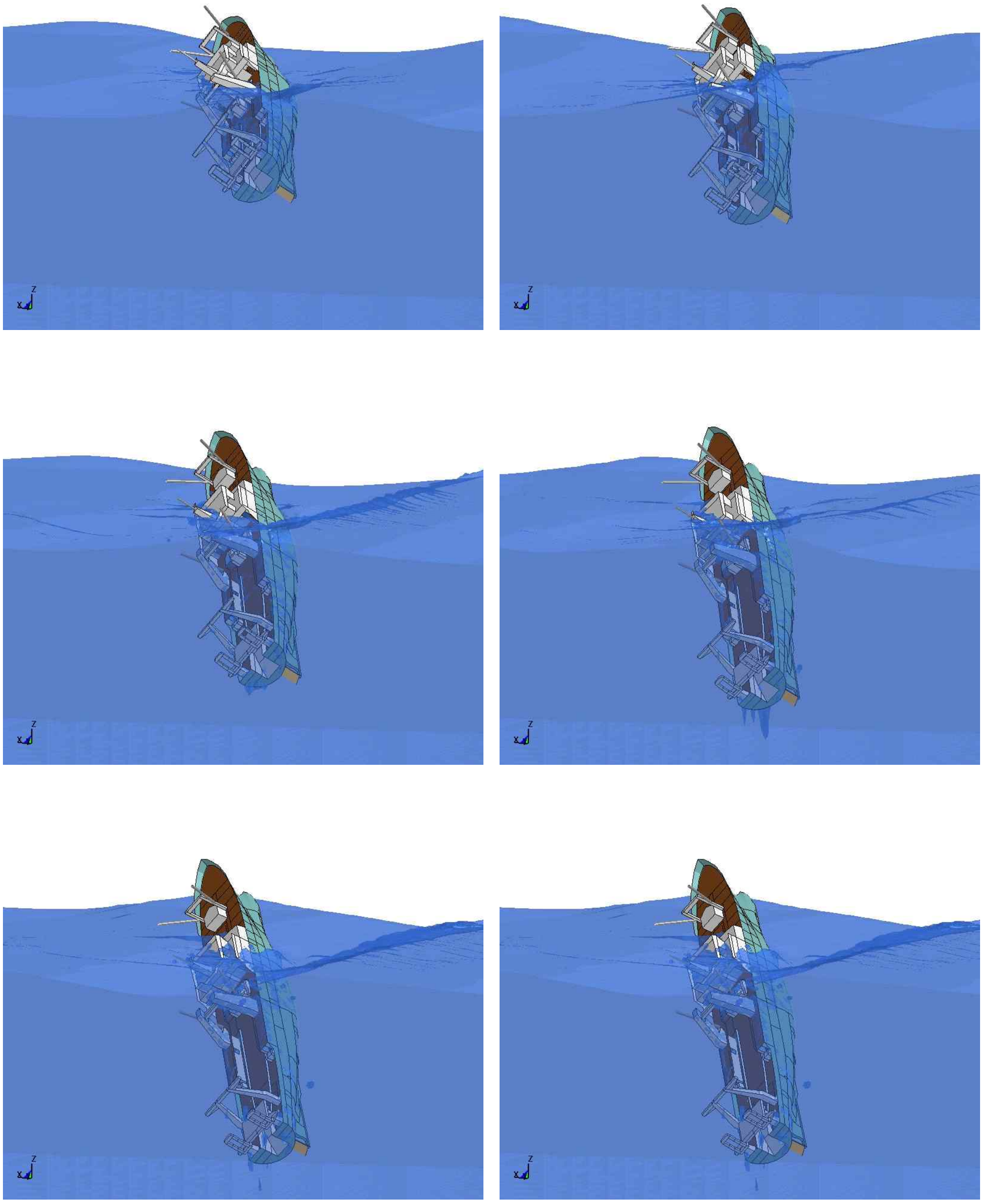
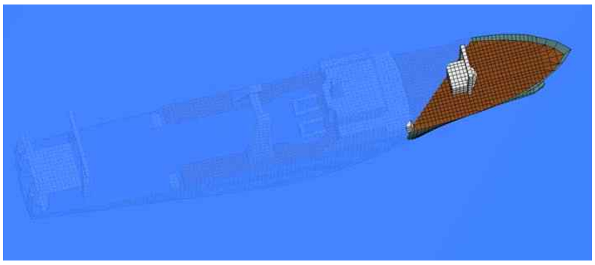
[Image 43] Status of seawater inflow in Case 2-4



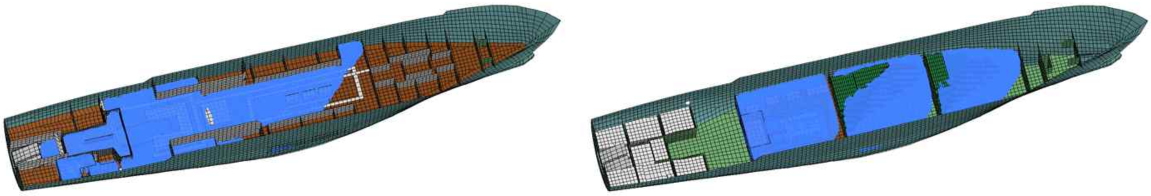


[Image 43-1] Movement in Case 2-4 observed at stern

4.3.4.20 In Case 2-5 (complete sinking, port incline of more than 80°), with waves continuing to crash into the starboard at an angle of 72.5°, the continuous inflow of seawater increased the transverse slope towards port by more than 80°, and the sinking accelerated. The amount of seawater in the vessel reached 1,910 tons.

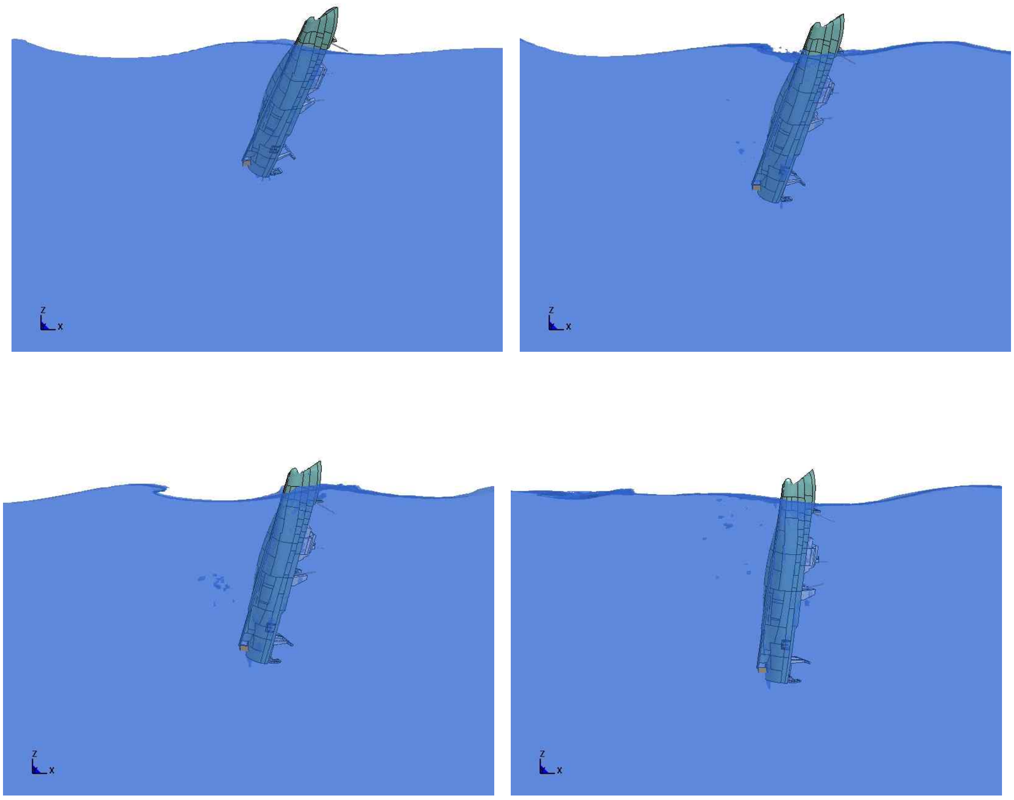


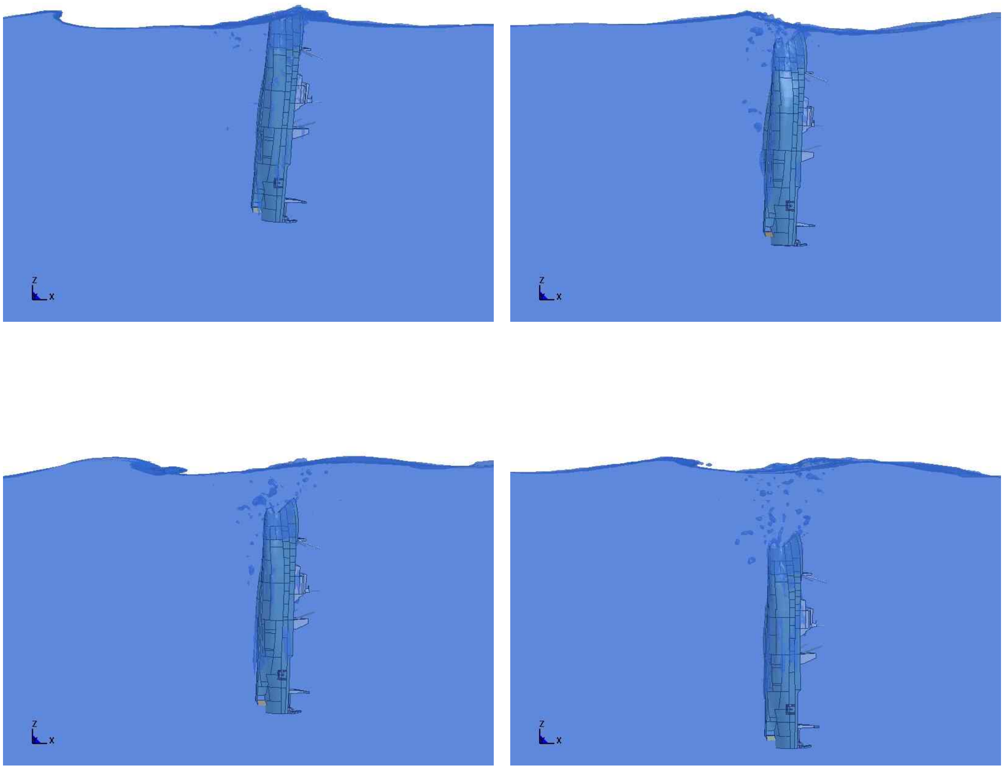
(a) Overall View of the Ship



(b) Fish Processing Room © Engine Room and Fish Hold

[Image 44] Status of seawater inflow in Case 2-5





[Image 44-1] Movement in Case 2-5 observed at port

4.3.5 Sub-conclusion

4.3.5.1 The simulation provides a multi-dimensional view for understanding the the entire process of the vessel's sinking starting from when the large amount of seawater poured into the fish bunker along with the catch of fish to when the vessel sank from stern.

4.3.5.2 Furthermore, after comparing the entire process of the simulation with testimonies of surviving crew members (including inspector) and nearby vessels that came into radio contact with 501 Oryong, it was confirmed that the results of the simulation generally matched the investigation conducted by the Special Investigation Team.

4.3.5.3 Through the simulation, it was confirmed that the casualty was triggered when the vessel continued its fishing operations in bad weather. In addition, releasing the catch of fish in the fish bunker while being hit by waves at stern and transferring the fuel and fish in the fish hold to port in order to restore balance when the vessel tilted starboard with a hatch cover that did not get fully closed and a broken rudder were major contributing factors.

4.3.5.4 Furthermore, the fact that the vessel turned to the other side to face waves from starboard to prevent further inflow of seawater into the sewage discharge outlet at port increased the inflow of seawater and exacerbated the hull incline. These factors were all found to have been the main factors leading to the sinking of 501 Oryong.

4.4 Human Factors

4.4.1 Insufficient Safety Management System

4.4.1.1 After departure, the chief officer of 501 Oryong held one training session for all crew members covering the use of fire extinguishers and life jackets, but did not execute any fire control or ship abandonment training.

4.4.1.2 Furthermore, the safety management checklist was completed during fishing and sent to Trawl Team 2 at the main office every Friday since departure, but it did not carry out any safety training specific to different casualty situations.

4.4.1.3 Although the vessel must conduct emergency response drills such as fire control training and life raft training more than once a month after departure in accordance with the Seafarers Act, such basic training was never implemented. So even when the crew faced a situation requiring ship abandonment, they were not aware of their duties or which positions to man.

4.4.1.4 Although the vessel sent the safety management checklist that includes emergency drills, the department that received the checklist was mainly in charge of managing catch, which is irrelevant to safety management. Thus, verification of safety management of the vessel barely took place.

4.4.1.5 Furthermore, while various safety management regulations including safety management for fishing in bad weather are available on board, all safety management was executed at the personal command of the captain without referencing a checklist based on the situation manual.

4.4.1.6 Although the vessel is not a liner, it carries as many crew as a liner. As it does not stop at port for a long time, it is very important to develop and comply with safety management guidelines on board to prevent safety casualties.

4.4.1.7 As a result, the state of safety management on the vessel in which safety protocols had been neglected both by the company and on the vessel, including the lack of execution of emergency drills, is assessed to have had a significant impact in causing the large number of casualties in this casualty.

4.4.2 Duty Shifts of Crew

4.4.2.1 On 501 Oryong, crew duty was often conducted in two shifts with the captain and the 3rd officer as a pair, and the chief officer and the 2nd officer as a pair charged with directing the setting and drawing of the net. As for the engineering department, the chief engineer and an engineer were a pair and the no.1 oiler and officer in charge of freezing fish were a pair in conducting the two-shift duty. Five foreign crew members performed the duties of the engineering department.

4.4.2.2 There were about 30 people in the processing room of the vessel. They were divided into three groups who rotated shifts comprising of 12 hours of work and 6 hours of rest. The shifts rotated at 06:00 and 18:00, led by the Korean and Indonesian officers in charge of processing fish.

4.4.2.3 This means that crew on shipboard duty worked in 2 shifts for 12 hours at a time. They worked for a day and 12 hours and rested for 12 hours. Workers in the processing room were on duty for a day and 16 hours and rested for 8 hours.

4.4.2.4 In considering such working hours, it would have been realistically difficult to allocate separate times to conduct emergency drills. It is assessed that safety management would have been difficult due to various factors such as frequent changes in operation schedule following various factors such as the formation of schools of fish.

4.4.2.5 Therefore, if such a work rotation method had continued for more than a few months, all crew, including on deck and in the processing room, would have been greatly fatigued. In particular, it would have been very difficult for main marine technicians, including the captain, to take rest.

4.4.3 Absence of Marine Technician

4.4.3.1 With gross tonnage of 1,753 tons and main engine output of 3,238 kilowatts (two 1,619 kilowatt engines), 501 Oryong is required to have 4 deck officers, 4 engineer officers, and 1 radio officer with qualifications in accordance with the minimum safe manning standards related to Article 22 (1) of the Enforcement Decree of the Ship Personnel Act on board.

4.4.3.2 However, of the deck officers on board, only the chief officer and 3rd officer were qualified, and the captain and 2nd officer did not meet the qualifications. Of the engineering officers, the chief engineer and 1st engineer did not meet qualifications, and 2nd and 3rd engineers were not on board. Also, the radio officer was not on board.

4.4.3.3 The presence of qualified officers on board is essential to secure the seaworthiness of the vessel. Because this vessel had less than the appropriate number of qualified crew on board, it can be said that the vessel's operational capacity was significantly undermined in terms of seaworthiness.

4.4.3.4 Although the ability to the command crew on board cannot be judged based on qualifications alone, possession of an officers' licence is appropriate in ascertaining a person's vessel management ability, including their navigation skills.

4.4.3.5 Among many crew members, in the case of the captain, a person with a 3rd class officer license was chosen to board the vessel although someone with a 2nd class officer license was needed. The inappropriateness of this particular decision is deemed to be incomparably more detrimental than the choice to board crew without the proper credentials in other positions aboard the vessel.

4.4.3.6 Although it is possible to obtain the 3rd class officer license with a written test alone, the 2nd class officer license requires an interview as well. In looking at the difference in procedure for obtaining the license alone, it can be determined that the required qualifications are drastically different. In particular, one's understanding of stability is often tested in the interview.

4.4.3.7 The role of the captain is very important at sea because it involves not only navigation, but also concerns authority in judicial matters. In particular, for fishing vessels like 501 Oryong, this is more so because all operations take place in a special situation where on-land assistance is not available extended periods, within a culture based on a strict chain of command.

4.4.3.8 The fact that two engineer officers were unqualified and two engineer officers were not on board strongly implies that various machinery, including the main engine, may not have been properly maintained.

4.4.3.9 There was many machinery on the vessel, including the main engine, and an officer is assigned to be in charge of each of them. The manning standard of engineer officers was enacted after taking this into consideration.

4.4.3.10 The absence of two engineer officers could mean that the other engineer officers on board had been burdened with additional work or that appropriate maintenance of machinery did not take place.

4.4.3.11 Many occurrences such as the malfunction of the rudder and its inoperability, the defective facsimile, and lack of action following the detachment of the sewage discharge outlet shutter serve as evidence.

4.4.3.12 In conclusion, the absence of crew members with appropriate qualifications is assessed to have had a large indirect impact in causing the casualty.

4.4.4 Inappropriate Management by the Captain (by Stage of Casualty)

4.4.4.1 Decision on Fishing Operation

4.4.4.1.1 From 00:00 to 01:00 on December 1, 2014, the day of the casualty, the captain of 501 Oryong took some rest after drinking a bottle of soju with an electrician. From 05:00 of the same day, he instructed the net to be set.

4.4.4.1.2 Although weather conditions were not inappropriate for operation when setting the net, bad weather was forecasted. However, the captain could not analyze the climate chart directly as the weather facsimile was broken.

4.4.4.1.3 At around 07:30 on the same day, the vessel was advised by Oyang 96 that “it would be best to make the decision to get underway quickly as the weather is worsening.” It started to haul in the net from 11:00 of the same day.

4.4.4.1.4 It can be inferred from a comprehensive understanding of the situation that the captain of 501 Oryong had not been fully aware of the weather conditions before operation that day, and because he had only slept a few hours, he would not have been able to recover from his fatigue.

4.4.4.1.5 In considering that Zaliv Zabiyaka, Carolina 77, and Oyang 96 all undertook operation nearby, it cannot be said that the decision to fish on that day was inappropriate. However, because of his lack of understanding of climate conditions, on an unstable vessel, he was not able to haul in the net on time and this is assessed to have prevented the vessel from getting underway in a timely manner.

4.4.4.2 The Impact of Fatigue on the Captain's Decision-Making Abilities

4.4.4.2.1 In general, fatigue refers to reduced[38] performance capacity, and the International Maritime Organization (IMO) defines it as a reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength; speed; reaction time; coordination; decision making; or balance.

4.4.4.2.2 In addition, to enhance the overall understanding of fatigue and

38) IMO, MSC/Circ. 813

prevent it, a fatigue guideline which proposes the definition, causes, and impacts of fatigue was developed. It is also written in Rule 8/1, Article 8 of the STWC Convention that each office of authorities should stipulate the rest time of crew in order to relieve crew fatigue. More specifically, the rest time is written in Code A and B of the STWC Convention.

4.4.4.2.3 An example of an casualty that took place as a direct impact of crew fatigue is that of Exxon Valdez, which struck a reef while crossing Prince William Sound after departing from the port of Valdez[39] in 1989.

4.4.4.2.4 While the inebriated captain's absence in the steering room was also a cause, the direct cause of the casualty was that the 3rd officer was not veer the vessel on time, due to lack of sleep resulting in the vessel leaving its course.

4.4.4.2.5 In the case of the captain of 501 Oryong, the captain had maintained a working schedule that inevitably increased fatigue for an extended period of time from July 22nd, when the vessel arrived at the fishing ground, to the day of the casualty. In particular, as he had consumed alcohol and did not get enough sleep, he was undertaking operations and commanded the crew while greatly fatigued.

39) Introduction to Maritime Human Factors, Kim Hong-Tae, page 11: the main cause of the Exxon Valdez accident is stated to be lack of sleep.

4.4.4.2.6 Considering that the captain failed to respond appropriately in urgent situations at each stage of the casualty, it is assessed that the captain was not able to perform normal decision-making due to accumulation of fatigue.

4.4.4.3 Decision to Turn the Bow When Hauling the Net

4.4.4.3.1 In general, when weather conditions are moderate, stern trawlers like 501 Oryong haul in the net with the stern upwind, lift the net on deck, and release the catch of fish into the fish bunker.

4.4.4.3.2 However, when there are large rolling waves as was during this casualty, the bow needs to point windward so that waves cannot swell onto the deck. Then, the net has to be hauled in and the catch of fish be poured into the fish bunker.

4.4.4.3.3 That way, any inflow of seawater into the fish bunker can be prevented when the hatch cover is opened. However, the captain opened the fish bunker hatch cover with the stern pointing upwind, and as a result, a large wind rolled over the stern and flowed into the vessel through the hatch cover.

4.4.4.4 Opening the Fish Bunker Hatch Cover

4.4.4.4.1 The fish bunker of the vessel is a flap-type that opens towards the lower deck from the upper deck. When there is seawater on the upper deck, it is very likely that the seawater flows into this opening along with the catch of fish.

4.4.4.4.2 Therefore, while it is easy to stock the catch in the vessel through the open hatch cover, it is also very likely that seawater flows into the vessel should waves swell onto the deck.

4.4.4.4.3 If the captain had been aware of such characteristics of the fish bunker hatch cover, the hatch cover should have been opened while avoiding a situation where waves swell onto the deck.

4.4.4.5 Operation to Restore Balance by Transferring Cargo

4.4.4.5.1 The vessel is designed so that there is no left or right transverse[40] incline in a light load state. In addition, load including fuel, cargo, and freshwater are stored in a way that longitudinally and transversely balances the vessel so as to prevent any transverse incline. However, depending on the load status of the vessel, there may temporarily be a transverse incline.

4.4.4.5.2 When the vessel experiences an excessive transverse incline, it not only has an adverse effect on stability but can also be problematic for the operation of various instruments, making it difficult for crew to carry out their duties. Therefore, much care is put into storing various load in the vessel to prevent the vessel from tilting.

40) The state at which no load, such as fuel, cargo, and freshwater are on board. The deadweight tonnage is calculated by subtracting the light load displacement from full load displacement.

4.4.4.5.3 When an excessive transverse incline does take place, measures to restore it must be taken. In the case of liners or commercial ships, topside ballast tanks with higher gravitational center are used to adjust the transverse incline with some ballast water.

4.4.4.5.4 However, fishing vessels like 501 Oryong do not have topside ballast tanks where the gravitational center is high, so they use the fuel in fuel tanks where the gravitational center is low to adjust the transverse incline. In the case of 501 Oryong, the fuel in fuel tanks were used to adjust any transverse incline.

4.4.4.5.5 Tanks that store various fuel oil such as the fuel tank are divided into many compartments. This seems to help reduce the free surface effect of fluids, and for this reason, it is difficult to say that the attempt to adjust the transverse incline by transferring fuel, in itself, is an excessive measure.

4.4.4.5.6 In the case of this casualty, the vessel had on board 608 kiloliters of fuel, which amounts to 92% of its total capacity (about 660kl). Thus, it is assessed to have been insufficient to adjust the transverse incline, and from the simulation results, it can be assumed that about 48 tons of fuel had been transferred, as is shown in Case 2-0.

4.4.4.5.7 Therefore, the captain likely judged that it was insufficient to adjust the transverse incline by transferring fuel alone and moved about 30 tons of cargo stored at starboard side to port side in order to restore the excessive transverse incline.

4.4.4.5.8 The fish hold of this vessel is divided into two compartments. The frozen fish get stored as rectangular cargo that weigh about 21.5kg per pan. With specific gravity of about 1.050, they are not much different from that of seawater, which is 1.025. So it is likely that they will be moved if seawater flows in.

4.4.4.5.9 In order to adjust the transverse incline by moving cargo, it must hold that the cargo does not move transversely, with the vessel being able to maintain its course.

4.4.4.5.10 The fact that the vessel can maintain its course at sea is very important in that it is able to account for the direction of incoming waves. If the vessel is not able to adjust its direction, the vessel could capsize from transverse incline when the wave length and period are consistent with the size of the vessel.

4.4.4.5.11 However, it is difficult to maintain such conditions at sea so when vessels like 501 Oryong decide to adjust the transverse incline by transferring its cargo, it needs to do so after careful consideration.

4.4.4.5.12 At the time of the casualty, a significant amount of seawater had already entered into the processing room, and maintaining course was impossible due to the malfunctioning rudder. Adjusting the transverse incline by transferring cargo in the face of the possibility of additional inflows of seawater is assessed to have been very inappropriate.

4.4.4.5.13 As a result, when the seawater flowed into the fish hold, causing the hull to sink further below the water, it became difficult to maintain course. Then the vessel, which initially received waves from port before the transfer of cargo, received waves from starboard, causing the hull to tilt port side. This also made all fluid on board, including seawater, lean to one side, accelerating a steep incline to port.

4.4.4.6 Timing of Ship Abandonment and Preparation Process

4.4.4.6.1 From 14:10 to 14:30 on the day of the casualty, 501 Oryong received a portable submersible pump from Carolina 77 that approached nearby. Three pumps, including the borrowed pump, were in operation, and were sufficient for the discharge operation.

4.4.4.6.2 Therefore, Carolina 77, which came close to 501 Oryong, stood by with bow set towards upwind without taking additional measures. 501 Oryong was being swept away by waves so the distance between the two vessels was increased.

4.4.4.6.3 In this situation, it seems that 501 Oryong did not fully recognize the danger stemming from the fact that its rudder had not been operating since 13:00 on the day of the casualty.

4.4.4.6.4 The malfunctioning state of the rudder in bad weather means that the vessel had already lost its seaworthiness. Then, even if the vessel had temporarily recovered its transverse incline, it should have requested for the nearby vessel to position itself where it can readily provide assistance.

4.4.4.6.5 In addition, as the weather was worsening, the state of the malfunctioning rudder could have placed the vessel in a dangerous situation if it continued. Therefore, the vessel should have prioritzed checking whether it was possible to fix the rudder.

4.4.4.6.6 The decision on the timing of ship abandonment must be made in consideration of many factors. In particular, in bad winter conditions as had been present at the casualty site, it is more advantageous to maximize the time spent on the vessel.

4.4.4.6.7 This is because it is difficult for an average adult to maintain his or her body heat in water temperatures of around 0°C for a long time without wearing a wetsuit.

4.4.4.6.8 At around 15:00 of the same day, the vessel shook violently from port to starboard after being hit be a large wave from stern, then began to tilt steeply to port. Then at around 17:06, the vessel sank completely. The time it took from the steep incline to the sinking was about 2 hours.

4.4.4.6.9 In looking at the process of sinking after 15:00 of the same day, the vessel steadily lost its buoyancy when the inflow of seawater exceeded that being discharged after the hull tilted steeply to port. It is assessed that the preparation for ship abandonment should have begun at around 15:30 when the stern began to sink.

4.4.4.6.10 Although the process of ship abandonment differs by situation, in general, the announcement for ship abandonment should be made so that all crew can be aware of it. The crew should then put on clothes to ensure maximum warmth maintenance then put on life jackets.

4.4.4.6.11 The life raft on the side should be inflated and placed to float on waters nearby. Then, it should be tied by a rope so that crew can make their way to the life raft at the appropriate time. Then, the rope should be disconnected and the crew should move as far away from the vessel as possible.

4.4.4.6.12 There were enough inflatable life rafts to accommodate all crew equipped on each side of the vessel. In addition, as there was a vessel that could provide assistance nearby, it would have been possible to reduce casualties if the preparation for ship abandonment had taken place earlier.

4.4.4.6.13 However, although the Russian inspector advised ship abandonment at around 15:30, the captain only made the decision and notified Carolina 77 at around 16:00 when the engine stopped operating and the vessel tilted to port by 40°.

4.4.4.6.14 Even after making the decision of ship abandonment, the captain did not make any announcement informing the crew to abandon ship. Instead, he contacted the shipping company for what seemed like a request for permission.

4.4.4.6.15 Crew members who recognized the gravity of the situation gathered to starboard stern one by one, when the vessel increasingly tilted to port and the stern began to sink, but key officers of the vessel did not take a leading role in the process of ship abandonment.

4.4.4.6.16 Because the announcement for ship abandonment was not made, many crew members were not aware of the situation. Some crew, including the boatswain who had been working on deck, began the preparation for ship abandonment from 16:30 by voluntarily tying rafts together with a rope and inflating them. Therefore, it is assumed that a significant number of crew died in other locations, such as in crew cabins, without being aware of the situation.

4.4.4.6.17 If the captain had been in panic and thus unable to respond to the above situation appropriately, other officers should have actively advised ship abandonment. However, there is no evidence that this had taken place.

4.4.5 Sub-conclusion

4.4.5.1 Large-scale casualties are not caused by a single factor. In the case of 501 Oryong, there are multiple causes even when only considering human factors, as was observed above. However, at the base of all human factors, two factors can be identified: an insufficient safety management system, and misjudgement by the captain due to fatigue.

4.4.5.2 In looking at the safety management system, the vessel did not comply with even the minimum standards in accordance with legal regulations that are required of ordinary high-sea fishing vessels. Also, most key officers either did not board the vessel or failed to meet the qualifications.

4.4.5.3 It is assessed that the such inadequacy of the system results from the management practices of shipping companies that prioritize the load of catch over safety, the captain and key officers' lack of safety awareness, and the lack of supervision on governing the vessel's compliance with safety related regulations.

4.4.5.4 In addition, after observing the problems attributable to human factors at each stage, it is assessed that there had been a misjudgement by the captain at every important turn, such as the decision to fish, open the hatch cover of the fish bunker, and transfer cargo when the vessel inclined. It also seems that the captains' accumulated fatigue had at least some impact on his decision-making capacity.

4.4.5.5 Various factors have an impact on people's decision-making ability. Such factors include the environment in which the person grew up, education, and other living conditions. As the captain has the absolute right to have the final say in many affairs on a vessel, the judgement of the captain is directly related to the safety of the vessel.

4.4.5.6 In looking at the situation which directly triggered the casualty, the boatswain had witnessed the continuous swelling of waves onto the deck from stern, and recognized the associated danger. He advised the captain to "not open the fish bunker hatch cover."

4.4.5.7 However, despite the advice of the boatswain, the captain opened the hatch cover and ordered the release of the catch into the fish bunker. With water continuously entering the vessel, the net got caught while hurrying to close the hatch cover.

4.4.5.8 When assuming the reason why the captain pushed through with the operation while ignoring the boatswain’s advice, it is assessed that the culture of a strict, hierarchical chain of command on vessel is likely to have had an influence rather than the concern over the possible loss that could be generated should the catch not get processed.

4.5 Hardware Factors

4.5.1 Hatch Cover of Fish Bunker

4.5.1.1 Like other deep-sea trawlers, there is a fish bunker hatch cover installed on the upper deck of 501 Oryong so that the catch of fish can get released into the fish bunker after hauling in the net above the deck. However, in the general layout of the vessel, it is carelessly marked without accuracy.

4.5.1.2 Therefore, while it is difficult to know the exact location, size, and method of operation, it is assessed that there was one fish bunker (transverse, 1.8m x length 2.4m) installed in the middle, based on the testimonies of relevant personnel, such as the port engineer of the shipping company.

4.5.1.3 After acquiring the vessel in 2010, the shipping company had replaced two previously small (1.5m x 1.5m) hatch covers with one larger cover in the middle, as was requested by the captain for the purpose of convenience in operation.

4.5.1.4 In addition, the fish bunker hatch cover previously lifted upwards and closed downwards. However, also for the convenience of operation, the hatch cover was re-installed as a flap type that opens downwards and closes upwards.

4.5.1.5 Because the vessel had been inspected by the Russian Classification Society numerous times after being modified, there were no problems in terms of inspection. However, during this casualty, the following problems arose.

4.5.1.6 First, as two small hatch covers were replaced by a larger one, the overall surface area of hatch covers decreased but the area per hatch cover increased. So when opening the hatch cover in bad weather conditions like on the day of the casualty, this meant the area through which seawater can enter the boat along with the catch of fish is increased.

4.5.1.7 Second, with the change in the hatch cover from opening upwards and closing downwards to a flap type that opens downwards and closes upwards, it became impossible to respond to casualties by using gravitational force.

4.5.1.8 With the method that closes downwards, it is impossible to open the hatch cover when there is an issue with the operation of hydraulic pressure, but closing it, using gravitational force, is possible. For the opposite method, however, the gravitational force works in the direction of opening so it becomes impossible to use the gravitational force in a situation where the hatch cover has to be closed.

4.5.1.9 In this case, as the seawater continued to flow in through the hatch cover, it would have been possible to take emergency measures to prevent the inflow of seawater had the method of operation the other way around.

4.5.2 Sewage Discharge Outlet

4.5.2.1 Like other deep-sea trawlers, there is a sewage discharge outlet on the outer surface of the port side of 501 Oryong so that various waste generated while processing fish can be disposed in the sea. However, there was no indication of the sewage discharge outlet on any of the key blueprints, including the general layout.

4.5.2.2 Therefore, while it is difficult to know the exact location, size, and method of operation, it can be concluded from the testimonies of crew members that there is an opening (width 0.6m length 0.7m) on the outer surface that is connected to the floor of the processing room, located on the upper surface of frames 17 and 18 on the port side of the vessel. In addition, there is a rotational shutter installed at the opening.

4.5.2.3 The length of the slope from the outer opening to the vessel's interior is 1.2m, and the opening is 1.2m above the floor of the processing room [refer to Image 3 in section 3.1.4.1]

4.5.2.4 The outer opening is located 6.4m above the baseline of the vessel, and the inner opening of the sewage discharge outlet is located 7.6m above the vessel. Overall, it is located above the full load draft (5.69m above the baseline), and below the upper deck and the freeboard deck (8.4m above the baseline).

4.5.2.5 Therefore, it is assessed that the opening of the sewage discharge outlet requires the same intensity and watertightness as the outer surface below the upper deck. It can thus be assessed that the damaged sewage discharge outlet has the same effect as a hole of the same size on the outer surface of the vessel.

4.5.2.6 The vessel operated normally since mid-September when the shutter of the sewage discharge outlet got detached until the day of the casualty. Since this is equivalent to operating the vessel with a hole on the outer surface, it can be said that the seaworthiness of the vessel had been weakened considerably as it fell short of the inspection standards since mid-September.

4.5.2.7 Therefore, in calculating the intact stability of the vessel, the location of the sewage discharge outlet through which seawater could have actually entered the boat should have been counted as a value of inflow angle. As a result, there is also a significant difference in the result of stability calculations.

4.5.3 Equipment and Support for Weather Updates

4.5.3.1 Although the vessel was equipped with a weather fax machine to receive weather charts, it had not been able to receive the weather chart on the day of the casualty due to the facsimile's malfunction which began at an unknown date.

4.5.3.2 In general, the duty of receiving weather charts is performed by the radio officer but there was no radio officer aboard 501 Oryong. Although the shipping company was aware of the fact that there were issues with the captain's understanding of weather conditions due to the malfunctioning fax machine, no measures were taken to immediately repair or replace it.

4.5.3.3 Understanding weather conditions on vessel is not limited to forecasting the weather conditions. Instead, by analyzing the upper climate data and weather charts from received from various sending offices, local weather conditions between nearby vessels can be identified.

4.5.3.4 Therefore, being able to receive the necessary climate charts regularly and actively is very important for securing vessel safety by accurately identifying climate conditions. Communicating weather information through e-mails or phone calls is very passive and limited in nature.

4.5.4 Sub-conclusion

4.5.4.1 Although human factors are an important cause of the casualty, hardware factors such as machines are also critical. Even if the most qualified crew are on board, the risk of an casualty increases greatly with malfunctioning equipment.

4.5.4.2 Before being acquired by the shipping company that owned it during the casualty, the vessel operated in waters with much more moderate weather conditions than the North Pacific Ocean, and the fish bunker hatch cover was made to fit this nature. Therefore, modifying it for the mere purpose of convenience is assessed to have been a careless action considering that the vessel was to operate in rough waters.

4.5.4.3 Although the sewage discharge outlet installed on the outer surface below the upper deck needs to have the same intensity and watertightness as the outer surface, there was a lack of management of this facility. Considering that a large amount of seawater entered through it during the casualty, the fact that the vessel operated while aware that the outlet had been detached was a significant error in terms of vessel safety.

4.5.4.4 Although the malfunction of the weather fax machine had no direct impact on the casualty, it is assessed to have had some impact as it hindered the captain's ability to make suitable decisions at the time.

4.6 External Factors

4.6.1 Safety Management System of the Shipping Company

4.6.1.1 The shipping company operating the vessel made a manual for safety management of the vessel, even though it was not required by the law, and implemented it while sailing, fishing, and mooring and when entering or departing the port.

4.6.1.2 Also considering the diverse nationalities of the crew, the safety management regulation of the fishing vessel is written in English(Filipino), Indonesian, Chinese, and Vietnamese.

4.6.1.3 Although it is not compulsory for this vessel to develop and implement a safety management manual since it is not subject to the International Convention for the Safety of Life at Sea (SOLAS), given that the shipping company operates vessels with many more people than ordinary commercial boats, it is deemed to be very suitable to do so.

4.6.1.4 However, in examining the organization and operation of the shipping company for its safety management practices, the following problems can be identified. First, there is no specific organization assigned for safety management, and safety management is focused on vessel repair.

4.6.1.5 This can be inferred from the fact that there is no department in charge of safety management, no inspectors in charge of the vessel repair, and that different inspectors were assigned each time the vessel entered the Busan Port for repair.

4.6.1.6 In addition, as most inspectors had been in charge of construction supervision, they were familiar with vessel repair. However, they were not familiar with safety issues related to vessel management, which made them unable to provide appropriate advice in situations such as this casualty.

4.6.1.7 Second, the team in charge of safety management is different before and after departure. Before departure, the Fisheries team of the Busan office is in charge of safety management but after departure, the Fisheries team at the main office in Seoul is placed in charge. Therefore, the safety management checklist from the vessel was sent to the Fisheries team in Seoul after departure.

4.6.1.8 However, the main task of the Fisheries team at the main office in Seoul is not safety management, but tracking fishing operations of the vessel, managing quota consumption, and selling fish products after departure.

4.6.1.9 Therefore, the person in charge of 501 Oryong in the Fisheries team at headquarters merely stored the safety management checklist sent from the vessel and did not analyze it or confirm if it was actually being conducted.

4.6.1.10 Also, the person in charge at the Fisheries team who received the reports of local conditions did not have the ability to offer advice or suggest alternative plans, as vessel safety management was an unfamiliar topic.

4.6.1.11 Therefore, even though the shipping company had known that the shutter of the sewage discharge outlet broke off in mid-September, it failed to recognize the severity of the issue and the ship was left to continue sailing.

4.6.2 System to Confirm Crew Qualifications

4.6.2.1 While a qualified chief officer and 3rd officer were on board, no 2nd engineer, 3rd engineer, or radio officer were on board. The 2nd officer, chief engineer, and 1st engineer who did board possessed licenses that did not meet the minimum qualifications.

4.6.2.2 One of the most basic factors that determine the seaworthiness of a vessel is whether qualified crew are on board. However, only 2 of the 9 officers were fully qualified. Therefore, it is assessed that the vessel had not been seaworthy since its departure.

4.6.2.3 Vessels with a serious defect like 501 Oryong should not have been allowed to depart the port except for in special circumstances. However, the vessel departed without special restrictions and the fishing operation lasted for 4 months until the casualty.

4.6.2.4 The observed institutional problems are as follows. First, there is no regulation to confirm whether crew members who have been officially approved have actually boarded the ship.

4.6.2.5 The official approval for crew on board is implemented by the Regional Office of Maritime Affairs and Fisheries at the request of the person in charge at the shipping company. Based on the submitted application, the public officer confirms whether the crew on the application is boarding the vessel in a position appropriate to remain in accordance with relevant regulations. This is a type of civil request that is processed immediately following approval.

4.6.2.6 Therefore, the officer in charge of approving the crew is not authorized to evaluate the possibility of the vessel's departure. Therefore, even if the shipping company orders the vessel to depart before securing qualified crew for reasons including the right fishing season, there is no way for authorities to be aware of this.

4.6.2.7 Second, the notice of departure is processed through digitally via computer at the port authority but the confirmation of the crew list is not regulated at the same time. Therefore, it is not confirmed whether appropriate crew members have boarded the vessel at the time of the departure. Also, while the immigration management office of the Ministry of Justice confirms the crew list, it does not check whether the crew are qualified.

4.6.2.8 When it must be checked for special reasons, the vessel must be stopped and the crew list has to be submitted. Then, it is assessed to be necessary to match whether appropriate crew are on board the vessel and whether this has been approved appropriately in accordance with the Ship Personnel Act.

4.6.2.9 This kind of task can be carried out by vessels with mobility at sea by the Coast Guard or with inspection vessels of the Regional Maritime Affairs and Fisheries Office. However, making a vessel stop without any particular information could not only hinder port logistics flow and business operations, but it is also very difficult to inspect the numerous number of vessels departing one at a time. As a result, it is realistically difficult to inspect departing vessels at sea.

4.6.3 Adequacy of Inspection by Inspectors

4.6.3.1 The Korean Register executed a preliminary inspection of 501 Oryong from February 12, 2014 to February 14, 2014 for the transfer of classification society (withdrawal from the previous classification society on January, 21, 2014). From the 17^{th} to 28^{th} of the same month, it underwent the classification survey after construction (TOC, Transfer of Classification), annual survey, and regular inspection on behalf of the

Korean government, and received a fishing vessel survey certificate valid through May 5, 2018 in accordance with the Ship Safety Act on February 28, 2014.

4.6.3.2 In accordance with the regulations of the International Association of Classification Societies, the headquarters of the inspection organization approved the general layout of the blueprint, and the stability data and the shipboard oil pollution emergency plan data. Once approved, the general layout was reviewed for its living space and sanitation conditions. The sewage discharge outlet at the bottom of the upper deck was not indicated on the general layout or any of the other blueprints.

4.6.3.3 During the inspection of the vessel, the vessel had been moored to the port of another vessel. At that state, it was difficult to examine the bottom of the upper deck at port unless the vessel was moved.

4.6.3.4 During the on-site inspection, the overall condition of the vessel was assessed. In particular, the opening at the bottom of the upper deck was carefully examined but given the fact that the left and right side of the vessel are generally identical, only the starboard, and not the port, was inspected.

4.6.3.5 In particular, it was the first time for the inspector of the vessel to examine a stern trawler, and thus, the inspector did not know that there is generally a sewage discharge outlet at the bottom of the upper deck of trawlers. Also, there was no indication of the sewage discharge outlet in any of the blueprints so it could not be examined unless the outer surface of the port was observed.

4.6.3.6 Eventually, the inspection was completed without the vessel inspector even knowing about the sewage discharge outlet, which is an important opening located below the upper deck that should maintain the same intensity and watertightness as the outer surface.

4.6.3.7 This means that appropriate inspectors were not assigned to conduct the inspection of the vessel and that the inspection did not take place effectively. The following is the assignment method of vessel inspectors of the inspection organization.

4.6.3.8 First, for inexperienced inspectors, vessels irrelevant to the Port State Control (PSC[41]) such as tugboats, barge, and fishing boats are mainly assigned. For more experienced inspectors, commercial vessels related to the PSC, especially those highly likely to have defects, such as vessels that are old, are assigned.

41) Port state control: A system in which the port state inspects whether a foreign vessel that has entered its port is in compliance with the standards set by the main conventions.

4.6.3.9 However, this kind of assignment method is customary and not regulated, thus, it can be changed depending on the personal characteristics of the director in charge of the assignment.

4.6.3.10 Thus, it is essential for the inspection organization to consider various factors like the vessel type in assigning inspectors so that inspection on such important aspects does not go unnoticed again in the future. It is also assessed that efforts need to be made to improve the quality of inspectors.

4.6.4 Cooperation System with Nearby Operating Vessels

4.6.4.1 The vessel usually received weather related information by communicating with other vessels nearby. On the day of the casualty, it had also communicated via radio with a few other vessels that were operating close by.

4.6.4.2 In the case of Oyang 96, it suggested the vessel to quickly make the decision to get underway through a radio call, and when the vessel called for help, Carolina 77 and Zaliv Zabiyaka immediately stopped their operations and set sail to provide assistance.

4.6.4.3 In the case of Carolina 77, it moved near the vessel to lend a portable submersible pump, but after hearing that the vessel was recovering, it intentionally did not maintain its proximity with the vessel, and the distance between the two naturally widened.

4.6.4.4 In examining various situations, it is assessed that the vessel maintained a very cooperative relationship with nearby vessels despite the vulnerable local conditions.

4.6.4.5 As a result, 7 crew members managed to survive based on the fast rescue operations by nearby vessels although the local conditions made it extremely difficult for crew members that abandoned ship to survive.

4.6.4.6 However, in considering that the fish bunker hatch cover had not been fully closed and the steering system was not in operation, it would have been possible to reduce the number of casualties if they had given more active advice and placed themselves on standby nearby.

4.6.5 Sub-conclusion

4.6.5.1 Although the casualty was not directly caused by external factors, when examining fundamental the causes, it can be said that they had a significant impact.

4.6.5.2 In particular, it is certainly necessary to improve the safety consciousness of shipping companies, which tend to prioritize the catch of fish and its management over the safety of the vessel and the crew.

4.6.5.3 Although it is not legally mandatory for shipping companies of fishing vessels to construct a safety management system, as the shipping company of this vessel operates many vessels, each carrying a large number of crew, it is necessary to expand the organization for safety management and assign expert personnel.

4.6.5.4 In addition, having qualified crew board the ship is the most basic condition for safety management. As it is very important to confirm such status, it is necessary to prepare institutional instruments that can secure this in the future.

4.6.5.5 Furthermore, while the inspection of the vessel took place according to the necessary process, the inspection to check the status of the sewage discharge outlet was not executed thoroughly. Therefore, it is necessary for the inspection organization to improve the system to prevent any re-occurrence.

5. Causes of the Marine Casualty

5.1 Direct Causes

5.1.1 Excessive operation in bad weather

5.1.1.1 At around 05:00 on December 1, 2015, 501 Oryong decided to proceed with fishing operations and set its net despite the bad weather forecast.

5.1.1.2 At around 11:00 on the same day, it started to haul in the net amidst the bad weather and aimed to take in the catch of fish that was lifted onto the deck even with the seawater running over the deck.

5.1.2 Captain's Misjudgement on Net Hauling in Rough Weather

5.1.2.1 Although the bow has to face the wind and waves in rough waters to prevent the waves from swelling over the stern deck, the captain sailed so that the stern faced the wind and waves.

5.1.2.2 It has been determined that the captain made an error in decision-making. Although it is not possible to know the exact cause of the error, it is assumed to be attributable to the fact that they had to get underway after quickly finishing the operation and that the course was facing the wind.

5.1.3 Inflow of Seawater from Opening Hatch Cover of Fish Bunker

5.1.3.1 The captain of 501 Oryong ordered opening the hatch cover of the fish bunker to continue operation even though the boatswain had warned him not to open the hatch cover since the seawater was coming up the deck, and water was pooling.

5.1.3.2 After opening the hatch cover of the fish bunker, a large amount of seawater flowed in and in the process of trying close it quickly, the net got stuck between the hatch cover so it could not be closed completely.

5.1.4 Exacerbated Stability and Inflow of Seawater from Destroyed Sewage Discharge Outlet

5.1.4.1 In mid-September of 2014, even though the shutter of the sewage discharge outlet at the outer surface had been detached by waves, and the outlet could not maintain the same intensity and watertightness as the outer surface, the fishing operations were continued without repair.

5.1.4.2 As a result of the casualty, seawater continuously flowed into the vessel through the sewage discharge outlet and it exacerbated the stability and the buoyancy of the vessel.

5.1.5 Malfunction of Bilge Discharge Equipment inside Fish Processing Room

5.1.5.1 At the time of the casualty, the wooden wall that divided the fish bunker from the fish processing room was damaged and the fish and the seawater that flowed into the fish bunker moved to the fish processing room. As a result, the bilge well filled up with waste, including fish.

5.1.5.2 Such waste blocked the bilge well making it impossible to discharge the seawater using the bilge pump from the engine room of the vessel.

5.1.6 Malfunction of Steering Gear due to Inflow of Seawater in Steering Gear Room

5.1.6.1 Due to the inflow of seawater into the fish bunker and the fish processing room, the vessel tilted to starboard. This allowed seawater to continuously flow into the steering room, which damaged the distribution panel and disabled the rudder.

5.1.6.2 At that moment, as the vessel's stern trim was over 1.5 meters and the entrance of the steering room had been open, causing an accelerated inflow of seawater.

5.1.7 Transfer of Fuel Oil and Cargo to Restore Starboard Incline

5.1.7.1 In the early stage of the casualty, the fuel oil and fish were transferred from starboard to port to restore the starboard incline.

5.1.7.2 Therefore, the incline was restored temporarily but there was a change in direction of external forces including wind and the waves, which resulted in a sudden incline to the port side.

5.1.8 Loss of Buoyancy from Inflow of Seawater into Fish Hold and Engine Room

5.1.8.1 After the casualty, the inflow of seawater exceeded that being discharged, causing seawater to flow into fish holds 1 and 2, and eventually into the engine room.

5.1.8.2 The fish hold and the engine room were located at the bottom of the vessel so the seawater that flowed into the vessel lowered the center of gravity, exacerbating the buoyancy and leading the vessel to sink without being overturned.

5.1.9 Inadequacy of Timing of Ship Abandonment

5.1.9.1 The captain of the vessel decided to abandon ship when the vessel tilted steeply to port and started to sink from stern after losing its buoyancy.

5.1.9.2 Before the decision to abandon ship, other vessels such as Carolina 77 had approached near the vessel but the captain did not call for the vessel to standby for assistance as he judged the situation optimistically.

5.2 Indirect Causes

5.2.1 Insufficient Safety Management System of Shipping Company

5.2.1.1 The shipping company of 501 Oryong did not have a team specifically dedicated to safety management, and the team in charge of 501 Oryong changed from its time of entry into port and departure. In addition, staff in charge were not fully aware of navigation and vessel safety.

5.2.1.2 As a result, the severity of the detachment of the shutter of the sewage discharge outlet was not recognized and the vessel was left to set sail even though it was not seaworthy.

5.2.2 Insufficient Vessel Support System

5.2.2.1 The shipping company of the vessel provided the equipment for fishing operations and fuel oil by sending a carrier in a timely manner, but they were negligent about the broken weather fax machine and the detached shutter of the sewage discharge outlet.

5.2.2.2 This implies that while the shipping company provided operated a support system for its own profit, it lacked a system for the safety of the vessel.

5.2.3 Misjudgment of Captain due to Fatigue

5.2.3.1 The captain of the vessel led the fishing operation without sufficient sleep despite accumulated fatigue from the continuous fishing operations.

5.2.3.2 Such circumstances influenced the captain to make misjudgements and miss the right timing for ship abandonment in the during the casualty.

5.2.4 Inappropriate Modification of Hatch Cover of Fish Pond

5.2.4.1 After acquiring the vessel, the shipping company replaced two fish pond hatch covers on the left and right side that opened upwards, with one big hatch cover that opens downwards, following the request of the captain based on convenience of operation.

5.2.4.2 As a result, the surface area per hatch cover increased, making the area for potential inflow of seawater along with fish, larger. This made it difficult to use gravitational force in response to urgent situations.

5.2.5 Careless Vessel Inspection

5.2.5.1 While conducting the classification survey after construction (TOC, Transfer of Classification), annual survey, and regular inspection on behalf of the Korean government in January, 2014, the inspection organization of the vessel did not point out the fact that the sewage discharge outlet at the bottom of the upper deck was not marked on any blueprints, including the general layout.

5.2.5.2 Also, at the time of the on-site inspection, only the starboard side of the outer surface was inspected as the vessel had been moored. Therefore, factors directly related to the safety of the vessel, such as the watertightness of the sewage discharge outlet which was installed on the port side, did not get inspected.

5.2.6 Absence of Main Marine Technicians

5.2.6.1 The vessel had on board the captain, 2nd officer, chief engineer, and the 1st engineer, none of whom met qualifications in accordance with the Ship Personnel Act. The 2nd engineer, 3rd engineer, and radio officer were not on board at all.

5.2.7 Lack of Training for Emergency Situations

5.2.7.1 After departure, the chief officer held one training session for all crew members on the use of fire extinguishers and life jackets but did not execute any fire control or ship abandonment training.

5.2.7.2 Since its departure, 501 Oryong filled in the safety management checklist during fishing and sent it to Trawl Team 2 at the main office every Friday. However, it did not execute specific safety drills in preparation for different casualties.

5.2.8 Crew Relationship Strictly based on Chain of Command

5.2.8.1 As a result of strict crew relationship based on the chain of command, it is assumed that appropriate advice or communication did not take place.

5.2.8.2 This can be inferred from the fact that the captain made a unilateral decision to open the hatch cover in the early stage of the casualty and to abandon ship, in addition to the fact that main officers did not give active advice to the captain when he was seemingly in panic.

5.2.9 Duty Shift System that Worsens Fatigue

5.2.9.1 All crew members of the vessel had not been getting sufficient rest due the duty shift system. Two groups worked in two shifts for fishing operation and navigation while two out of three groups worked on processing fish.

5.2.9.2 This made it difficult to conduct emergency drills and had an impact on the decision-making capacity of crew members, including the captain.

6. Areas for Institutional Improvement

6.1 Introduction of Safety Management System and Monitoring of Safe Operations

6.1.1 In principle, the shipping company is generally responsible for vessel navigation. Therefore, the management and supervision of crew members, as well as nomination of the person in charge of safety management of vessels, and transfer of rights should be performed in accordance with relevant regulations.

6.1.2 However, Sajo Industries failed to have crew members conduct emergency drills regularly in practice, and as no one was in charge of the safety management of the vessel, the related work was not properly performed.

6.1.3 To improve the situation, it is necessary to encourage the increase in the shipping company’s interest and investment in safety management such as an introduction of a safety management system for deep-sea fishing vessels which carry numerous crew members.

6.1.4 Therefore, there should be an organization in charge of vessel safety management and the person designated to be in charge should have the necessary experience and knowledge to prevent the same mistakes from occurring again.

6.1.5 After departure, the chief officer held one training session for all crew members on the use of fire extinguishers and life jackets, but did not execute any fire control, life raft, or emergency training that need to be practiced once a month according to the Ship Personnel Act.

6.1.6 In addition, the checklist for safety management during fishing operation was sent to the main office to ensure that safety management, including emergency drills, was being conducted. However, in practice, these protocols were not being executed.

6.1.7 To improve the situation, the checklist for safety management needs to be streamlined to suit local conditions, and necessary drills such as emergency training, should be constantly recorded in order to be verified by the shipping company.

6.2 Prevention of Reserve Buoyancy Loss

6.2.1 Seawater continuously entered 501 Oryong through the fish bunker hatch cover and the sewage discharge outlet below the upper deck amidst worsening weather conditions, exacerbating the stability and buoyancy, which eventually sank the vessel.

6.2.2 For a vessel to maintain its buoyancy, watertightness at the bottom of the upper deck is essential. In the case of this vessel, if seawater had not flowed into the steering room, the fish hold, and the engine room through the hatch cover of the fish bunker and the sewage discharge outlet, the vessel could have retained its reserve buoyancy.

6.2.3 The entry into the steering room, fish hold, and the engine room from the fish bunker and the fish processing room is weather-tight. Had it not been for the open weather-tight door, the vessel would not have sunk after losing buoyancy, or it could have bought more time.

6.2.4 Therefore, although the weather-tight door has to be closed at all times except when passing through it, it had been left open for convenience. Despite the emergency situation, it was left neglected.

6.2.5 Therefore, the crew members have to be trained to close the weather-tight door of the upper deck at all times and the weather-tight door needs be replaced with a quick closing door[42] that opens and closes easily and quickly.

6.3 Confirmation System of Adequate Crew Members on Board

※ It is stipulated in the Enforcement Rule of the Act on the Arrival, Departure, ETC. of Ships (2015.8.4. Ministry of Oceans and Fisheries) that when fishing vessels make entry or departure in and from port, the list of crew and passengers on board should be submitted.

6.3.1 The most fundamental factor that determines the seaworthiness of a vessel is whether qualified crew are on board. However, 501 Oryong had only two qualified officers out of nine. Therefore, the vessel did not meet the qualification for seaworthiness since departure.

42) Quick closing door: a number of door-knobs are mechanically connected so that the door can be opened and closed with a single door knob.

6.3.2 Vessels with such serious defects should not be allowed to depart unless under special circumstances, but 501 Oryong departed without any special restrictions and fishing operations had lasted 4 months before the casualty.

6.3.3 To prevent vessels from departing without qualified crew on board, crew list submission should become a legal obligation. In addition, it would be useful to confirm the status of qualified crew with a data system that automatically rejects the departure of a vessel that does not satisfy the minimum manning standard after comparing it with the actual crew on board, should such a system be developed and applied.

6.4 Improvement of Hatch Cover of Fish Bunker

6.4.1 The hatch cover of the fish bunker of the vessel opens to the bottom of the deck and closes upwards so it is convenient for releasing the catch of fish. However, this structure made it difficult to use gravitational force to respond to the emergency situation.

6.4.2 Accordingly, the hatch cover that opens downwards to the fish bunker needs to be changed so that it opens upwards and closes downwards. If this is inevitable due to the nature of the operation, there is a need to change standards to include supplementary measurse, such as installation of an external cover to be used in case of emergencies.

6.5 Improvement of Sewage Discharge Outlet

6.5.1 The sewage discharge outlet of the vessel discharges waste through a grinder that is installed at the outer surface. Therefore, it is important to require the same intensity and watertightness as the outer surface. However, there is no mark of this on various blueprints nor any instructional guideline.

6.5.2 The purpose of the sewage discharge outlet is to discharge waste produced from processing fish so it is generally installed on the same deck of the fish processing room. Therefore, when it is damaged, it acts as a critical factor that seriously exacerbates the stability and the buoyancy of the vessel.

6.5.3 To prevent similar casualties, there is a need to relocate the external opening of the sewage discharge outlet to the top of the upper deck. When this is not feasible due to operational procedures, it can be located on the bottom of the upper deck and augmented by installing an alarm device that should make it possible to monitor its status from the steering room. Inspections related to this need to be reinforced to include these measures.

6.6 Maneuvering Characteristics and Crew Training on Emergency Response

6.6.1 In looking at the progression of the casualty, the main officers, including the captain, could not take appropriate measures in many instances as they had not been fully acquainted with the maneuvering characteristics of the vessel.

6.6.2 Therefore, to prevent any occurrence of a similar casualty, an educational program that includes maneuvering characteristics during emergency situations for different vessels and different fishing methods needs to be developed. Furthermore, education in preparation for emergency situations such as ship abandonment need to be reinforced.

6.7 Stronger Standards for Life-saving Equipments (wetsuit etc.) (revised on July 31, 2015)

6.7.1 One of the common traits shared by surviving crew members of this casualty is that they had layered on clothes to maintain their body temperature before jumping into the sea. The Russian inspector survived after wearing a wetsuit.

6.7.2 The Russian inspector, knowing that wetsuits were on board, without being discarded, even though equipping the vessel with wetsuits was no longer compulsively due to the transfer of classification, was able to maintain his body temperature by wearing a wetsuit when other crew members could not.

6.7.3 To prevent more casualties of this kind in the future, it should be made mandatory to equip the vessel with temperature-preserving gear, such as wetsuits, for each person on board, for vessels operating in extreme temperatures and crew should keep these personally to be available to wear during emergencies.

6.8 Revision of the Checklist and Procedure including Assignment of Inspectors

6.8.1 The inspector of the vessel did not have any experience with stern trawlers or any knowledge of the existence of the sewage discharge outlet on the vessel. Therefore, not only was the inspection on the sewage discharge outlet omitted, he failed to point out that it was not marked on any of the blueprints.

6.8.2 To prevent casualties of a similar kind, the inspection organization should improve the customary inspector assignment method that is focused on control of the port state and create a written guideline for inspector assignment that takes into account one’s familiarity of the structural characteristics and types of vessels.

6.8.3 Even if the suitable inspector cannot be assigned, it is necessary to revise the checklist that is used for inspection to prevent important equipment that can have an impact on seaworthiness, like the sewage discharge outlet, from being omitted.

6.9 Establishment of Standards for taking shelter by Tonnage in Different Weather Conditions

6.9.1 In this casualty, 501 Oryong lost its timing for getting underway by continuing to operate without fully identifying the weather conditions, while other vessels nearby were wrapping up their operations after deciding to take shelter.

6.9.2 It is assumed that the external factors, such as the system for evaluating the captain's ability, in line with the amount of catch had an impact on the decision of the captain to proceed with fishing operations despite the bad weather conditions.

6.9.3 Therefore, it is important to develop a standard for taking shelter for each tonnage of trawlers that takes into consideration the navigational capacity of vessels making it possible for decisions to get underway to be made without being influenced by external factors.

6.10 Monitoring of Deadweight Tonnage based on Relevant Reporting System (can be linked with the deep-sea fishing vessel electronic reporting system implemented on August 3, 2015)

6.10.1 This casualty occurred when the vessel exceeded the deadweight tonnage, which is directly related to the safety of the vessel, by about 130 tons, resulting in insufficient reserve buoyancy.

6.10.2 Whether the vessel exceeded the deadweight tonnage would be best determined on board, but it can also be easily confirmed by closely reading the daily report with some background knowledge.

6.10.3 Therefore, to prevent sailing with such excessive loads, the vessel should be cautious about exceeding the maximum deadweight tonnage. However, the shipping company on land should also monitor it continuously.

6.11 Relieving Fatigue and Strengthening Communication among the Crew

6.11.1 Fatigue of the crew and the captain, drinking before fishing, and the absence of communication among the crew are some of the reasons behind the increase in number of casualties.

6.11.2 To prevent such circumstances, the crews' hours of duty should be changed to a day and eight hours in the long term, and there should be voluntary self-regulations set stipulating a certain amount of rest to be taken before performing duties after consuming alcohol.

6.11.3 It also seems necessary to find measures to mitigate the culture of strict chain of command on board to encourage more communication between crew members of different ranks and among the crew in general.

Appendix

The Crew Status of 501 Oryong[43)]

No	Nationality	Position	Name	Date of boarding	Note
1	Korea	Captain	Kim ○○	14.03.08	Missing
2		1st officer	Yoo ○○	14.03.08	Dead
3		2nd officer	Kim ○○	14.03.08	Dead
4		3rd officer	Kim ○○	14.03.08	Dead
5		Boatswain	Jung ○○	14.03.08	Dead
6		Able seaman	Choi ○○	14.03.08	Missing
7		Chief engineer	Kim ○○	14.03.08	Missing
8		1st engineer	Kim ○○	14.03.08	Missing
9		No.1 oiler	Lee ○○	14.03.08	Dead
10		Officer in charge of freezing fish	Kim ○○	14.03.08	Dead
11		Officer in charge of processing fish	Ma ○○	14.03.08	Missing
Total 11 / 6 Dead 5 Missing					

43) Names are not revealed to protect personal information

No	Nationality	Position	Name	Date of boarding	Note
12	Philippines	Crew	L. R	14.08.16	Dead
13		Crew	E. E	14.08.17	Dead
14		Crew	B. A	14.07.10	Missing
15		Crew	S. G JR	14.07.10	Dead
16		Crew	L. J	14.07.10	Dead
17		Crew	A. R	14.07.10	Rescued
18		Crew	S. M	14.07.10	Rescued
19		Crew	E. M	14.07.10	Missing
20		Crew	S. R	14.07.10	Missing
21		Crew	A. H	14.07.10	Missing
22		Crew	P..T JR	14.07.10	Rescued
23		Crew	D. R	14.07.10	Missing
24		Crew	N. A	14.07.10	Dead
Total 13 / 3 survived 5 dead 5 missing					

No	Nationality	Position	Name	Date of boarding	Note
25	Indonesia	Crew	R. A	14.03.06	Dead
26		Crew	M. A	14.03.03	Missing
27		Crew	W. N. B	14.03.03	Rescued
28		Crew	K. A	14.03.03	Missing
29		Crew	H.	14.03.06	Dead
30		Crew	J.	14.03.06	Dead
31		Crew	L. C. E	14.03.06	Missing
32		Crew	T. G. J	14.03.06	Dead
33		Crew	M. M	14.03.06	Dead
34		Crew	S.	14.03.06	Dead
35		Crew	M. R. S	14.03.06	Missing
36		Crew	A. J	14.03.06	Dead
37		Crew	T	14.03.06	Dead
38		Crew	I. D	14.03.06	Dead
39		Crew	H. T	14.03.06	Rescued
40		Crew	T. A	14.03.06	Dead
41		Crew	WA.	14.03.06	Rescued
42		Crew	B. A	14.03.06	Missing
43		Crew	W.	14.07.10	Dead

44		Crew	P.	14.07.10	Missing
45		Crew	R. T	14.07.10	Missing
46		Crew	K. N	14.07.10	Dead
47		Crew	R. D. R	14.07.10	Missing
48		Crew	S. H	14.07.10	Missing
49		Crew	K. A	14.07.10	Missing
50		Crew	A.	14.07.16	Missing
51		Crew	R.	14.07.10	Missing
52		Crew	M.	14.07.10	Dead
53		Crew	I. M	14.07.10	Dead
54		Crew	D. E	14.07.16	Missing
55		Crew	AB.	14.07.10	Missing
56		Crew	U. K	14.07.10	Missing
57		Crew	H. M	14.07.10	Missing
58		Crew	HE.	14.07.10	Dead
59		Crew	BA.	14.07.10	Dead
Total 35 / 3 survived, 16 dead, 16 missing					

No	Nationality	Position	Name	Date of boarding	Note
60	Russia	Inspector	S. A	14.10.10	Rescued
Total 1 / 1 survived					