Inquiry MO-2014-201: *Dream Weaver*, flooding due to structural failure of the hull, Hauraki Gulf, 23 February 2014

Final Report

Marine inquiry MO-2014-201
Dream Weaver
flooding due to structural failure of the hull, Hauraki Gulf
23 February 2014

Approved for publication: October 2015

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of the occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

The *Dream Weaver* at sea

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Abbreviations

FRP	fibre-reinforced plastic
MetService	Meteorological Service of New Zealand

Glossary

bilge	a well into which seepage drains to be pumped away
bow-pulpit	an extension of the deck, usually encircled by a 'U' shaped handrail that opens to the deck. The pulpit may house navigation lights, cleats, the anchor roller and the anchor as well as provide a place to stand at the very forepart of the vessel
bridgedeck	the deck between the two hulls of a catamaran
catamaran	a vessel with two hulls of equal length
chain locker	a compartment where the chain or cable of an anchor is stowed when the anchor is raised
con (conning)	to direct the course and speed of a vessel
conning position	the position where the person directing the course and speed of a vessel stands or sits
footwell	a boxed opening in the deck of a small vessel affording more comfortable seating for passengers
FRP tabbing	a typical vessel construction, which involves bonding structures to the hull with strips of fibreglass cloth wetted with resin
gunwale	the upper edge of a vessel's hull
knuckle line	a small step in the surface of a hull shell, usually inserted for cosmetic reasons. It provides discontinuity in the structure that can act to concentrate the stresses acting on a laminate, which in turn increases the likelihood of a crack initiating or propagating (growing) at that location
lifting foil	a small hydrofoil located between the two hulls of a catamaran to lift the vessel and reduce resistance and so improve the performance of the vessel
pulpit rail	an elevated metal guardrail extending around the bow or stern of a yacht or other small vessel
scupper	an opening cut through the bulwarks of a vessel so that water falling on deck may flow overboard
shoulder	an area of a vessel between the bow and the main width of the vessel, usually where the hull widens as in a shoulder on a person
slamming	a term that describes the heavy contact of a ship's forepart when pitching in a seaway. This is a violent contact and may cause ship damage. The effect of slamming can usually be tempered by a reduction in speed
squall	a sudden, violent wind often accompanied by rain
washboard	a thin plank fastened to the side of a boat or to the sill of a freeing port to keep out the sea and the spray

Data summary

Vehicle particulars

Name:	*Dream Weaver*
Type:	passenger
Class:	Safe Ship Management
Limits:	restricted, enclosed and inshore
Classification:	Maritime New Zealand
Length overall:	18.3 metres
Breadth:	5.47 metres
Built:	Nustar Boats, Queensland, Australia, c1997
Propulsion:	two Caterpillar C9 ACERT diesel engines, each one driving a fixed-pitch propeller through a Twin Disc MG 5085A reduction gearbox
Service speed:	22 knots
Owner/operator:	Dream Weaver Charters Limited
Port of registry:	Auckland
Minimum crew:	one to three dependent on passenger loadings

Date and time	23 February 2014 at about 1340[1]
Location	Hauraki Gulf
Persons involved	36 passengers, four crew
Injuries	several minor
Damage	laminated fibreglass hull fully ruptured at bow between port hull and centre bow. Other cracks to main deck, and below-deck supporting structures stressed

[1] Times in this report are in New Zealand Daylight Time (co-ordinated universal time +13 hours) and are expressed in the 24-hour format.

1. Executive summary

1.1. At about 1000 on Sunday 23 February 2014, the charter passenger catamaran[2] *Dream Weaver* departed Westhaven Marina in Auckland for a dolphin- and whale-watching trip in Auckland's Hauraki Gulf. There were 36 passengers and a crew of four on board, comprising the master, the manager, the deckhand and a hospitality worker.

1.2. The weather conditions were forecast to deteriorate throughout the day, with winds predicted to reach 40 knots from the southwest by evening.

1.3. After about 50 minutes the *Dream Weaver* encountered a pod of dolphins in the inner Hauraki Gulf and spent about 40 minutes interacting with the pod. The master then decided to head out further to the outer Hauraki Gulf in search of whales.

1.4. The master turned the *Dream Weaver* around off Flat Rock near Kawau Island into the wind and waves. The wind speed had increased to 23 knots gusting to 33 knots, and the sea had become rough. The *Dream Weaver* was shipping seas onto its foredeck and waves were slamming[3] against the centre bow under the bridge deck.

1.5. After about 30 minutes the bilge[4] alarm sounded for the port hull. The laminated fibreglass on the port side of the centre bow had ruptured and seawater had flooded the forward compartment of the port hull.

1.6. The suction pipe on the primary bilge pump had become blocked with debris and the deckhand had not been trained to operate the secondary bilge-pumping arrangement. With the master committed to controlling the vessel, the crew were unable to pump out the water.

1.7. The master made a "Mayday" distress call as he sought shelter by taking the *Dream Weaver* closer to the shore. Several Royal New Zealand Coastguard vessels and the New Zealand Police launch responded. The *Dream Weaver* reached the shelter of a bay, where the passengers were transferred to the Police launch and taken back to Auckland. With the help of salvage pumps from the Coastguard, the *Dream Weaver* was able to continue to the nearby Gulf Harbour Marina, where it was lifted out of the water for inspection and repair.

1.8. The Transport Accident Investigation Commission (Commission) found that after 16 years of continual operation the *Dream Weaver*'s hull had failed in a typically high stress area for catamaran vessels – in the bridge deck structure near the bow; and that the *Dream Weaver* had been driven too hard, outside its permitted wave-height/speed limits, for the sea conditions at the time, causing the hull to rupture at its most vulnerable point, the weakened areas near the bow.

1.9. The Commission also found that the operator's Safe Ship Management system (prescribed by Maritime New Zealand) had not addressed the following safety issues:

- poor 'housekeeping' practices on board that prevented the bilge-pumping system working
- a lack of sufficient crew training for emergency equipment, meaning the crew were unable to control the flooding
- the wave-height/speed operating restrictions for the vessel were not conspicuously promulgated and enforced.

1.10. One recommendation has been made to the Director of Maritime New Zealand for him to ensure that the *Dream Weaver* is fit for its intended purpose and that the operator's safety management system is working as it should.

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[2] A vessel with two hulls of equal length.

[3] A term that describes the heavy contact of a ship's forepart when pitching in a seaway. This is a violent contact and may cause ship damage. The effect of slamming can usually be tempered by a reduction in speed.

[4] A well into which seepage drains to be pumped away.

1.11. The key lessons identified from the inquiry into this occurrence are:

- because of their qualities and characteristics, catamarans can easily be operated outside their design parameters with catastrophic consequences. It is paramount that skippers be aware of and keep within any operating restrictions
- fibre-reinforced plastic's strength degrades with cyclic loading, which is usually synonymous with a vessel's age. Operators and surveyors should factor in vessels' ages when inspecting, maintaining and setting operating parameters for such vessels
- heading in the same direction as the wind and waves in a boat can be deceptively benign. When on return trips, skippers must be absolutely aware of how their vessels will perform once turned into the wind and waves, particularly when initially travelling away from a sheltering coast with a deteriorating weather forecast
- crew members must be familiar with and well trained in operating emergency systems on board their vessels
- bilge suctions are easily blocked by debris. Bilge spaces must be kept clear of debris if a bilge-pumping arrangement is to be effective
- seawater trapped on the deck of any vessel is a potentially serious situation. Arrangements for freeing water from the deck must be adequate and kept clear at all times.

2. Conduct of the inquiry

2.1. On Monday 24 February 2014 the Transport Accident Investigation Commission (Commission) learned through the media of an accident involving the passenger vessel *Dream Weaver* that had occurred on Sunday 23 February 2014 at about 1340.

2.2. The Commission opened an inquiry into the occurrence under section 13(1) of the Transport Accident Investigation Commission Act 1990, and appointed an investigator in charge.

2.3. On 24 February two investigators accompanied by the Commission's general counsel travelled to Auckland. On 25 February the investigators inspected the vessel; collected evidence; and interviewed the master and the manager of the vessel. One of the investigators remained behind for another day to complete the remainder of the interviews with the crew.

2.4. Information was sought from the Royal New Zealand Coastguard (Coastguard), New Zealand Police, Maritime New Zealand and the harbourmaster. Two of the passengers were interviewed. A further 10 passenger groups were contacted and asked to complete a questionnaire about the occurrence.

2.5. Seven completed questionnaires from individuals and family groups were returned to the Commission.

2.6. On 26 August 2015 the Commission approved the draft final report to be circulated to interested persons for comment.

2.7. The report was distributed to seven interested parties on 4 September 2015, with the closing date for receiving submissions as 27 September 2015. Three submissions were received that included comments and four submitters declined to comment.

2.8. The Commission has considered in detail all submissions made and any changes as a result of those submissions have been included in the final report.

2.9. On 28 October 2015 the Commission approved the report for publication.

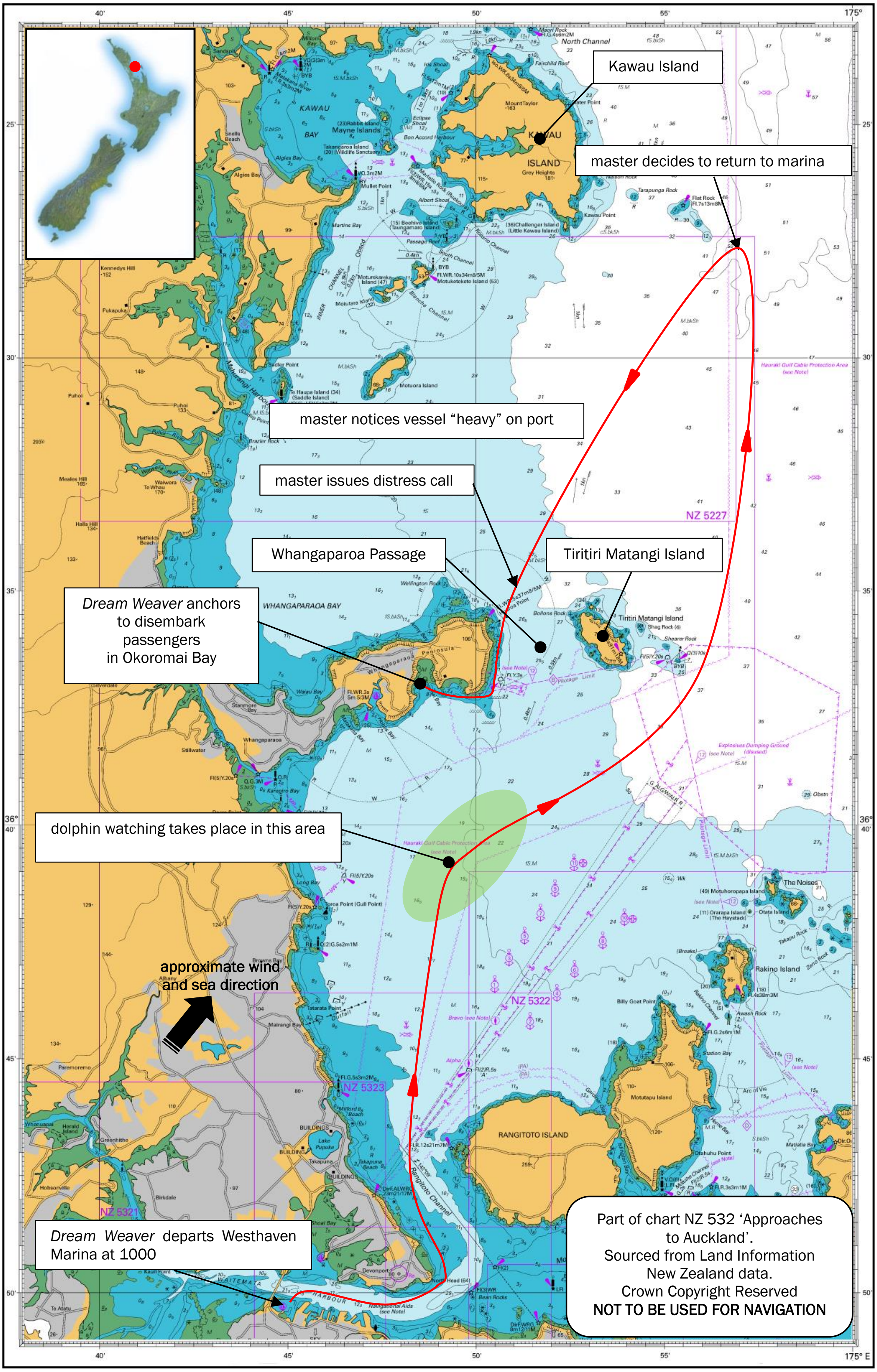

Figure 1
General area of the accident

3. Factual information

3.1. Narrative

3.1.1. During the evening of Saturday 22 February 2014, the manager of the *Dream Weaver* contacted the vessel's master to discuss if the weather forecast was suitable for the trip planned for the next day.

3.1.2. The manager and the master of the vessel decided to delay the decision until 0600 the next day, when a better estimate of the weather could be made.

3.1.3. At 0426 on Sunday the Meteorological Service of New Zealand (MetService) issued a forecast for the area in which the trip would be made, sea area Hauraki Gulf, Bream Head to Cape Colville (see Appendix 1 for full forecast information):

> Southwest [wind] 15 knots rising to 25 knots gusting 35 knots around midday, and to 30 knots gusting 40 knots this evening; sea becoming rough around midday. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.

3.1.4. The master decided to go ahead with the trip, as he believed that he could be out and back before the forecast weather arrived. He informed the manager, who then notified the passengers who had booked for the trip.

3.1.5. The passengers, who had been gathering on the quayside, were embarked just before 1000. The master and the deckhand then carried out a safety briefing, including a demonstration of how to put on and secure a lifejacket. This was followed by an explanation of what the passengers could expect to see during the excursion.

3.1.6. Just after 1000 the *Dream Weaver* left Westhaven Marina and the master took the vessel out into the Hauraki Gulf (see Figure 1). At about 1050 a pod of dolphins was encountered and the *Dream Weaver* spent about 40 minutes interacting with the pod.

3.1.7. At about 1130 the master decided to continue further out into the Hauraki Gulf, to the east of Tiritiri Matangi Island and then towards Kawau Island in search of whales. As the vessel passed Tiritiri Matangi Island the master told the manager and hospitality worker that this would be a good time to serve lunch, as the motion of the vessel would become worse once a turn for home was made.

3.1.8. After lunch had been served the master initially altered his course to the west across the weather, and then at about 1315 brought the vessel on to a course that was approximately south-southwest towards the Whangaparaoa Passage (see Figure 1). Within a few minutes of bringing the vessel on to the new course, the vessel was engulfed in a rain squall[5]. During the squall the master slowed the vessel and adjusted its course to encounter the waves on the vessel's shoulder[6].

3.1.9. Once the squall had passed the master continued on his course to the Whangaparoa Passage and increased the speed of the vessel. The vessel was heading into the seas and started taking water over the bow. Two of the passengers who were sitting outside in the foredeck seating area were drenched and had to be assisted inside. The manager noted that the water coming over the bow was taking what appeared to be a long time to disperse from the deck and the seat squabs were floating free in the foredeck seating area.

3.1.10. Waves were slamming up under the bridgedeck between the two hulls, which was causing severe shaking and shuddering through the hull. At some time the television set cover fell off the television when one of the passengers grabbed it to steady himself, and unfixed furniture was moving. Several of the passengers were frightened and suffering from seasickness.

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[5] A sudden, violent wind often accompanied by rain.

[6] An area of a vessel between the bow and the main width of the vessel, usually where the hull widens as in a shoulder on a person.

3.1.11. After about 15 minutes of heading into the waves and the wind, the automatic bilge alarm activated in the wheelhouse and remained on. As the *Dream Weaver* came under the relative shelter of Whangaparaoa Peninsula the master noticed that the port bow was riding low in the water, so he instructed the deckhand to move the passengers to the stern of the vessel, and he reduced the speed. The deckhand did so, then reported back to the master that this was not the problem and asked where the bilge alarm was before going to the lower cabin to investigate the reason for the bilge alarm. He lifted the access hatch from the main deck to the port lower cabin and saw that it was nearly full of water.

3.1.12. The deckhand reported his finding back to the master, who told him to go to the starboard engine room and set the engine-driven bilge-pumping arrangement to pump out the port cabin space. The deckhand attempted to arrange this but he was unsure which valves to operate, so he returned to the wheelhouse and told the master.

3.1.13. Around this time the master issued a distress (Mayday) call on very-high-frequency radio channel 16, which was logged by Auckland Maritime Radio at 1340. Auckland Maritime Radio answered the master's call and issued a Mayday relay call for the Auckland region. At 1342 the Coastguard responded to the Mayday relay call.

3.1.14. The master later said that during this period his whole focus had been on getting the vessel close to land so that he could beach the vessel if necessary. The crew handed out the lifejackets and ensured that everyone donned the lifejackets correctly. The deckhand then returned to the engine compartment to try to get the bilge pumps started, but was unsuccessful.

3.1.15. At 1348 a Coastguard vessel was alongside the *Dream Weaver*, with other Coastguard vessels nearby responding. A Police launch from Auckland and a harbourmaster's launch were also responding. The first Coastguard vessel escorted the *Dream Weaver* into Okoromai Bay (see Figure 1) where the master anchored the vessel.

3.1.16. Once the *Dream Weaver* was anchored in Okoromai Bay the passengers were transferred by Coastguard vessel from the *Dream Weaver* to the *Deodar III,* the Police launch. The *Deodar III* then returned to Westhaven Marina where paramedics were waiting to attend to the passengers.

3.1.17. The Coastguard placed two salvage pumps on board the *Dream Weaver* and with the help of the deckhand pumped the water out of the forward port hull. The master then hauled the anchor and proceeded to Gulf Harbour Marina.

3.2. Post-accident examination and testing

Structural

3.2.1. The examination of the *Dream Weaver's* hull and superstructure revealed that:

- the underside of the bridgedeck had damage to the fibre-reinforced plastic (FRP) laminate on both sides of the centre bow, including a rupture of the hull skin that had allowed water to enter the port hull (see Figure 3)
- on the centre bow the FRP of the hull skin had delaminated and ruptured
- on the hydrofoil the starboard side of the lifting foil[7] was dented and the hydrofoil port tie rod was bent. This was later established to be pre-existing damage
- on the foredeck the port shoulder gunwale[8] was cracked and deformed
- in the chain locker[9] the FRP laminates that had been secondary bonded to the hull had delaminated
- in the footwell[10] some of the corners had sustained minor cracking
- in the area of the bow-pulpit[11] the pulpit rail[12] had been torn out of the deck
- on the shoulder of the port hull, the join between the bridge deck and the hull had split
- in both the port and starboard cabins the mirrors that had been glued to the bulkhead were cracked (the mirror in the port cabin was reported to have been cracked before the accident)
- under the bunk inside the port lower cabin, delamination of secondary bonded structural laminate laid over the hull skin had occurred. This laminate was possibly from a previous repair
- in the lower port cabin a non-structural plywood frame had broken away from the hull where the FRP tabbing[13] had delaminated, and the frame itself had snapped at either end.

3.2.2. The examination also noted the following 'housekeeping' issues:

- the port forward bilge well was partially filled with a bucket, cardboard and other small, loose items. Some of this matter was blocking the bilge pump strainer (see Figures 6 and 7)
- on the foredeck washboards[14] were a new addition to the vessel; they had been fitted on both the port and starboard sides to prevent any water shipped onto the bow from flowing back onto the aft passenger decks. On each side this left only one small scupper[15] through which water could drain back overboard
- on the foredeck the LPG gas canister was too big to stow away correctly in its locker (see Figure 8).

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[7] A small hydrofoil located between the two hulls of a catamaran to lift the vessel and reduce resistance and so improve the performance of the vessel.
[8] The upper edge of a vessel's hull.
[9] A compartment where the chain or cable of an anchor is stowed when the anchor is raised.
[10] A boxed opening in the deck of a small vessel affording more comfortable seating for passengers.
[11] An extension of the deck, usually encircled by a 'U' shaped handrail that opens to the deck. The pulpit may house navigation lights, cleats, the anchor roller and the anchor as well as provide a place to stand at the very forepart of the vessel.
[12] An elevated metal guardrail extending around the bow or stern of a yacht or other small vessel.
[13] A typical vessel construction, which involves bonding structures to the hull with strips of fibreglass cloth wetted with resin.
[14] A thin plank fastened to the side of a boat or to the sill of a freeing port to keep out the sea and the spray.
[15] An opening cut through the bulwarks of a vessel so that water falling on deck may flow overboard.

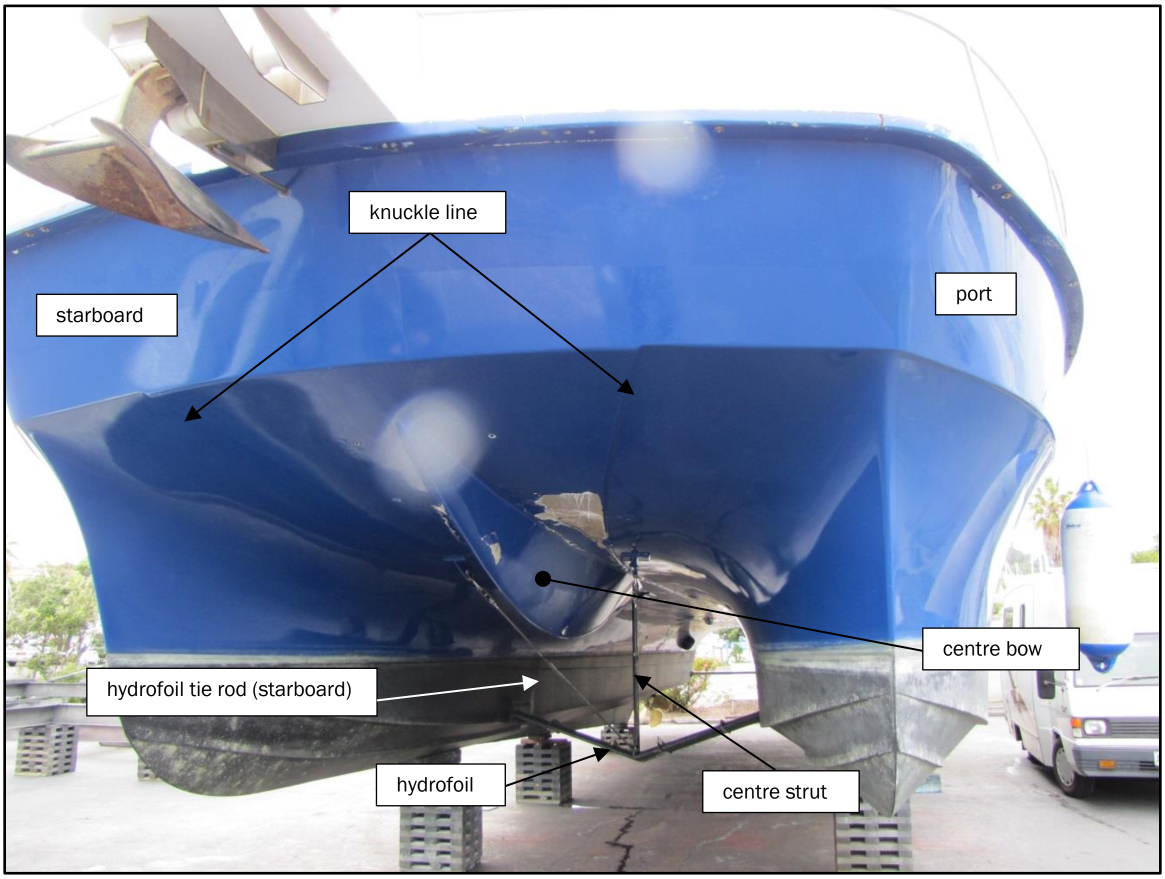

Figure 2
View looking at bows of *Dream Weaver*

Figure 3
Damage sustained to port underside of bridgedeck

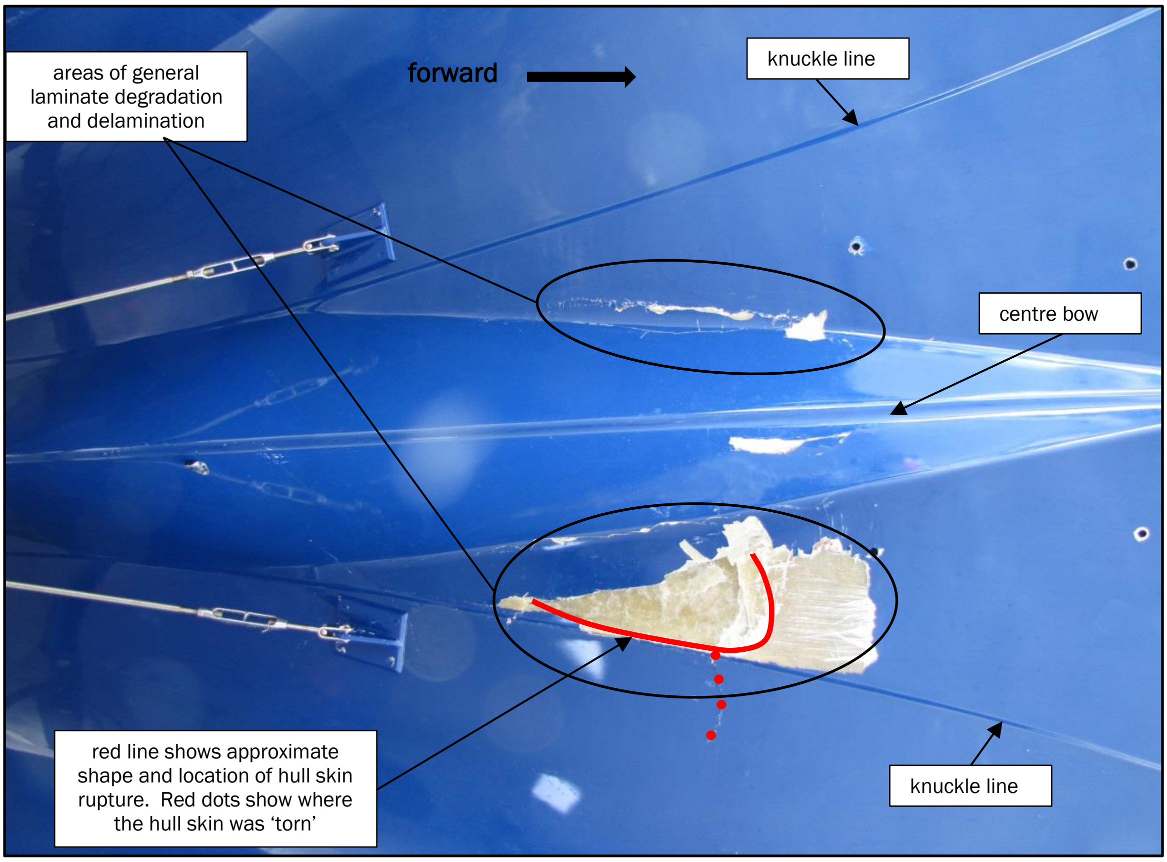

Figure 4
View looking up at centre bow of *Dream Weaver*

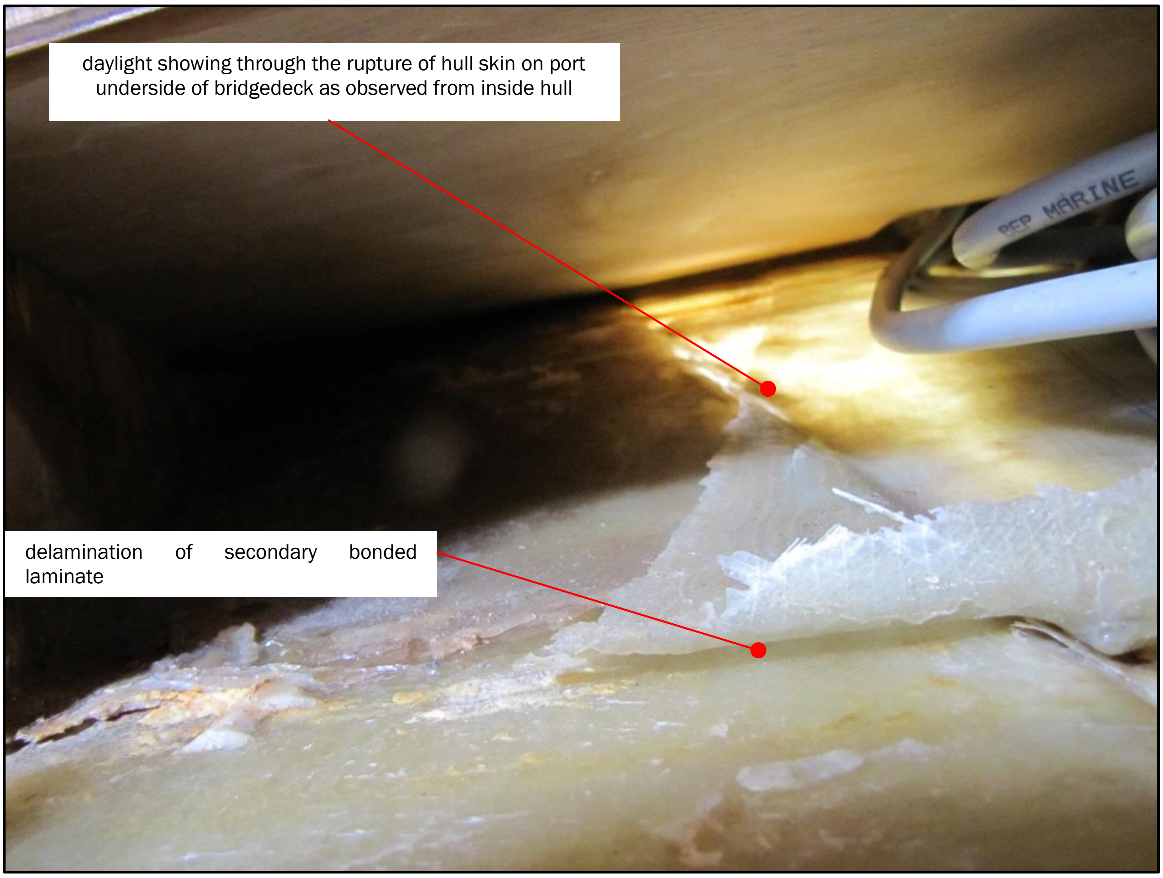

Figure 5
Secondary bonding delamination on inside of hull skin

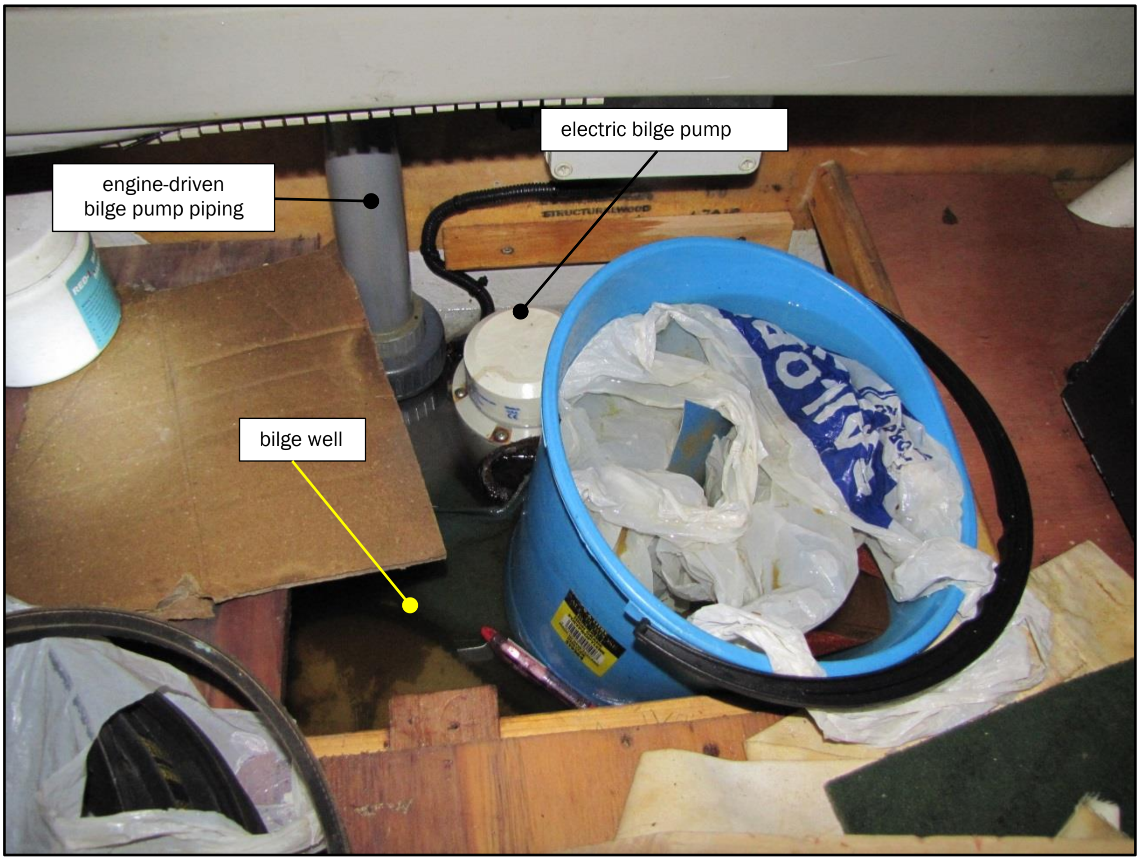

Figure 6
Port forward bilge and suction, showing bucket and other detritus in bilge well after plywood bilge well cover had been removed

Figure 7
Items recovered from port forward bilge well that were obstructing the bilge suction strainer

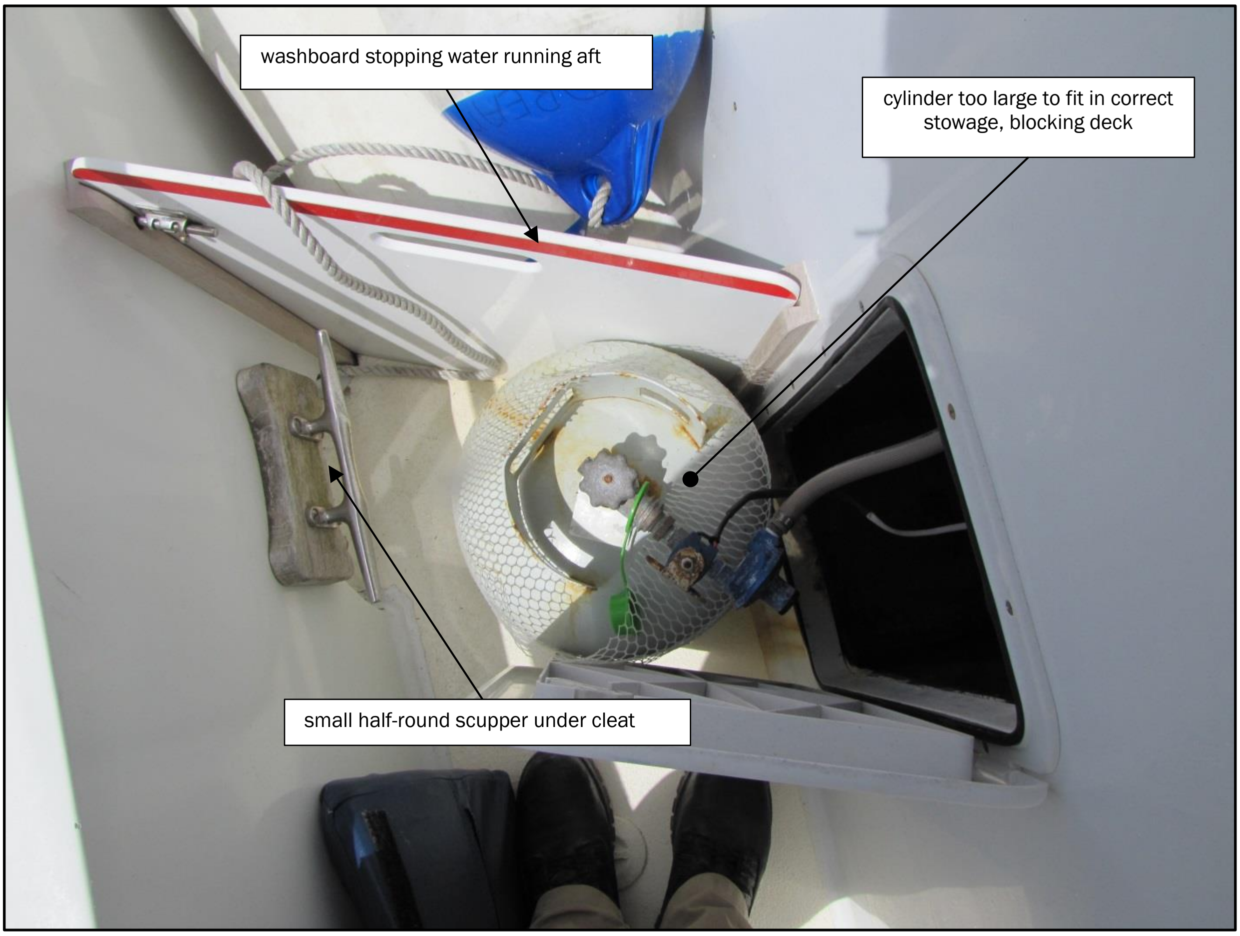

Figure 8
Starboard scupper, washboard and gas cylinder stowage

3.3. Vessel information

3.3.1. The *Dream Weaver* was built circa 1997 in Australia by Nustar Boats, Queensland. It was a 15-metre-long catamaran constructed in FRP. It had a breadth of 5.47 metres and a depth of 1.40 metres.

3.3.2. The *Dream Weaver* was originally fitted with two Yanmar 6CXGT2 diesel engines, one in each hull. Each engine produced 373 kilowatts driving a fixed-pitch propeller through a Twin Disc MG 5085A reduction gearbox. In September 2011 the owner had the engines replaced with two Caterpillar C9 ACERT diesel engines, each producing 423 kilowatts. At the same time new, more efficient propellers were fitted.

3.3.3. The *Dream Weaver* was brought from Australia to Nelson, New Zealand in about 2001. The then owner had planned to sail the vessel across the Tasman Sea. However, partway through the voyage the vessel had had to return to Australia for repairs to the hull. The hull had delaminated, possibly in the same general location as in this accident, although this could not be confirmed. The vessel was then shipped to New Zealand instead. The present owner purchased the vessel in Nelson in late 2001.

3.3.4. In Nelson a Safe Ship Management company, Survey Nelson, issued a Safe Ship Management certificate that allowed the current owner to sail the vessel from Nelson to Auckland. In 2002 the owner decided to carry out a major refit of the vessel, which included lengthening the vessel and modifying its superstructure.

3.3.5. A naval architect approved the new plans and produced a new, and approved, Damaged and Intact Stability book in October 2002. This book contained the stability information required to be carried on board the vessel by the Maritime Rules. As part of the plan approval and structural strength calculations, the naval architect specified that a speed versus wave-height restriction was to be placed on the vessel (see Table 1).

Table 1: Speed and wave-height restrictions placed on vessel during plan approval

Vessel speed (knots)	Maximum observable wave height (metres)
22	0.6
18	1.1
14	1.8
10 and below	2.2

3.3.6. A new Safe Ship Management certificate was issued by an Auckland-based Safe Ship Management company, Maritime Management Services, on 31 January 2003. The owner then decided to have a hydrofoil fitted to improve the performance of the vessel. The plans for the hydrofoil were approved by a Maritime New Zealand-approved naval architect in May 2003. This plan approval reiterated the wave-height/speed restrictions on the vessel.

3.3.7. The *Dream Weaver* was used for eco dolphin- and whale-watching excursions in the Hauraki Gulf and was available for corporate event charters. The owner of the *Dream Weaver* used the vessel occasionally for his own personal and business use.

3.3.8. Since the *Dream Weaver* arrived in New Zealand it had collided with Bean Rock in the Waitemata Harbour in 2003, and grounded in Kauri Bay in the Kawakawa Bay district, Auckland in 2006. The vessel had also undergone repairs for hull cracks in 2005 and hull damage in 2012.

4. Analysis

4.1. Introduction

4.1.1. The *Dream Weaver*'s hull design was typical for the period in which it was built. The bridge deck was closer to the waterline than more modern-style catamarans, which typically have bridge decks higher out of the water to reduce wave slamming forces.

4.1.2. The hull was constructed of single-skin FRP laminate with timber structural components. Since its construction both the design (higher bridge decks) and stronger, more resilient construction methods have evolved, as has the understanding of composites and their failure mechanisms.

4.1.3. This accident occurred due to the hull rupturing in the centre bow region under the bridge-deck, which allowed seawater to enter and flood the forward section of the port hull. This flooding caused the vessel to settle by the bow and list to port, forcing the master to seek assistance and sheltered waters with the intention of evacuating the passengers. The hull shell laminate in the area around the centre bow where the rupture occurred was found to have degraded and delaminated.

4.1.4. The vessel design was fit for its intended purpose at the time of build, and would have continued to be so provided it was operated within its design parameters, taking into account its design, age and the consequences these had for hull strength and performance.

4.1.5. The following analysis discusses the likely factors that contributed to the hull failure, and also discusses three safety issues:

- crew awareness of the operating limitations of the vessel
- crew operating knowledge of on-board emergency systems
- housekeeping practices on board affecting the safe operation of the vessel.

4.2. Hull failure

Ageing

4.2.1. The *Dream We*aver was built in about 1997 and, from what records were available, it had been in continual operation since, other than for the usual periods of layover for maintenance. Thus the *Dream Weaver* had spent approximately 16 years in operation.

4.2.2. The general degradation and delamination of the *Dream Weaver*'s hull shell laminate was symptomatic of the fatigue failure mechanism described by Eric Greene Associates.

4.2.3. Eric Greene is a pre-eminent expert in marine composites. He noted in his publication Marine Composites:

> Composite materials exhibit very complex failure mechanisms under static and fatigue loading because their strength and stiffness characteristics vary depending on what direction the load is applied. Fatigue causes extensive damage throughout the specimen volume, leading to failure from general degradation of the material instead of a predominant single crack. There are four basic failure mechanisms in composite materials as a result of fatigue: resin cracking, delamination between plies, debonding of the resin-fibre interface, and fibre breakage for solid FRP laminates, with the addition of debonding of skins from the core in sandwich laminates. The different failure modes combined with the inherent variation in strength and stiffness characteristics, complex stress fields, and overall non-linear behaviour of composites severely limit our ability to understand the true nature of fatigue. (Eric Greene Associates, 1999)

4.2.4. Figure 9 shows a graph that Gougeon Brothers produced comparing the tensile fatigue of materials typically used in boat construction (Gougeon Brothers Incorporated, 2005). Under fatigue testing the strength of glass fibre materials was found to reduce to 20% of the original strength. Gougeon Brothers estimated that it would take between about 30 hours (for a high-speed power craft) and 830 hours (for a sail yacht) of continuous operation to accumulate one million (10^6) load cycles. The wide variation in time is due to the unknown operational profile of the vessel, be it a sailing yacht or a high-speed power craft.

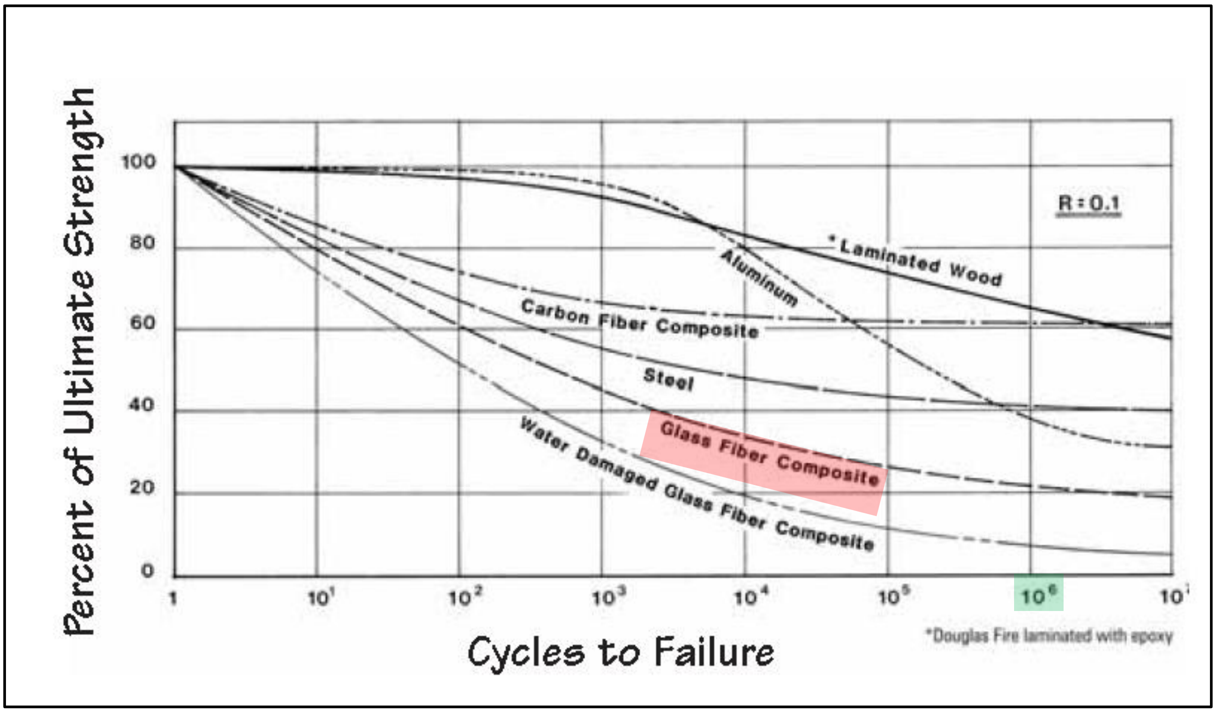

Figure 9
Tensile fatigue comparison of materials (Gougeon Brothers)

4.2.5. A glass laminate being only 20% of its original strength does not, however, mean that it will fail. Vessels are generally designed with sufficient scantlings[16] to absorb normal operating forces as their strength deteriorates with age and use.

4.2.6. It is difficult to estimate the number of load cycles to which the *Dream Weaver*'s bow structure would have been subjected in 16 years. It would have depended, on average, on how often and how hard the vessel was driven and in what sea conditions. It is safe to say, however, that the glass laminate in the bow region was significantly less strong than when it had been built. The various previous repairs noted around the vessel, including in the area where the rupture occurred, were evidence that supported this conclusion.

4.2.7. The point at which the hull of a boat will fail is largely a determinant of the forces acting through it during operation. The design characteristics of catamarans and the speed at which they can be operated provide additional challenges for designers and operators alike. These are discussed in the following sections.

Forces

4.2.8. Chris McKeeson is a university lecturer and author of the book Practical Design of Advanced Marine Vehicles. In his book McKeeson notes the difference between mono-hull and catamaran vessels:

> The big difference here is that [catamarans] are designed to specific limiting sea conditions. A commercial catamaran [should be] provided with a placard

[16] The dimension of a building material or a structural part of a ship.

displayed on the bridge that shows the limits for speed and wave height in which the craft can operate. It is the master's responsibility to ensure that the craft stays within those limits.

> [Catamarans] CAN be driven outside their permitted envelope, but they MUST not be. Operating a [catamaran] is much more like flying an airplane, or even driving a car, than it is like operation of a displacement monohull: it is entirely possible to go too fast for the conditions, and break the ship, capsize, or otherwise end catastrophically. (Chris B McKeeson, 2009)

4.2.9. With respect to the forces acting on the structure in a catamaran design, McKeeson says the forces on the structure are driven by dynamic events rather than static conditions. That is to say, the forces on the structure are dominated by the vessel's response to waves. Owing to the high accelerations there is high pressure and the dominant forces are localised.

4.2.10. There are two origins of fatigue in the bridgedeck structure between the bows:

- cyclic loading due to the buoyancy of the two hulls responding to waves slightly out of phase with each other, and acting against each other with the forces transmitted through the bridgedeck structure
- cyclic wave slamming against the underside of the bridge deck. Wave slamming loads would also include high-amplitude, single-event wave slams.

4.2.11. The stress field[17] acting on the hull shell laminate will be concentrated in certain areas by the shape of the hull shell. Figures 2 and 4 show the two areas of general laminate degradation along the knuckle lines[18] either side of the centre bow structure, of which one failed or ruptured totally in this accident. These areas are likely to be where (for the *Dream Weaver*) the cyclic stress field overwhelmed the 'fatigue endurance limit' of the hull shell laminate. The fatigue endurance limit describes the structural performance of a material over time. It is a function of the magnitude of stress applied to a material, and the number of cycles in which that stress can be applied before the failure of the material. For example, a typical fatigue endurance limit will show that when the load is very high the material will fail after only a few load cycles, whereas the same material will withstand many load cycles when the load is very low.

4.2.12. Other factors that would have altered or increased the stress field in the bow structure were the lengthening of the vessel, fitting more powerful engines and fitting the hydrofoil near the bow.

4.2.13. Lengthening a vessel adds more weight and potentially changes the stress points in a hull. Increasing the engine power allows the skipper to push the vessel harder through the waves. A hydrofoil also increases the speed potential of the vessel.

4.2.14. The hydrofoil had, at some time in the past, sustained damage along its trailing edge and one of the two hydrofoil tie rods had been bent. This damage was indicative of the hydrofoil hitting a submerged object, rather than normal operating forces. This possibly resulted from one of the two groundings known to have occurred since it had been fitted.

4.2.15. The hydrofoil usually exerts an upward force on the hull through the attachment points on the port and starboard hulls and through the central strut into the vessel's longitudinal centre bulkhead.

4.2.16. However, it is unlikely that the hydrofoil contributed directly to the hull shell laminate failure that resulted in the flooding, because the hull ruptured at a different place from where the hydrofoil tie rods attached to the port and starboard hulls.

[17] The stress field describes the magnitude of stress at each point in the structure.
[18] a small step in the surface of a hull shell, usually inserted for cosmetic reasons. It provides discontinuity in the structure that can act to concentrate the stresses acting on a laminate, which in turn increases the likelihood of a crack initiating or propagating (growing) at that location

4.2.17. Carrying shipped water on the foredeck would have increased the overall stresses in the bow region. Witness reports suggested that a significant amount of seawater was retained on the foredeck after the *Dream Weaver* turned into the wind and waves for the return journey. The fitting of washboards either side of the bridge-deck would have prevented shipped water draining overboard quickly. Carrying a large weight of water on the foredeck would have submerged the bow, thereby accelerating the accumulation of water on the deck and exacerbating wave slamming on the weakened underside of the bridge deck.

4.2.18. It is important to have adequate means for shedding seawater from the decks. The operator (Dream Weaver Charters Limited) will need to address this issue by either increasing the area of over-side openings or removing the washboards in inclement weather.

Speed and wave height

4.2.19. The MetService weather forecast for the day and sea area where the accident occurred was for wind from the southwest 15 knots rising to 25 knots, gusting 35 knots around midday, and to 30 knots gusting 40 knots in the evening – sea becoming rough around midday.

4.2.20. The weather between 1300 and 1400 (the time of the accident), recorded at the Tiritiri Matangi Island automatic weather station, was a 23-knot south-southwest wind with average gusts of 31 knots and a maximum gust of 33 knots, very similar to what had been forecast.

4.2.21. The company's written procedures were silent on the maximum wind speed or sea state in which the vessel could operate. The decision on whether a trip would proceed was left to the master alone.

4.2.22. Putting aside passenger comfort, it is the sea state that mostly affects the safety of catamaran operations. That was the reason for the naval architect placing wave-height and speed restrictions on the *Dream Weaver*. Wind speed does affect the sea state, but to varying degrees when operating in and around inshore waters. Relatively smooth seas can be found in the lee of land even when the wind is strong. The greater the distance the wind blows across the sea uninterrupted by land, the bigger the waves will become[19].

4.2.23. The topography of the Hauraki Gulf is such that when the wind blows from the southwest the seas get rougher the farther out into the Gulf a vessel goes. The master's decision to proceed with the trip in the forecast weather conditions was not inappropriate provided he intended to stay within the inner Hauraki Gulf, the area where the vessel had made contact and interacted with the pod of dolphins.

4.2.24. However, when the master decided to proceed further off-shore in search of whales, it was predictable that the sea conditions would exceed 2.2 metres, particularly as the tide was flooding into the Hauraki Gulf against the direction of the wind and waves[20]. When the tide or current opposes the direction of the waves, the waves shorten, rise up and steepen, creating more difficult conditions for small vessels.

4.2.25. It was highly likely that the observable wave height at the time and place of the accident exceeded 2.2 metres, as evidenced by the recorded weather conditions and the statements from the passengers and crew. At that time the *Dream Weaver*'s speed should have been kept to under 10 knots, and heavy slamming forces under the bow region should have been avoided. The deckhand recalled seeing on the GPS readout that the speed at that time was about 11.7 knots.

4.2.26. The skipper was vaguely aware of the wave-height/speed restriction table, but rarely considered it when operating the *Dream Weaver*. This is unsurprising given that the table had

[19] The length of water over which a given wind has blown is referred to as the 'fetch'.
[20] The National Institute of Water and Atmospheric Research's tide forecaster program predicted the time of high water near Tiritiri Matangi Island for 1400.

not been incorporated into the Safe Ship Management manual and neither had it been clearly placarded at the conning position[21].

4.2.27. As McKeeson states, it is generally easy for a skipper of a catamaran to exceed the safe operating speed and cause damage to the vessel. The *Dream Weaver* had two pre-existing areas of general laminate degradation along the knuckle lines either side of the centre bow structure. It is highly likely that these two weakened areas and the slamming forces caused by the *Dream Weaver* being driven too fast into the waves were the two main factors that contributed to the hull failure and subsequent flooding of the lower port hull.

4.2.28. It is a concern that the omission of safety-critical operating parameters in the Safe Ship Management system had gone undetected by the vessel owner and operator; had not been transferred with the change in Safe Ship Management provider; and had not been picked up during subsequent audits and surveys. In particular, the wave-height/speed restriction table was not in the Safe Ship Management manual and not visible in the wheelhouse. These concerns are especially significant given that the vessel was of older design and construction and known to have previously suffered structural failure due to heavy weather.

4.3. Response to the flooding

Training

4.3.1. The Safe Ship Management system includes the training of the crew to an acceptable standard.

4.3.2. The training records kept on board showed that basic training had been conducted for the crew. However, there was an absence of more encompassing training for emergency situations such as flooding and the use of the bilge system. The most recent documented training in the use of the bilge-pumping system had been in 2010. The deckhand confirmed that he had received no training in the use of the secondary emergency bilge-pumping systems.

4.3.3. The deckhand had received training on helming (driving) the *Dream Weaver* from previous masters. However, he had not received any training on how to drive the *Dream Weaver* from the current master. When the flooding occurred the master thought he was committed to driving the vessel. Therefore with the master committed to the wheel there was no-one else who had the knowledge to operate the pumping systems. This was a serious oversight of the training system on board that Dream Weaver Charters will need to address.

4.3.4. The *Dream Weaver* had two separate bilge-pumping systems. The secondary or emergency system was a main-engine-driven pump in each hull. The primary system included a series of automatic electric bilge pumps; four in each hull in separate compartments, each with a rated maximum capacity of approximately 14 cubic metres per hour. If both systems had been available to pump the water out of the forward port hull, it is feasible that the vessel could have returned to port without assistance and without any undue risk to the passengers and crew.

Housekeeping

4.3.5. The bilge suctions for both the primary and secondary bilge systems were housed in the same bilge compartment. Figures 6 and 7 show small items of equipment and refuse found in the bilge well during the post-accident inspection. These items were blocking the bilge suctions and were highly likely the reason for the primary pump being unable to keep up with the ingress of water through the ruptured hull. This also meant that even if someone had succeeded in getting the secondary bilge system operating, it too would have failed due to the blocked bilge suction.

[21] The position where the person directing the course and speed of a vessel stands or sits.

4.3.6. Poor housekeeping on board vessels is a safety issue. Good housekeeping is essential for maintaining a safe operation, particularly the cleanliness of machinery and other enclosed spaces.

4.3.7. There were other examples of questionable housekeeping practice on board the *Dream Weaver*. The storage of the LPG gas bottle on the deck was one.

4.3.8. Dream Weaver Charters will need to take action to address this safety issue.

5. Findings

5.1. The *Dream Weaver*'s hull ruptured in one of two areas weakened by general degradation and delamination of hull shell laminate near the centre bow, allowing seawater to flood the port forward hull compartment.

5.2. The fibre-reinforced plastic used in earlier boat-building times loses strength due to cyclic loading over time. After 16 years of continual operation the *Dream Weaver*'s hull failed in a typically high stress area for catamaran vessels: in the bridge deck structure near the bow.

5.3. The *Dream Weaver* was being driven too hard, outside its permitted wave-height/speed limitations, for the sea conditions at the time, causing the hull to rupture at its most vulnerable point: the weakened areas near the bow.

5.4. The master and crew were unable to pump out the flooded bow compartment for two reasons:

- the bilge suctions were blocked by articles and debris
- the crew had not been trained in the operation of the bilge-pumping arrangements.

5.5. The operator's safety management system for the *Dream Weaver* did not ensure that:

- wave-height/speed operating restrictions for the vessel were conspicuously promulgated and enforced
- the crew were adequately trained for emergency procedures
- an adequate standard of housekeeping was maintained on board the vessel.

6. Recommendations

General

6.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, recommendations have been issued to Maritime New Zealand, with notice of these recommendations given to Dream Weaver Charters Limited.

6.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

6.3. The skipper was vaguely aware of the wave-height/speed restriction table, but rarely considered it when operating the *Dream Weaver*. This is unsurprising given that the table had not been incorporated into the Safe Ship Management manual and neither had it been clearly placarded at the conning position.

The training records kept on board showed that basic training had been conducted for the crew. However, there was an absence of more encompassing training for emergency situations such as flooding and the use of the bilge system. The most recent documented training in the use of the bilge-pumping system had been in 2010. The deckhand confirmed that he had received no training in the use of the standard and emergency bilge-pumping systems. Nor had he been trained to drive the *Dream Weaver*.

Consequently, when the flooding occurred, the master was committed to driving the vessel and there was no-one else who had the knowledge to operate the pumping systems. This was a serious oversight of the training system on board that Dream Weaver Charters will need to address.

The bilge suctions for both the primary and secondary bilge systems were housed in the same bilge compartment. Small items of equipment and refuse were found in the bilge well during the post-accident inspection. These items were blocking the bilge suctions and were highly likely the reason for the primary pump being unable to keep up with the ingress of water through the ruptured hull. This also meant that even if someone had succeeded in getting the secondary bilge system operating, it too would have failed due to a blocked bilge suction.

Poor housekeeping on board vessels is a safety issue. Good housekeeping is essential for maintaining a safe operation, particularly the cleanliness of machinery and other enclosed spaces.

These safety issues collectively show that the Safe Ship Management for the *Dream Weaver* operation was not functioning as it should.

On 28 October 2015 the Commission recommended that the Chief Executive of Maritime New Zealand review the Dream Weaver *operation with a view to ensuring that the* Dream Weaver *is fit for its intended purpose and that the operator's safety management system, or the succeeding MOSS system, is operating as it should.(016/15)*

6.3.1. On 17 November 2015, Maritime New Zealand replied:

> Subsequent to this accident, the Dream Weaver operation entered the MOSS system. It was through this process that Maritime New Zealand reviewed the Dream Weaver's fitness for purpose and the operator's safety management system to ensure it was operating as it should.

7. Key lessons

7.1. Because of their qualities and characteristics, catamarans can easily be operated outside their design parameters with catastrophic consequences. It is paramount that skippers be aware of and keep within any operating restrictions.

7.2. FRP's strength degrades with cyclic loading, which is usually synonymous with a vessel's age. Operators and surveyors should factor in vessels' ages when inspecting, maintaining and setting operating parameters for such vessels.

7.3. Heading in the same direction as the wind and waves in a boat can be deceptively benign. When on return trips, skippers must be absolutely aware of how their vessels will perform once turned into the wind and waves, particularly when travelling away from a sheltering coast with deteriorating weather forecast.

7.4. Crew members must be familiar with and well trained in operating emergency systems on board their vessels.

7.5. Bilge suctions are easily blocked by debris. Bilge spaces must be kept clear of debris if a bilge-pumping arrangement is to be effective.

7.6. Seawater trapped on the deck of any vessel is a potentially serious situation. Arrangements for freeing water from the deck must be adequate and kept clear at all times.

8. Citations

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Appendix 1: MetService inshore weather situation and forecast extracts

Hauraki Gulf, Bream Head to Cape Colville

Forecast issued	Forecast	Outlook
0212 Saturday 22-Feb-2014 Valid to midnight Saturday	**Saturday:** Easterly 10 knots turning northeast late morning, then changing southwest 10 knots tonight. Sea slight. Areas of fog, with poor visibility in morning drizzle and afternoon showers.	**Sunday:** Southwest rising to 20 knots in the morning. Showers clearing. **Monday:** Becoming variable 10 knots, but southeast 15 knots about the Outer Gulf. Mainly fine.
0441 Saturday 22-Feb-2014 Valid to midnight Saturday	**Saturday:** Easterly 10 knots turning northeast late morning, then changing southwest 10 knots tonight. Sea slight. Areas of fog, with poor visibility in morning drizzle and afternoon showers.	**Sunday:** Southwest rising to 20 knots in the morning. Showers clearing. **Monday:** Becoming variable 10 knots, but southeast 15 knots about the Outer Gulf. Mainly fine.
1106 Saturday 22-Feb-2014 Valid to midnight Sunday	**Saturday:** Easterly 10 knots, easing to variable 5 knots this afternoon, then changing southwest 10 knots this evening. Sea slight. Areas of fog, with poor visibility in patchy drizzle and afternoon showers. **Sunday:** Southwest 10 knots rising to 25 knots gusting 35 knots by late morning, and to 30 knots gusting 40 knots in the evening. Sea becoming rough in the evening. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.	**Monday:** Southwest easing 15 knots everywhere in the morning, tending easterly about the Outer Gulf in the morning, then dying out in the evening. Mainly fine.
1705 Saturday 22-Feb-2014 Valid to midnight Sunday	**Saturday:** Northerly 10 knots, changing southwest 10 knots late tonight. Sea slight. Areas of fog, with poor visibility in patchy drizzle and occasional showers. **Sunday:** Southwest 10 knots rising to 25 knots gusting 35 knots around midday, and to 30 knots gusting 40 knots in the evening. Sea becoming rough around midday. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.	**Monday:** Southwest easing 15 knots everywhere in the morning, tending easterly about the Outer Gulf in the morning, then dying out in the evening. Mainly fine.
0022 Sunday 23-Feb-2014 Valid to midnight Sunday	**Sunday:** Southwest 10 knots rising to 25 knots gusting 35 knots around midday, and to 30 knots gusting 40 knots this evening. Sea becoming rough around midday. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.	**Monday:** Southwest easing 15 knots everywhere in the morning, tending easterly about the Outer Gulf in the morning, then dying out in the evening. Mainly fine.
0220 Sunday 23-Feb-2014	**Sunday:** Southwest 10 knots rising to 25 knots	**Monday:** Southwest easing 15 knots

Valid to midnight Sunday	gusting 35 knots around midday, and to 30 knots gusting 40 knots this evening. Sea becoming rough around midday. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.	everywhere in the morning, tending easterly about the Outer Gulf in the morning, then dying out in the evening. Mainly fine.
0426 Sunday 23-Feb-2014 Valid to midnight Sunday	**Sunday:** Southwest 15 knots rising to 25 knots gusting 35 knots around midday, and to 30 knots gusting 40 knots this evening. Sea becoming rough around midday. Areas of fog, with fair visibility in a few showers, both clearing mid-morning, then fine.	**Monday:** Southwest easing 15 knots everywhere in the morning, tending easterly about the Outer Gulf in the morning, then dying out in the evening. Mainly fine.
1056 Sunday 23-Feb-2014. Valid to midnight Monday	**Sunday:** Southwest 20 knots rising to 25 knots gusting 35 knots this afternoon. Sea becoming rough this afternoon. Mainly fine. **Monday:** Tending southerly 25 knots gusting 35 knots early morning, becoming southeast 10 knots but 15 knots north of Whangaparaoa late morning, and variable 5 knots everywhere in the afternoon. Rough sea easing late morning. Fine.	**Tuesday:** Variable 10 knots, but southeast 10 knots about the Outer Gulf. Fine.

Appendix 2: Automatic weather station readings, Tiritiri Matangi Light

Date and time	Wind direction ° true	Wind speed knots	Average wind gust knots	Maximum wind gust knots
23 Feb 2014 00:00	230	10	12	16
23 Feb 2014 01:00	240	13	16	17
23 Feb 2014 02:00	230	13	15	20
23 Feb 2014 03:00	240	9	13	14
23 Feb 2014 04:00	240	11	15	15
23 Feb 2014 05:00	200	21	26	26
23 Feb 2014 06:00	210	16	21	30
23 Feb 2014 07:00	210	25	30	30
23 Feb 2014 08:00	220	20	26	29
23 Feb 2014 09:00	220	23	29	29
23 Feb 2014 10:00	220	22	27	30
23 Feb 2014 11:00	210	24	30	30
23 Feb 2014 12:00	220	22	32	32
23 Feb 2014 13:00	210	23	31	37
23 Feb 2014 14:00	210	23	31	33
23 Feb 2014 15:00	210	27	37	39
23 Feb 2014 16:00	210	33	45	45
23 Feb 2014 17:00	210	33	43	44
23 Feb 2014 18:00	210	37	45	46
23 Feb 2014 19:00	220	39	47	47
23 Feb 2014 20:00	210	33	44	47
23 Feb 2014 21:00	200	34	44	48
23 Feb 2014 22:00	210	32	42	45
23 Feb 2014 23:00	200	31	42	46

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10-201	Bulk carrier *TPC Wellington*, double fatality resulting from enclosed space entry, Port Marsden, Northland, 3 May 2010
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11-201	Interim Factual report - Passenger vessel *Volendam*, lifeboat fatality, port of Lyttelton, New Zealand, 8 January 2011

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