Commonwealth of Massachusetts
Division of Marine Fisheries
251 Causeway Street, Suite 400
Boston, MA 02114
(617) 626.1520
Fax (617) 626.1509

Dear Interested Readers,

This report represents results from the laboratory portion of a project by the Division of Marine Fisheries and the Atlantic Offshore Lobstermen's Association to test the durability of different brands of sinking groundline. A line-testing machine was developed specifically for this project to simulate wear over time. While our preliminary results are useful and informative, they do not constitute an endorsement of a specific brand of groundline. Fishermen consider many factors when deciding what groundline to purchase -- how a line handles, how a line fishes, how it sounds in the hauler, etc. Fishermen will make a final decision to balance costs and performance based on many factors not examined by this study. DMF and AOLA are currently working on the field-testing component of this project, providing selected lobster fishermen with samples of line that performed well on the testing machine. These promising lines will be configured as groundlines and fished by offshore trap fishermen in the field for no less than two years.

If you have questions about the results or the continued progress of the project, contact Dick Allen (rballen@cox.net), Erin Burke (erin.burke@state.ma.us), or Bonnie Spinazzola (bonnie@offshorelobster.org).

Evaluation of the Performance, Characteristics, and Economic Feasibility of Non-Buoyant Rope for Groundlines in the Atlantic Offshore Lobster Fishery.

Phase 1: Development of Line Tester and Protocols, and Preliminary Testing of Lines.

Submitted to the
National Fish and Wildlife Foundation
and NOAA Fisheries

July 31, 2005

From

Edward Lyman, former Protected Species Specialist
Erin Burke, current Protected Species Specialist
Daniel McKiernan, Acting Deputy Director
Division of Marine Fisheries
251 Causeway St., Suite 400
Boston, MA 02114

Richard Allen, Fisheries Consultant
35 Bliss Rd, Wakefield, RI 02879

Bonnie Spinazzola, Executive Director
Atlantic offshore Lobstermen's Association
114 Adams Rd., Candia, NH 03034

John Kenney, Fisheries Engineer
NMFS Protected Resources Division, NER
Gear Research Team
P.O. Box 1692, N. Kingstown, RI 02852

Mitt Romney, Governor
Ellen Roy Herzfelder, Secretary to Executive Office of Environmental Affairs
David Peters, Commissioner of Department of Fish and Game
Paul Diodati, Director

Massachusetts Division of Marine Fisheries

Abstract:

Massachusetts Division of Marine Fisheries worked with the Atlantic Offshore Lobstermen's Association, the cordage industry, fishermen, and NOAA Fisheries to find and/or develop "optimal" non-buoyant lines for use by the offshore lobster industry to lower groundline profiles and thereby reduce the risk of entanglement. For the lobster industry, "optimal" are lines that do not degrade due to abrasion from contact with the substrate, are strong enough to withstand hauling loads, and are not substantially more expensive than currently used rope products. The study canvassed the trap-fishing industry to determine what non-buoyant lines were already being used, designing and fabricating a line-testing machine, and subsequently testing lines in a controlled lab setting to measure line durability as a precursor to testing lines in the field. Over 700-groundline surveys were sent out to pot/trap fishermen along the East Coast of the United States between Maine and Virginia. Of these, 161 were returned, representing a 23% response rate. Ten lines provided by 7 different manufacturers/ distributors were successfully tested on the specially designed line-testing machine that simulated the wear resulting from contact with a sandy substrate and being hauled under great loads. Promising lines from machine testing will be tested in the field. Lines that maintained higher breaking strength or exhibited little loss of strength were considered promising. Lessons learned from this testing will be used to improve and manufacture non-buoyant lines that are practical alternatives to floating lines for offshore pot/trap fishermen and pot/trap fishermen as a whole, and thereby greatly reduce the threat of entanglement for endangered whales, like the North Atlantic right whale. Line testing will continue in order to improve upon lines tested here and to test additional lines that manufacturers provide as they step up to meet the challenge.

Background:

Entanglement in fixed-fishing gear is a threat to many marine mammals, especially the critically endangered North Atlantic right whale (Knowlton and Kraus, 2001; Knowlton *et al*, 2002; and Kraus, 1990), for which only about 350 remain. Pot/ trap gear (hereafter referred to as 'trap gear') is one of the primary types of fixed-fishing gear. Trap gear, configured as a trawl, consists of multiple traps or pots connected together by a single line. They are comprised of a "groundline" (or "mainline"), which is the line that connects the traps to each other, gangions, which are short lines that connect the traps to the groundline, and a "buoyline", which is the line that connects the traps (and groundline) to a surface buoy system.

The type of line that is used for groundline varies according to local bottom conditions, the type of trap fishery, and evolved customary practice. In inshore areas with rocky bottom, fishermen typically use floating groundlines so that the line will not get wedged under rocks ("rock down") or abrade against the substrate. This reduces gear loss and can extend the lifespan of the line. Floating groundline also enables fishermen to find and recover trawls that have lost their buoylines. Most depth sounders are capable of displaying a floating arc of line above the substrate. Floating groundlines allow fishermen to more easily retrieve trawls by towing a grapnel hook perpendicular to the trawl hoping to hook onto the trawl mainline. In inshore areas with few hangs and a high trap density, sinking rope is commonly used to avoid snagging another fisherman's groundline.

The trap-fishing industry prefers to use groundlines that float for several other reasons. Floating line is typically comprised in part or entirely of polypropylene, making it less expensive than sinking line, which typically includes varying amounts of more expensive polyester. In addition, the high density of sinking line means that the same length of line weighs more. Line is sold by the pound, meaning that heavier line is more expensive for the same length. Currently, sinking polyester line is about three times as expensive as floating polypropylene line of the same length and size.

Floating line is the standard in the offshore lobster trap fishery. Offshore trap fishermen choose this product over sinking line for economic reasons, but also because sinking line picks up sand particles within the lay of the line. Offshore fishermen reported that sediment particles in non-buoyant lines act like sandpaper as the line is being hauled, destroying both the line itself and the equipment that hauls it. The heavy strain and twisting action that occurs when offshore trawls are hauled up from great depth may intensify the grinding action of the sand in the line.

However, the use of floating line results in arcs in the water column. The height of these arcs depend on how the gear is configured (e.g. the distance between traps), how taut the groundline is, which depends on setting speed and direction in relation to the current, and environmental conditions (e.g. sea state, windage, and currents). Division of Marine Fisheries (*MarineFisheries*) observations in 1997 using a remote operated vehicle (ROV) to look at inshore trap gear demonstrated that the use of floating lines produced groundline arcs that were 10 to 18 feet above the substrate (Carr, 1998). *MarineFisheries* went on to further quantify these arcs through the use of SCUBA and demonstrated floating groundline in Cape Cod Bay (CCB) arc on average 18 feet of the bottom (McKiernan *et al*, 2002). *MarineFisheries* using mini-loggers to profile floating groundlines recently demonstrated the dynamic nature of groundline arcs by showing that the arcs of inshore trap gear ranged from 1 to 21 feet off the ocean floor (Lyman and McKiernan, unpublished 2005). Groundline height varied as a function of tidal currents, with the maximum heights being reached at slack tide. The average height of these arcs over time was just over 8 feet. The same logger profiling demonstrated that the floating groundline arcs of offshore trap gear ranged from 3 to 40 feet off the ocean floor, with an average height of 17 feet.

Unfortunately, groundline arcs increase the potential for whale entanglement if the whale is feeding near or traversing along the bottom. Both humpback and right whales have been shown to feed and travel along the bottom. (Baumgartner and Mate, 2003; Goodyear, 1993; Wiley and Goodyear, 1998). Distributional studies of these whales' forage also suggest that these animals may routinely use the lower portion of the water column (Mayo, personal communication). Groundlines from the trap fisheries have been shown to entangle all large whales. (Johnson *et al*, 2005; NMFS stock assessments, 1991). It has been determined that requiring the use of non-buoyant groundlines for the

lobster industry would eliminate approximately 85 percent of the line within the water column, thereby greatly reducing the likelihood of entanglement (66 FR 59394).
Since 2004, trap fishermen in Cape Cod Bay have been required to fish non-buoyant groundlines year-round. Other Massachusetts inshore trap fishermen have also begun to replace their floating line with non-buoyant alternatives. In the fall of 2004, *MarineFisheries* partnered with the International Fund for Animal Welfare (IFAW) in a National Fish and Wildlife Foundation-funded buyback program to assist coastal Massachusetts lobster trap fishermen in replacing their floating line with non-buoyant line. Many fishermen took advantage of this opportunity and it is estimated that nearly all coastal Massachusetts fishermen will be using sinking groundlines in the near future.

MarineFisheries' position has been that the most effective strategy to reduce entanglement is to lower the profiles of groundlines by prohibiting the use of floating line in that portion of the gear, but at the same time the use of the non-buoyant line should be practical and safe for the fishermen. Offshore fishermen, working with NOAA Fisheries, have tested so-called ”neutral-buoyant” line (line with a specific gravity close to that of seawater) as an alternative to floating groundlines with only limited success (Salvador and Kenney, 2002). Some fishermen reported that these lines did not hold up well. More work was necessary to find a practical non-buoyant alternative to floating groundline for the offshore lobster industry.

II. Statement of Problem:

Although some lobstermen have begun to replace floating line with non-buoyant alternatives, long-term durability issues have not been fully resolved. This is especially true among offshore lobstermen, which have reported little success with non-buoyant lines. The reported internal abrasion caused by sand within the lay of the lines results in rapid degradation of the line, often within one year. A satisfactory line(s) that are both low in profile (non-buoyant) and durable for the fishing industry needed to be found.

III. Objectives:

This project responds to the potential entanglement risk of whales in offshore lobster trap trawl gear configured with floating groundlines. *MarineFisheries* has teamed up with the Atlantic Offshore Lobstermen’s Association (AOLA) and NOAA Fisheries to work with fishermen and the cordage industry to find or develop an “optimal” non-buoyant line for use as lobster trap groundlines in order to lower groundline profiles and thereby reduce the risk of entanglements with large whales. For the lobster industry, “optimal” will be lines that do not degrade due to abrasion from substrate contact, are strong enough to withstand hauling loads, and are not substantially more expensive than currently used rope products.

IV. Methods:

<u>Surveying the Fishing Industry:</u>

A survey was designed and mailed to over 700 fishermen from Maine to Virginia to canvass both the inshore and the offshore trap fishery on the relative use of buoyant and non-buoyant lines, current line types in use with their associated advantages and shortcomings, and summarize the progress on existing line types that are being fished as alternatives to floating line.

<u>Cordage Industry:</u>

Line manufacturers and distributors supplying the fishing industry on the East Coast were interviewed to determine their capability and interest in producing non-buoyant rope suitable for use as groundline for the offshore lobster trap fishery. The special problem of internal abrasion under heavy hauling loads was emphasized in these discussions. A meeting of rope manufacturers and distributors was held on April 28, 2004 at *MarineFisheries'* Annisquam River Marine Laboratory in Gloucester, MA.

<u>Line Testing Machine:</u>

A line-testing machine that simulates and accelerates some of the long-term wear and tear on trap trawl lines was completed in January of 2004. The machine was designed by Richard Allen and subsequently fabricated by Rhode Island Engine Company of Narragansett, RI. The testing machine subjects non-buoyant test lines to a sand substrate representing a generalized offshore environment by allowing the line to lay in a relaxed (no load) state for a period of time within a 12-foot long basin of sand and water. The test line is then subject to a load typical of hauling offshore lobster gear from great depths by running the line between a 16" trap hauler and an 11" diameter drum working against each other. The cycle of simulated set and haul is repeated for a predetermined number of times before the line is tension-tested to provide a quantifiable comparison. The simulator/ tester is housed at the *MarineFisheries'* Annisquam River Marine Station in Gloucester, Massachusetts.

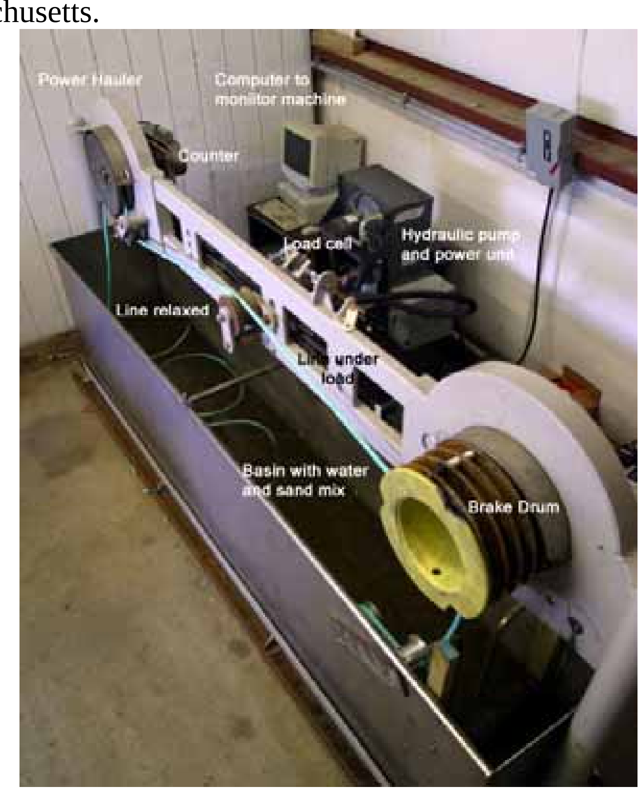


Figure 1: Line testing machine.

Preliminary Test Runs:

Preliminary test runs were made on the machine to establish testing protocols. However, analysis of these early test runs and the results of a meeting held with the cordage industry on April 28, 2004 determined that modifications to the testing machine were necessary to account for certain variables and reduce the affect of others. Some of these modifications, included the replacement of a pot hauler acting as a brake with a 11” diameter drum, mentioned above, to better reduce line slippage; the fitting of a helical plate around the drum to guide the test line; the replacement of the drive pump with a higher capacity pump and sprocket system; the installation of a pressure reducer valve on the brake side to allow the power side to “haul” under greater loads; and the filling and plating of machine components to reduce machine wear. With these modifications, and others suggested by the industry, protocol runs were resumed and another 23 test runs were made.

In part, some of these preliminary runs were made to establish comparisons with known line use in the field. To this end, over 45 line samples, many representing lines retired by fishermen after use in the field, were tension-tested to their breaking point by John Kenney of the NOAA Fisheries Gear Research Team. Beginning in September 2004 an additional 20 test runs were performed on floating lines to determine at what load and for how many cycles (hauls) the machine needed to run to approximate the breaking strengths found for floating line in the field as determined by the tension-tests.

Testing Protocols:

Over 140 hours of line testing and another 200 hours in modifying the testing machine were logged prior to formal line testing. The effort was successful and provided a testing protocol of 250 test cycles or simulated hauls, and an in-line load during the haul of approximately 1160 pounds. These values represent the average number of hauls of offshore gear during its lifespan, and the average haul load of a 40-trap offshore trawl from approximately 175 fathoms depth. The average number of hauls of offshore lobster gear was derived as a product of the average number of hauls per year, and the average lifespan of offshore groundlines. Here, the lifespan of a line is the length of time that the fisherman deems the line usable as offshore groundline. Survey results indicated that offshore lobstermen haul their gear as many as 50 times per year, and that trawls configured with floating groundlines have an average lifespan of approximately 5 years. Hauling loads on differently configured offshore lobster trawls were obtained by the NOAA Fisheries Gear Research Team by attaching archiving load cells to the gear during their hauls (Salvador and Kenney, 2002). Offshore lobstermen whom we consulted agreed that while this load did not represent maximum loads the lines could be subjected to; it was a good representation of the average load placed on offshore gear.

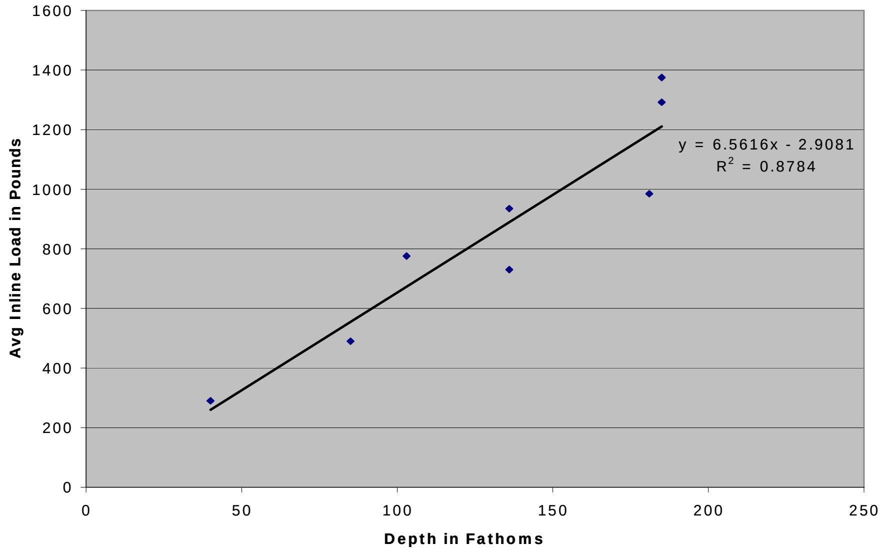


Figure 2: NOAA Fisheries Gear Team data showing relationship of average haul load to depth of set for offshore lobster gear.

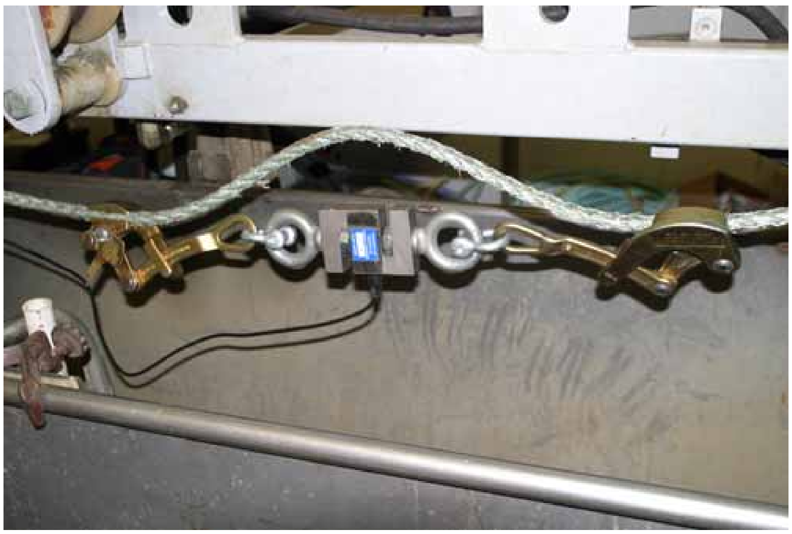


Figure 3: Using an electronic load cell and line clamps to measure in-line load of a line running on the testing machine

For our testing, in-line load was measured directly at the beginning and end of every test run by using line clamps to secure an electronic load cell in line and running it between the brake drum and pot hauler. The in-line load was determined by taking the average of the 3 to 5 highest load values during the run. Load was monitored for consistency during the test run by running the line over a levered fairlead roller that was attached to the load cell. Load values were recorded to a computer.

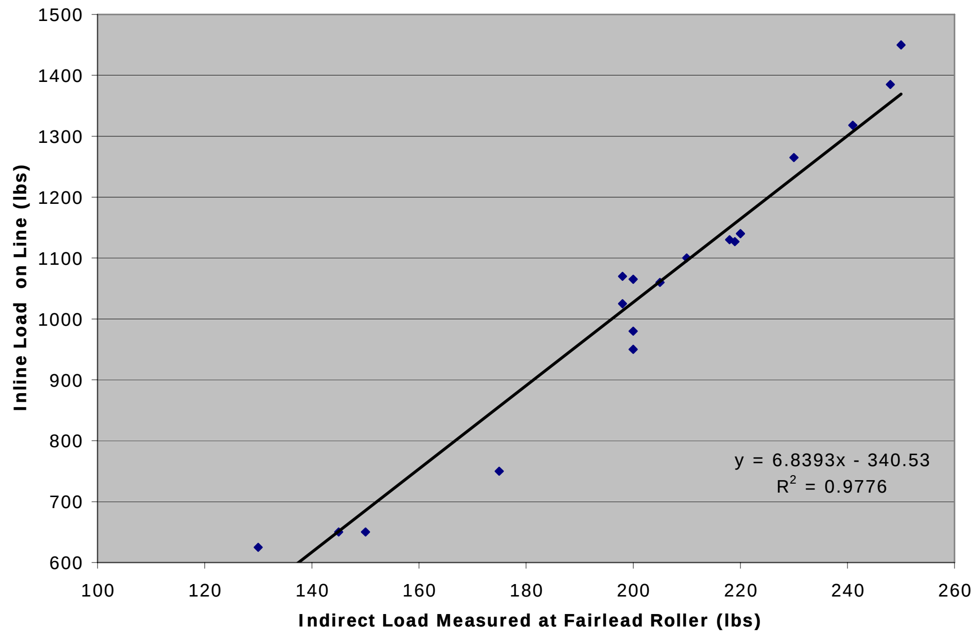


Figure 4: Comparison of in-line load measured directly to that measured indirectly off the levered fairlead roller.

Over time indirect measures of in-line load were plotted against direct measures of in-line load to arrive with an equation (linear regression) of the relationship between them (Figure 4). Indirect load measures were then compiled and converted to in-line load using the equation (y = 6.8393X – 340.53) to show consistency and arrive at an average load the test line was subjected to during the run.

Substrate Composition:

While bottom composition varies throughout the Gulf of Maine's offshore waters, a mix of sand particles made up of masonry sand and silt was used to approximate the average bottom-type of sandy offshore environment. Particle size was quantified by running a sample of the substrate through a set of sieves, drying the separated sub samples, and weighing them for comparison. For the most part (>95% by weight) sand particles ranged in size between .0049" and .0787" in size (see Figure 5). The sand substrate was raked between every test run and a cell of water between 6 – 9 inches deep was maintained. Sand that tended to aggregate at one end of the tank (the hauled end) was removed and redistributed between and during test runs.

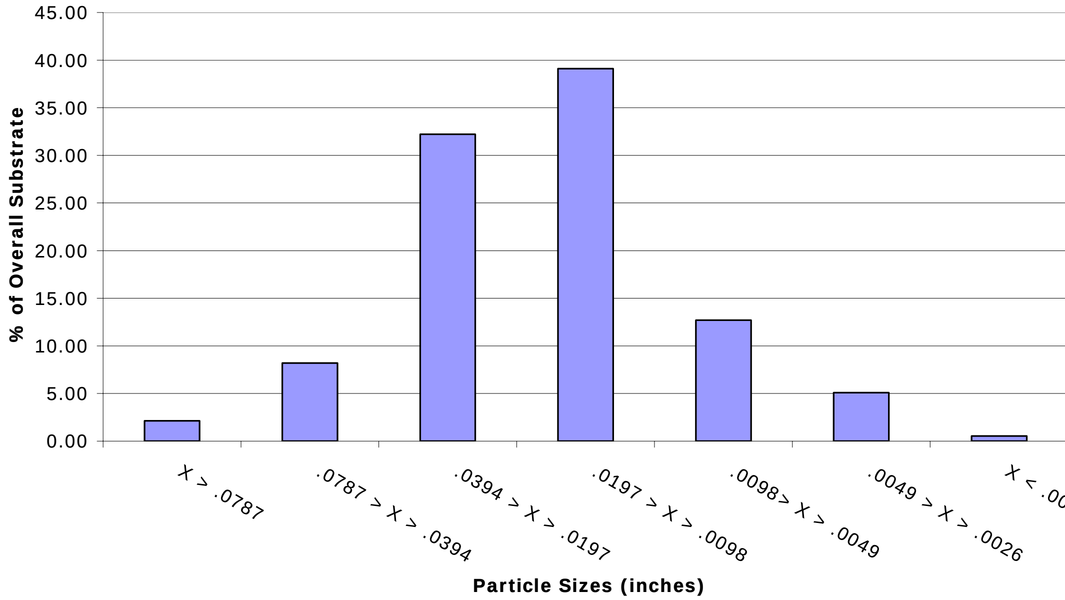


Figure 5: Substrate particle size distribution in test machine basin.

<u>Line Testing:</u>

To date, 9 manufacturers have submitted 15 lines for testing. Five of these lines were categorized as inshore (line diameter less than 9/16") and 10 were categorized as offshore (line diameter 9/16" or greater). Since the objective of this study is the determination of a practical, non-buoyant offshore groundline, the offshore lines were prioritized and run first. The inshore lines will be run at a later date (See Section VII: Projected Activities).

Test lines were run on the testing machine for three repetitive runs. Each set of 10 lines was randomized within a repetitive run. To monitor any possible drift resulting from machine wear, the operation of the machine, and/or any maintenance, control lines represented by a single commonly used line type, Polysteel Atlantic Polysteel©, were run at the beginning and the end of each run. In between each run maintenance was performed consisting of: adjusting the water level, greasing fairlead rollers, and if necessary, providing a new splitter surface (either by installing a new splitter or turning over the existing splitter), changing the drum helix surface (accomplished by removing the helix, turning it around and remounting), and/or changing sheaves on the pot hauler. To reduce the wear and resultant friction at the helix, which was installed to allow the test line to ride off the drum on the loaded side, the helix was nickel-plated and Teflon coated. In addition, a sump pump was installed to draw water from the basin and over the helix to further reduce friction forces and remove any heat (an unwanted variable) that might result from any friction of the line against the helix.

Figure 6: Running a test loop of line on the testing machine.

Lines were mounted on the machine and spliced into a 47-foot loop using a “long splice” where no two splice points were close enough to fall in the hauler at the same time (30 wraps or approximately 24 inches apart). This provided for a more uniform load as the line ran through the hauler. Splices were made with 5 tucks in either direction and trimmed to within 3/4 inch.

At the beginning of each run, hydraulic pressure at the hauler, drum, and drive systems were adjusted to provide the correct load on the line as measured by the load cell at the center roller. While the length of the test loop was the same at the beginning of every test run, lines of slightly different diameters stretched over time, and occasionally parted and had to be re-spliced. Thus the number of clicks on the counter (which was re- zeroed at the beginning of each run) to accomplish one cycle was monitored over time. If stretching occurred or the test loop shortened due to re-splicing, the counter count was adjusted to maintain 250 cycles or hauls.

Each test run took approximately 4 hours to reach 250 cycles (simulating approximately five years of use), and another hour to setup and breakdown. Lines were spliced and the machine operated by either *MarineFisheries*’ Protected Species Specialist or a contracted local fishermen.   Both operators maintained strict operating protocols and logged all pertinent settings and observations for each test run.

Test lines were photographed before and after each test run. Samples of the lines were kept at DMF, sent to the line manufacturers and to Northwest Laboratories of Seattle for specific gravity and tension testing.

<u>Tension Testing:</u>

John Kenney of the NOAA Gear Research Team performed tension testing on all preliminary, calibration, and final line testing runs, as well as, on retired field-used lines. These early tension tests were used to establish protocols and an early association between lines used in the field to those tested on the machine. Three breaks were performed for each line tension tested. At first, lines were secured to the commercial-grade tension-testing machine by a bowline knot, but later were secured by custom–made line grips. Some tension tests were done to determine how the two methods of securing the line compared. The NOAA Fisheries Gear Team performed more than 250 tension tests.

Figure 7: John Kenney of NOAA Fisheries Gear Team performing tension tests.

Northwest Laboratories of Seattle also performed tension tests on the lines undergoing formal testing on the machine. As in the earlier tests, three breaks were performed on each test line and averaged to come up with break strength of the line. Test lines were secured around a 2” O.D. mandrel (or drum). However, the small drum diameter (for the 5/8” lines) was believed to compromise the line, resulting in lower tension test values. For this reason, only relative values of percent loss in strength were used from the Northwest Laboratory’s tests.

Specific Gravity Testing:

Northwest Laboratories of Seattle performed specific gravity tests for all test lines. Specific gravity was performed relative to freshwater, not saltwater, thus specific gravity equal to and greater than 1.03 (NOAA Fisheries criteria for non-buoyant line) were considered non-buoyant. The generalized specific gravity of seawater in the Gulf of Maine is listed as 1.023.

Field Component:
As a result of the lab-component, those sample lines that have high breaking strength rankings after having run on the machine will be purchased and distributed among the offshore fishing industry for field-testing. The field-component of the study will continue through the summer of 2006.

V. Results

Survey Results:
Of the 700-groundline surveys sent out to trap fishermen along the East Coast of the United States between Maine and Virginia, 161 were returned, representing a 23% response rate. However, two (2) of the returned surveys indicated that the fisherman was not fishing trawls. For the remaining 159 surveys, 104 were inshore fishermen and 55 were offshore fishermen. For our purposes "offshore" represents trap fishing effort in Lobster Management Areas (LMA) 3 or the LMA 2- LMA 3 overlap, while "inshore " represents pot/ trap fishing effort in LMAs 1, 2, 4, 5, 6, and/ or "Outer Cape Management Area". The lobster fishery was the predominant trap fishery represented, but fishermen from the hagfish and crab-trap fisheries also responded.

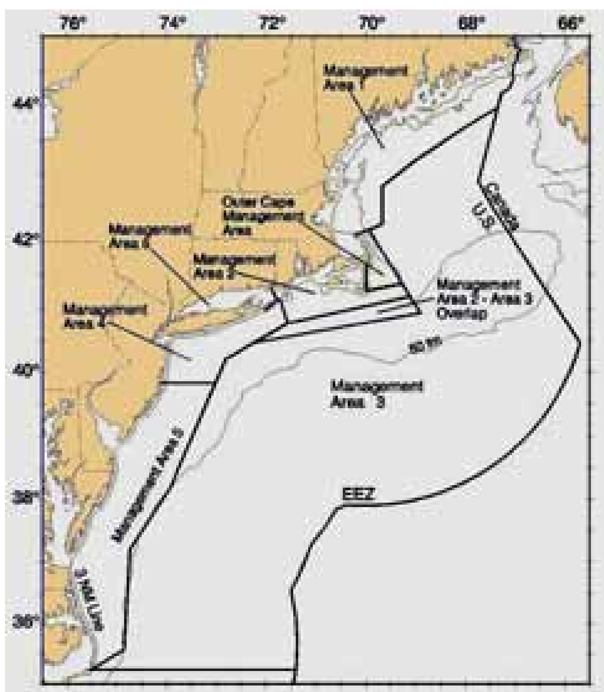


Figure 8: Lobster Management Areas (LMAs) for Northeastern US.

Though the survey does not represent random sampling, it indicates that of those inshore fishermen who responded, those using non-buoyant groundlines believed they fished a less rocky bottom (by 15%) and that their groundlines generally lasted a year longer (5.3 vs 6.3 years). There was however a large range in the use of sink line. Some fishermen had used it for several years (probably a result of regulations in CCB), while others had used it all their lives (30 + years). A small number (n = 9) of inshore fishermen indicated that they were using "neutral-buoyant" lines as their groundlines.

Of the 55 offshore fishermen who responded to the survey, 38 used float line and 17 used non-buoyant groundlines. Here the lifespan values were reversed with floating groundline lasting longer than the non-buoyant alternatives (5.25 years vs. 1.67 years). The difference in reported lifespan between the buoyant and non-buoyant lines was mostly a result of the low lifespan values (1.6 years) for the "neutral-buoyant" groundlines. Fishermen who used non-buoyant lines indicated that chafe was a major factor contributing to degradation. An outline of survey results is included in Appendix A.

<u>Cordage Industry:</u>

Nine rope manufacturers/distributors are actively participating and have already fabricated and submitted for testing over 15 types (samples) of line as potential "optimal" non-buoyant groundline. The lines range in size from 1/2" to 5/8" in diameter. A list of manufacturers/ distributors supplying lines under this study can be found in Appendix B.

<u>Specific Gravity Tests:</u>

Northwest Laboratories' specific gravity results for the test lines are shown in Table 1. The report from Northwest Laboratory providing specific gravity results and outlining the procedures on how specific gravity was determined is included in Appendix C.

Table 1. Results of specific gravity testing on study groundlines by Northwest Laboratories of Seattle.

Product	**Line ID**	**Type**	**Apparent Specific Gravity**
Everson 5/8"	L1	Neutral	1.073
Frank-Winne	L7	Neutral	1.064
Orion Ropeworks: Orco	L13	Sink	1.091
Portuguese 4-strand	L2	Sink	1.084
Anacko	L10	Neutral	1.033
Orion Ropeworks: Extra Lean	L14	Neutral	1.044
Orion Ropeworks: Hoverline	L12	Neutral	1.021 *
New England Ropes:Polycombo	L8	Sink	1.225
Polysteel Atlantic: Esterpro	L16	Sink	1.088
Polysteel Atlantic: Hydropro	L17	Neutral	1.107

* Line does not meet NOAA Fisheries criteria of non-buoyant line.

The apparent specific gravity is an estimate of the specific gravity of the line itself, not including anything filling spaces between threads of the line (such as air). The experimental results should be compared to a seawater specific gravity of 1.023. Lines with values less than 1.023 will generally float in the waters of the Gulf of Maine; those above 1.023 will generally sink. As results show all but one test line met the NOAA Fisheries' requirement of non-buoyant line, which is a specific gravity of 1.03. Orion's Hoverline, which is listed as "marginally non-buoyant" by the manufacturer, had a specific gravity of 1.021, and thus does not meet the definition of non-buoyant line. It is, however, very close to the generalized specific gravity of seawater in the Gulf of Maine. In colder, deeper water, the specific gravity of seawater is slightly higher than 1.023.

Testing Machine/ Simulator:

Three repetitive test runs for each of the 10 test lines and buttressed (prior to and after test line runs) control lines were run on the simulator/ testing machine between March 24 and May 13, 2005. A log of these test runs, including parameters measured and noted is included in Appendix D. The operation log also provides qualitative information on whether lines had to be re-spliced, their noise level in the hauler, whether the line squared up in the hauler, how much the line stretched, and how they generally ran (hauled) in the machine.

As another means of documenting a line's performance in the line tester, digital images were taken of each line prior to and after each test run. These images can be supplied upon request. Figure 9 provides two examples of how lines looked prior to and after line testing.

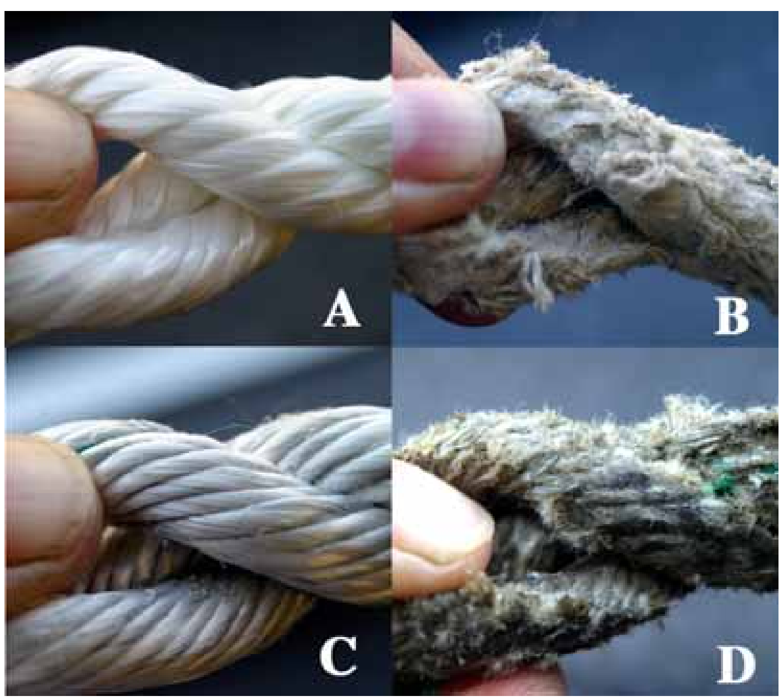


Figure 9: Comparison of lines before and after being run on the test machine. A) Line 1 before, B) Line 1 after, C) Line 2 before, and D) Line 2 after.

There appears to some early indications of drift, or change in results over time, as a result of machine operation. In other words, as the table in Appendix E and Figure 8 below show there was a small decrease in breaking strengths of the polysteel control lines over time that have been tension-tested to date. An additional three control lines have yet to be tension-tested and could provide more insight into any possible machine drift. However, a close look at the tension-testing results of the test lines themselves over time show no such decrease (drift) of breaking strength over time (see Appendices E and F). Figure 10 illustrates the tension tests results of the control lines plotted over time.

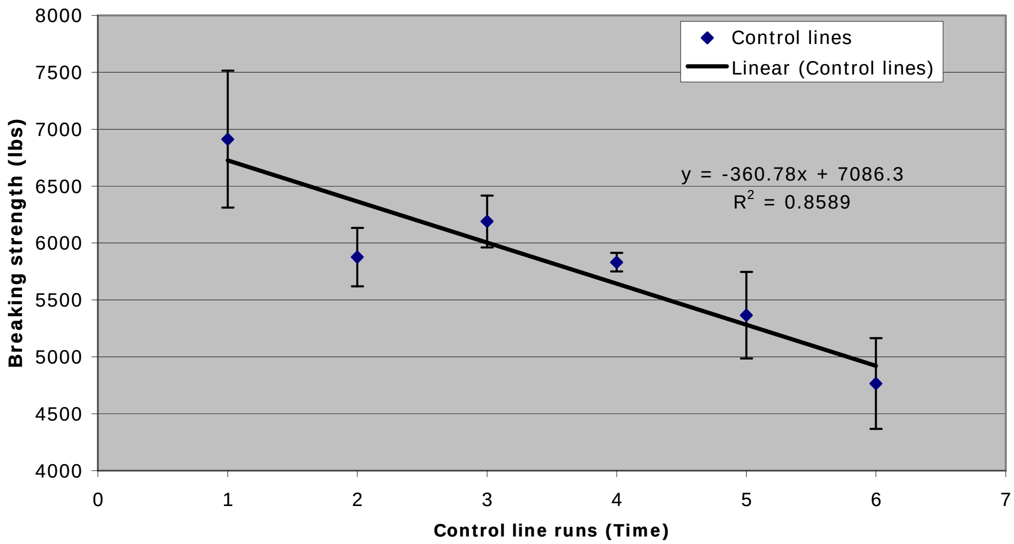


Figure 10: Comparison of average breaking strengths of control line over time (vertical lines represent 95% confidence intervals)

Another important parameter was maintaining a constant in-line load on the test lines during the test run. The table in Appendix G, showing the average and 95% confidence intervals of load applied to the central fairlead roller during the test runs, indicates that loads were similar and variation was small over the test runs. While in-line load values, which were measured directly and derived indirectly from the fairlead load on the line, may have varied by several hundred pounds during test runs, the overall average load applied to the line varied very little. This is shown in Table 2, which provides each line’s average load for each run and the average load for all the lines’ runs. Derived and averaged in-line loads for all runs ranged between 1134 and 1172 pounds. The average in-line load for each test line over all three runs ranged between 1147.3 to 1169.8 pounds; a difference of only 22.5 pounds, and averaged 1156.7 pounds over all runs and all lines.

Hauls speeds varied between 43 and 60 feet/ minute; much of the variation a result of the different line diameters of the test lines. Each cycle or haul on the machine typically took between 50 to 60 seconds. Approximately 18 percent of the cycle had the test line under load, representing the hauling of traps from depth, while about 36 percent of the cycle had the test line relaxed and in contact with the substrate, representing the setting of traps. The remaining 46 percent of the time the test line was either falling off the hauler or running to and around the drum.

In an attempt to establish a connection with or calibration of lines tested on the machine to those used in the field, retired floating groundline was tension-tested and compared to tension-test results of floating lines (Polysteel) run on the machine. “Retired” lines were those lines that fishermen deemed no longer usable. Of the lines collected from fishermen, six met this criteria of “retired” and had breaking strengths of 5398, 7373, 8079, 6003, 7655, and 7655 pounds. This works out to an average breaking strength of 6710 pounds or approximately 33.9% loss in strength. The Polysteel lines run as controls on the machine ended up with an average of 42.6% loss in strength. This indicates that the machine was wearing the lines to the same degree (actually slightly beyond) that has been found in the field.

Table 2: In-line loads for all test runs

Test Line	Run 1	Run 2	Run 3	Mean	STD
Everson 5/8”	1153.9	1165.5	1143.6	1154.3	62.5
Frank-Winne	1158.0	1157.3	*	1157.6	49.1
Orion Ropeworks: Orco	1171.0	1171.0	1151.8	1164.6	63.0
Portuguese 4-strand	1172.3	1170.3	1166.9	1169.8	58.5
Anacko	1140.2	1144.3	1157.3	1147.3	52.7
Orion Ropeworks: Extra Lean	1153.2	1149.1	1166.2	1156.2	67.7
Orion Ropeworks: Hoverline	1134.0	1152.5	1161.4	1149.3	63.8
New England Ropes:Polycombo	1135.4	1162.1	1166.9	1154.8	64.1
Polysteel Atlantic: Esterpro	1153.9	1158.0	1123.1	1145.0	79.5
Polysteel Atlantic: Hydropro	1146.3	1154.5	1173.0	1157.9	55.7

* Test line failed prior to reaching required number of cycles.

The results of tension tests performed by NOAA Fisheries Gear Team for each line run are shown in Appendix F, while results of tension tests performed by Northwest Laboratories are shown in Appendix G. Both suites of tension tests indicate that breaking strength values within each line were fairly consistent between runs. Results of Northwest Laboratory’s tension tests are summarized in Table 3, while results of NOAA Fisheries’ tension tests are summarized in Table 4.

Table 3: Breaking strength results from Northwest Labs.

Product	Breaking strength: of new lines *	Breaking strength: post machine	% loss in strength	Ranking using % loss of strength #
Everson 5/8”	6400	4571	28.6	1
Frank-Winne	6040	2630	56.5	8
Orion Ropeworks: Orco	6913	4084	40.9	4
Portuguese 4-strand	8323	4533	45.5	6
Anacko	5840	3662	37.3	2
Orion Ropeworks: Extra Lean	5933	2780	53.1	7
Orion Ropeworks: Hoverline *	7667	4740	38.2	3
New England Ropes:Polycombo	6540	2438	62.7	10
Polysteel Atlantic: Esterpro	6900	3940	42.9	5
Polysteel Atlantic: Hydropro	8500	3693	56.5	9

* Orion’s Hoverline was positively buoyant in seawater.
# Lower rank numbers are better.

Table 4: Breaking strength results from NOAA Fisheries Gear Team.

Product	Breaking strength: of new lines *	Breaking strength: post machine	Ranking using breaking strengths	% loss in strength	Ranking using % loss of strength #
Everson 5/8”	9658	5745	2	40.5	2
Frank-Winne	7249	2743	10	62.2	9
Orion Ropeworks: Orco	9442	5154	4	45.4	3
Portuguese 4-strand	10196	5381	3	47.2	5
Anacko	8938	4182	7	53.2	7
Orion Ropeworks: Extra Lean	7092	3408	8	51.9	6
Orion Ropeworks: Hoverline *	10020	7043	1	29.7	1
New England Ropes:Polycombo	10664	3187	9	70.1	10
Polysteel Atlantic: Esterpro*	9419	5113	6	45.7	4
Polysteel Atlantic: Hydropro*	11228	5144	5	54.2	8

Lower rank numbers are better
* Represent data from only two runs.

As the results indicate some lines maintained higher breaking strength values, while others did not. There appeared to be no correlation between the specific gravity of the lines (their density) to their performance as quantified by their percent loss in breaking strengths (Figure 11).

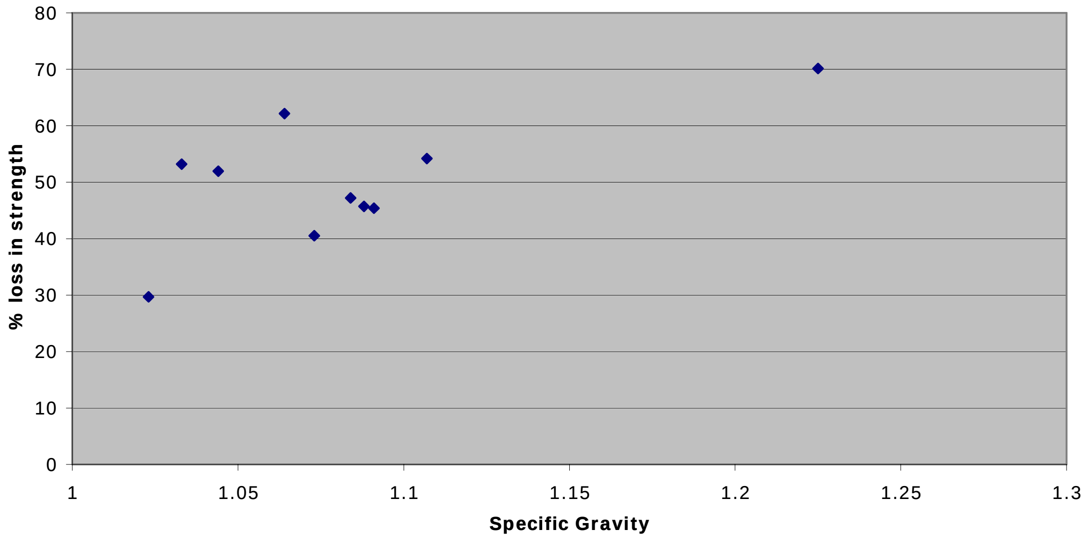


Figure 11: Comparison of % loss of breaking strength to specific gravity of the line.

The non-buoyant lines that performed best in terms of breaking strengths and the relative measure of percent loss in breaking strength were the Everson neutral-buoyant, the Portuguese 4 –strand, the Orion Orco, the Anacko neutral buoyant lines, and the Polysteel Atlantic Esterpro and Hydropro. Though, the Orion Hoverline did not lose much strength on the machine, it also did not meet the definition of a non-buoyant line with it specific gravity of 1.021. The Frank-Winne sink line and New England Rope Polycombo lines as they now stand had low ranking performances, and the Orion Extra Lean had moderate ranking based on their breaking strengths after having run on the machine.

While some line's splices failed before reaching the required 250 hauls, many did not. However, those splices that did not fail still showed signs of wear, both externally and internally. Sand particles did impregnate the lay of the lines, but it was more apparent at splices, whether they failed or not, which were typically laden with sand. Splices were more open to the environment as a result of the back tucking required to make the splice. The amount of sand found within the lay of the line and at splices between lines did vary. Lines with polyester cores became wetted (saturated with water) and were found to have large amounts of sand adhered to their surfaces.

VI. Discussion and Conclusions:

Machine Validity:

The goal of this line tester was to provide a controlled setting in which to compare how several environmental factors, namely contact with a sandy substrate, affect the durability (strength) of lines, and thereby their lifespan and associated cost of use. One indication that the testing machine may have been successful in achieving this goal is the fact that breaking strength values of lines tested on the machine were comparable to those found for retired lines used by fishermen in the field. This is important since the comparison of lines run on a machine would not be valid if they were not being worn to nearly the same point as those used in the field by fishermen. While no line testing machine could ever entirely simulate or subject a line to all variables that would affect the line out in the field, they can come close, and at the same time account for variables that otherwise could not be accounted for or measured out in the field.

Close inspection of lines after testing indicated that there was indeed internal abrasion as a result of the sand substrate impregnating the line. While the machine probably provided additional external wear on the test lines compared to what might be found out in the field, the external wear was most likely minimal and only a factor of the helix. The fact that floating lines, which were subject to the same external wear forces, exhibited less wear as measured by their breaking strengths, than their non-buoyant counterparts suggests that internal abrasion, not external abrasion, was a significant contributing factor to loss of strength.

The testing machine compared well to field-use by approximating an average haul load of line in the field (~1160 lbs) and the number of hauls (250) for the typical offshore lobster trap trawl. Discussions with fishermen and NOAA Fisheries' load cell work provided load values for hauling offshore lobster trap gear from depth. In this case the target load of 1160 pounds approximates the average haul load for hauling a 40-trap trawl of offshore gear from 175 fathoms of water. Survey results indicated that offshore lobstermen haul their gear as much as 50 times per year, and that trawls configured with floating groundlines have an average lifespan of approximately 5 years. This equates to 250 hauls, which is the number of hauls or cycles the machine was run. Though the machine's haul speed was much slower than that found in the field, it was deemed not to be as important a variable as the sand impregnation, hauling loads, and haul count.

In addition to having the machine simulate and account for variables that might wear non-buoyant lines in the field, these variables had to be held constant over time as not to affect one test line more than another. Many precautions were taken to do just this, including: a randomized testing order, routine maintenance, periodic running of control lines, and monitoring the haul load on the machine over time. As indicated in the results, average haul loads for each test line differed very little. The fact that none of the test lines showed any drift or trend in breaking strengths over time attests that to the success in achieving this goal.

It appears that the line-testing machine does indeed provide a controlled environment that approximates the wear on lines resulting from contact with a sandy substrate. The similarities in wear, as indicated by their breaking strength values, between lines tested on the machine to those used in the field, along with similar haul loads and haul counts, suggests that there is a correlation between the two. Comparison of future field-test results with machine-tested lines may strengthen this association making the line testing machine an even more useful tool for testing lines.

Breaking Strength Results:

Overall, the testing machine provided preliminary results that can be used by the fishing industry in choosing non-buoyant lines currently available and by the cordage industry to improve the desirable characteristics of non-buoyant groundline. The first suite of 10 line tests indicated that several lines provided high rankings on tension test values, and on relative loss of strength. These lines were: the Portuguese-made 4-strand sink line, Anacko neutral buoyant line, Orion's Orco sink line, Everson Cordage neutral buoyant lines, and the Polysteel Atlantic Esterpro sink line and Hydropro neutral-buoyant line. The Orion Extra Lean provided moderate rankings, while the Frank-Winne sink line and New England Rope Polycombo lines provided lower rankings of tension test values after having run on the machine. One of the line brands – Everson - was also listed in the survey results as a popular alternative to floating line. The three lines at the bottom of the ranking also tended to fail more often than the others during the test runs and had to be re-spliced during several test runs and in some cases multiple times. One line – the Orion Hoverline- did not meet the NOAA Fisheries – derived definition of a non-buoyant line, of specific gravity of 1.03 or greater.

While there was a difference in breaking strengths between the buoyant and non-buoyant lines, there was no discernable difference or correlation between breaking strengths and the specific gravities of the lines within these groupings. In other words, for the few lines tested here, heavier non-buoyant lines did not wear more or have lower breaking strength values than the lighter non-buoyant lines. This would suggest that other factors, such as how the materials are woven, the lay of the line, and material content, may be more a factor for determining endurance to wear, than the "weight" of the line or degree of contact with the substrate.

Other Important Factors in Line Choice:

Here we used a line's breaking strength after wear testing to quantify its durability to a sandy substrate in a controlled lab setting, as well as in the field. However, the cost of individual lines is not addressed in this study. As fishermen choose a non-buoyant alternative to their floating line, they will have to make individual business decisions in order to balance cost with a line's measured durability. Additionally, fishermen may consider how a line handles, fishes, and sounds in the hauler. In the end, the fisherman will make the final choice balancing cost and performance that include factors not examined by this study.

Ancillary Results:

This project represents the first instance of objective operational testing of trap fishing components by focusing on line performance using standard trap hauling equipment. However, this project also provided insights on other components of the hauling system that warrant investigation in terms of their impact on the durability of groundlines, and the resulting expense associated with using non-buoyant groundlines. In particular, the bend radius that groundlines are subjected to as they run through fairlead blocks to the hauling discs may be critical. The project results also raise the question of whether an alternative to the standard hauling discs that are universally used to haul lobster traps should be investigated. Whereas the testing machine has demonstrated the feasibility of simulating years of actual use in a few hours, research on other aspects of the hauling system may now offer additional benefits.

VIII. Projected Activities:

Line Testing:

The line testing outlined in this report represents a suite of preliminary tests done on 10 lines provided by 7 different manufacturers/ distributors as practical non-buoyant alternatives to buoyant groundlines that are presently being used by the offshore trap fishing industry. Additional machine testing will be performed on lines that have been improved upon based on results of initial testing, represent newly available alternatives to buoyant line not yet tested on the line-testing machine, and/ or represent non-buoyant line alternatives for the inshore trap fishery. Future line testing will be performed as outlined in this report and may require additional funding to support.

Field Component:

Field-testing will involve providing selected lobster fishermen with samples of line that performed well on the testing machine. “Well” means having a high ranking based on breaking strength tests after having been run on the line-testing machine. These promising lines, which may also include future lines tested on the machine, will be configured as groundlines, as part of a trawl, and fished by offshore trap fishermen in the field for no less than two years. Samples of these field-tested lines will be tension-tested annually to quantify just how well they perform (based on breaking strength testing) *in situ* or in actual conditions.

Machine Component Wear:

The line-testing machine has already provided some insight on how different components of the trap hauling system are impacted, and how these components in turn might impact the durability of groundlines that are in contact with the substrate. For the purpose of increasing the lifespan and thereby reduce the economic impact of using non-buoyant lines, we propose to test machine component wear of the trap hauling system on line by investigating the use of an entirely different hauling system, and through the use of different machine components on the existing hauling system. Funds have been requested of the NFWF for this investigation in the Massachusetts Right Whale Conservation Program 2006 grant proposal.

VIII. Acknowledgements:

This project acknowledges the collaborative effort between the Atlantic Offshore Lobstermen's Association, Massachusetts Division of Marine Fisheries, the NOAA Fisheries Gear Research Team, line manufacturers and distributors, and many pot/ trap fishermen, including Michael Frontiero for his assistance in operating the testing machine. The National Fish and Wildlife Foundation and NOAA Fisheries provided funding support through the Whale Conservation Fund and direct support for the Commonwealth's Right Whale Conservation Program.

IX. References:

Baumgartner, M. and B. Mate. 2003. Summertime foraging ecology of North Atlantic right whales. *Marine Ecology Progress Series* 264:123-135.

Carr, A., 1998. *In Situ* Observations of Lobster Gear. Unpublished report submitted to Massachusetts Division of Marine Fisheries, 50A Portside Drive, Pocasset, MA 02559.

Clapham, P. 2001. Right whale entanglements: gear analysis. Unpublished report available from the Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

Federal Register/ Vol. 66, No / Notices

Goodyear, J. D. 1993. A sonic/radio tag for monitoring dive depths and underwater movements of whales. J. Wildl. Manage. 57(3), 503-513.

Johnson, A., G. Salvador, J. Kenney, J. Robbins, S. Kraus, S. Landry, and P. Clapham. 2004. Analysis of Fishing Gear Involved in Entanglement of Right and Humpback Whales. Marine Mammal Science (in press).

Knowlton, A. and S. Kraus. 2001. Mortality and serious injury of Northern right whales (*Eubalaena glacialis* in the western North Atlantic. International Journal of Cetacean Research and Management. In press.

Knowlton, A., M. Marx, H. Pettis, P. Hamilton, and S. Kraus. 2002. Scarification analysis of North Atlantic right whales (*Eubalaena glacialis*): Monitoring rates of entanglement interaction. Final report to the US National Marine Fisheries Service (unpublished). Available from the New England Aquarium, Central Wharf, Boston, MA.

Kraus, S. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). Mar. Mamm. Sci. 6(4):278-291.

Lyman, E and D. McKiernan. 2005. The use of mini-loggers in profiling fixed-fishing gear. Unpublished data. Massachusetts Division of Marine Fisheries, Annisquam River Marine Laboratory, 30 Emerson Ave, Gloucester, MA 01930.

McKiernan, D., M. Pol, and V. Malkoski. 2002. A Study of the Underwater Profiles of Lobster Trawl Ground Lines. Massachusetts Division of Marine Fisheries, 50A Portside Drive, Pocasset MA 02559.

National Marine Fisheries Service. 1991. Recovery plan for the Northern right whale (*Eubalaena glacialis*). Prepared by the right whale recovery team for the National Marine Fisheries Service. Silver Spring, Maryland.

Salvador, G. and J. Kenney. 2002. NMFS Large Whale Gear Research Summary. NMFS Gear Research Team.

Wiley, D., and J. Goodyear. 1998. Movement, habitat use, and subsurface behavior of right whales, *Eubalaena glacialis*, in Cape Cod Bay, Massachusetts based on multi-sensor telemetry. Final report submitted to Massachusetts Environmental Trust. 40 pp.

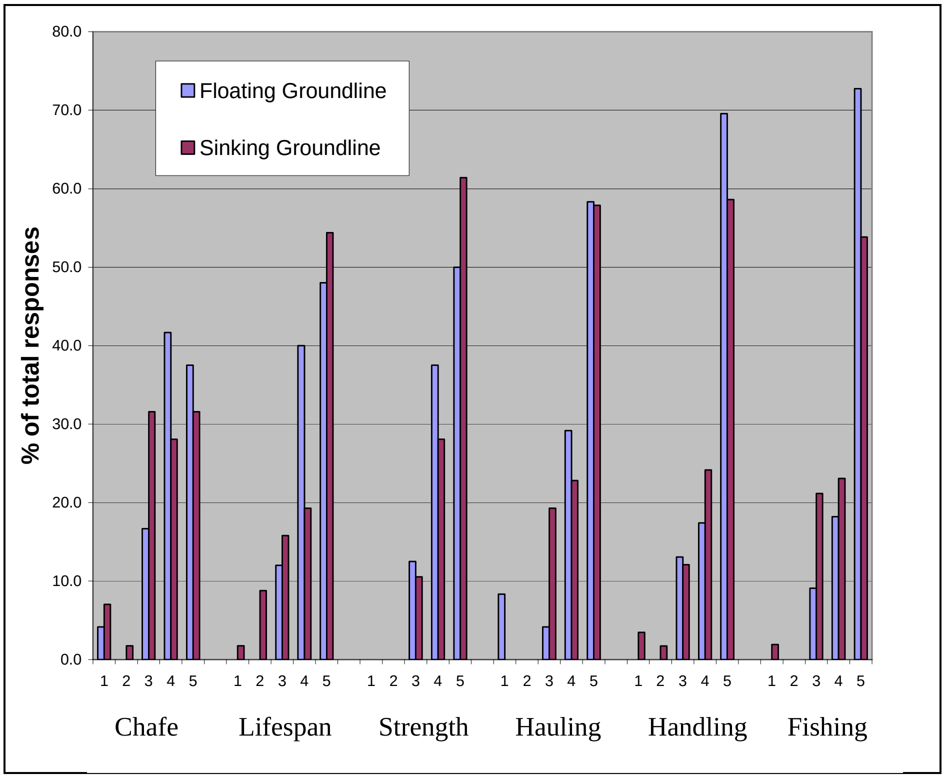
X. Appendices:

A. Survey Results

RESULTS OF
GROUNDLINE SURVEY
4/28/04

INSHORE LOBSTER – 107 PARTICIPANTS

Use floating groundline – 33 participants
Use sinking groundline – 71 participants



Line characteristics based on ratings 1 – 5, with 1 being not satisfactory and 5 being very satisfactory

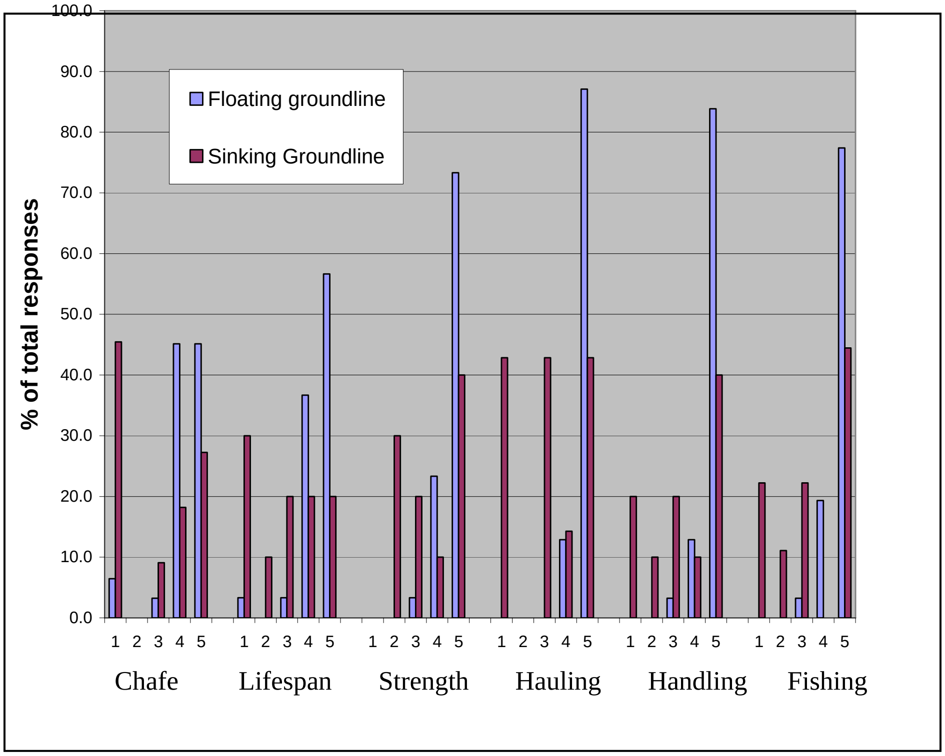
Average number of years between changing groundline

Floating groundline: 5.26 (± 2.67 SE)
Sinking groundline: 6.33 (± 4.17 SE)

RESULTS OF
GROUNDLINE SURVEY
4/28/04

<u>OFFSHORE LOBSTER – 50 PARTICIPANTS</u>

Use floating groundline – 36 participants
Use sinking groundline – 14 participants



Line characteristics based on ratings 1 – 5, with 1 being not satisfactory and 5 being very satisfactory

Average number of years between changing groundline

Floating groundline: 5.25 (± 1.66 SE)
Sinking groundline: 1.67 (± 0.61 SE)

B. Table of Cordage Companies

Anako Cordage
102 Dean Knauss Drive
Narragansett, RI 02882
401-423-0112

Brook Trap Mill
Beachwood
Thomaston, ME 04861
800-426-4526

Crowe Rope Industries
23-10-T Akerley Boulevard
Dartmouth, NS B3B1J4
902-468-9003
No longer in business

Everson Cordage Works
7180 Everson Goshen Road
Everson, WA 98247
360-966-4613

Frank W. Winnie, Inc,
44 N. Front Street
Philadelphia, PA 19106
508-58-6858

Hooven Allison
P.O. Box 340
677_T Cincinnati Ave
Xenia, OH 45385
800-543-0736

Hy-Liner Rope Co.
Spruce Head Road
Tenants Harbor, ME 04860

New England Rope, Inc
848 Airport Road
Fall River, MA 02720
508-678-8200

Novatec Braids Ltd.
P.O. Box 306
234 Water Street
Yarmouth, ME 04096
800-565-4212

Orion Ropeworks
RR 4 Box 2940
Winslow, ME 04901
207-877-2224

P & E Associates
No. Scituate, MA

Polystell Atlantic Ltd.
468 Portsway Avenue
Sydport Industrial Park
Edwardsville, NS B2A4T8
902-562-889

Samson Rope Technologies
2090 Thorton Road
Ferndale, WA 98248
800-227-7673

Seaside Rope Co.
1023 Eastern Road
Warren, ME 04864
207-273-4680

Tubbs Ropeworks
815 – T.E. 18th St
Tuscon, AZ 85719
520-798-3752

Wall Industries
P.O. Box 25
Spencer, NC 28159
800-316-5944 x 204

Wellington Commercial Products
1140-T Monticello Road
Madison, GA 30650
800-228-6680

Yale Cordage
77 Industrial Park Road
Saco, ME 04072
207-282-3396

C. Specific Gravity Tests

NORTHWEST LABORATORIES *of Seattle, Incorporated*

ESTABLISHED 1896

Technical Services for: Industry, commerce, Legal Profession & Insurance Industry

241 South Holden Street • Seattle, WA 98108-4359 • Phone: (206) 763-6252 • Fax: (206) 763-3949 • www. nwlabs1896.com

Report To: Mass. Div. of Marine Fisheries — Date: July 26, 2005

Attention: Ed Lyman

Report On: Specific Gravity — Lab No.: E79316

SUBMITTED: Two (2) Rope Samples

IDENTIFICATION: #1: L-16
#2: L-17

ANALYSIS:

Procedure

Samples were dried for 24 hours @ 80° C and subsequently weighed. The samples were then immersed in tap water for 72 hours. Samples were agitated to remove any air bubbles.

Samples were then weighed, to 0.01 of a gram, while immersed in the tap water. The samples were removed from the water and placed on a non-absorbent counter top, allowing the surface water to drip off. Any visible surface water was removed with a damp cloth. The specimens were again weighed at this saturated-surface-dry condition. The specific gravity was calculated in the following ways:

A = Weight of oven-dry test sample in air.
B = Weight of saturated-surface-dry test sample in air.
C = Weight of saturated test sample in water.

Bulk specific gravity (saturated-surface-dry) = B/(B-C)

Apparent specific gravity = A/(A-C)

Sample	Weight (g) Oven-Dry	Weight (g) Sat. Surface-Dry	Weight (g) Saturated in Water
#1	289.24	392.85	23.29
#2	292.54	397.23	28.33

NORTHWEST LABORATORIES *of Seattle, Incorporated*

Mass. Div. of Marine Fisheries
Page – 2 –
E79316

Sample	Bulk Specific Gravity (Saturated-Surface-Dry)	Apparent Specific Gravity
#1	1.063	1.088
#2	1.077	1.107

This report applies only to the actual samples tested. Northwest Laboratories does not certify, warrant, or guarantee any products manufactured by others. Samples will be discarded with **thirty (30) days** unless otherwise requested in writing by you.

NORTHWEST LABORATORIES, INC.

Omar Simon
Chemist

nbe

NORTHWEST LABORATORIES *of Seattle, Incorporated*

ESTABLISHED 1896
Technical Services for: Industry, commerce, Legal Profession & Insurance Industry
241 South Holden Street • Seattle, WA 98108-4359 • Phone: (206) 763-6252 • Fax: (206) 763-3949 • www.
nwlabs1896.com

Report To: Massachusetts Div. of Marine Fisheries Date: April 26, 2005
Attention: Edward Lyman

Report On: Specific Gravity Lab No.: E79013-1

SUBMITTED: Eight (8) Rope Samples

IDENTIFICATION:

L1	L-10
L-2	L-12
L-7	L-13
L-8	L-14

ANALYSIS:

Procedure
Samples were dried for 24 hours @ 80° C and subsequently weighed. The samples were then immersed in tap water for 72 hours. Samples were agitated to remove any air bubbles.

Samples were then weighted, to the 0.01 of a gram, while immersed in the tap water. The samples were removed from the water and placed on a non-absorbent counter top, allowing the surface water to drip off. Any visible surface water was removed with a damp cloth. The specimens were again weighed at this saturated-surface-dry condition. The specific gravity was calculated in the following ways:

A = Weight of oven-dry test sample in air.
B = Weight of saturated-surface-dry test sample in air.
C = Weight of saturated test sample in water.

Bulk specific gravity (saturated-surface-dry) = B/(B-C)
Apparent specific gravity = A/(A-C)

Sample	Weight (g) Oven-Dry	Weight (g) Sat. Surface-Dry	Weight (g) Saturated in Water
L-1	169.76	217.36	11.50
L-2	195.53	287.84	15.13
L-7	147.00	219.66	8.90
L-8	181.83	259.02	33.40
L-10	198.43	270.02	6.32
L-12	182.35	273.71	0.12
L-13	207.30	296.59	17.23

L-14	183.86	276.85	7.67

NORTHWEST LABORATORIES *of Seattle, Incorporated*

Mass. Div. of Marine Fisheries
Page – 2 –
E79013-1

Sample	Bulk Specific Gravity (Saturated-Surface-Dry)	Apparent Specific Gravity
L-1	1.073	1.056
L-2	1.084	1.056
L-7	1.064	1.042
L-8	1.225	1.148
L-10	1.033	1.024
L-12	1.0007	1.0004
L-13	1.091	1.062
L-14	1.044	1.029

This report applies only to the actual samples tested. Northwest Laboratories does not certify, warrant, or guarantee any products manufactured by others. Samples will be discarded with **thirty (30) days** unless otherwise requested in writing by you.

NORTHWEST LABORATORIES, INC.

Omar Simon
Chemist

nbe

D. Line testing log

Test ID[1]	Operator[2]	Test Date	Air temp (° F)	Water temp (° F)	Haul speed (ft/min)	# hauls	Time run (Hrs.)	Re-spliced[3]
PL1-1	MF/EL	3/24/05	66	64	50	251	3.9	Yes
L8-1	MF/EL	3/25/05	65	65	49	249	3.9	Yes
L1-1	EL/MF	3/28/05	64	66	47	250	4.2	No
L7-1	MF	3/28/05	71	72	43	250	4.5	Yes
L13-1	MF	3/29/05	72	74	49	250	4.0	No
L2-1	MF	3/30/05	68	72	47	251	4.2	Yes
L12-1	MF/EL	3/30/05	78	80	43	250	4.5	No
L10-1	EL	3/31/05	66	69	51	250	3.8	Yes
L14-1	EL	3/31/05	77	80	47	129	2.1	Yes
Pl-2	EL	4/1/05	66	66	49	250	4.0	No
PL-3	MF	4/4/05	64	66	50	251	3.9	Yes
L2-2	MF	4/4/05	72	72	48	250	4.1	Yes
L10-2	MF	4/5/05	70	72	50	251	3.9	Yes
L13-2	MF	4/5/05	78	78	49	249	3.9	Yes
L8-2	EL	4/6/05	75	76	48	253	4.2	Yes
L14-2	EL	4/6/05	78	81	47	249	4.1	Yes
L12-2	MF	4/7/05	76	80	45	250	4.3	No
L1-2	MF	4/7/05	80	84	51	252	3.8	N0
L7-2	MF	4/8/05	74	80	43	203	3.7	Yes
PL1-4	MF	4/8/05	78.0	84	47	250	4.2	Yes
PL1-5	MF	4/11/05	66	68	51	254	3.9	No
L2-3	MF	4/11/05	76	78	56	254	3.5	No
L7-3	EL	Not run due to shortfall in line						
L1-3	MF	4/12/05	72	74	46	251	4.2	No
L13-3	MF	4/12/05	76	82	54	250	3.6	No
L14-3	EL	4/13/05	77	78	49	248	4.0	Yes
L8-3	EL	4/14/05	72	74	48	249	4.1	Yes
L12-3	EL	4/14/05	77	80	51	250	3.8	No
L10-3	EL	4/15/05	69	75	56	249	3.5	Yes
PL1-6	EL	4/19/05	64	62	54	250	3.6	No
L16-1	MF	5/9/05	65	58	61	252	3.2	No
L17-1	MF	5/9/05	70	68	55	251	3.6	No
PL4-1	EL	5/10/05	68	68	54	116	1.7	No
PL1-7	MF	5/10/05	74	70	54	254	3.7	No
L17-2	MF	5/11/05	78	78	51	250	3.8	No
L16-2	EL	5/11/05	72	78	51	251	3.8	No
PL1-8	MF	5/12/05	72	74	56	253	3.5	No
L16-3	MF	5/12/05	80	82	51	249	3.8	No
L17-3	EL	5/13/05	70	74	50	250	3.9	No
PL1-9	EL	5/13/05	78	80	50	258	4.0	No

1. Use Table 2 in Results to identify line.
2. EGL = Ed Lyman; MF = Michael Frontiero
3. Was line re-spliced during the run of the line.

E. NOAA Fisheries-performed tension-test results

Test ID	Break 1	Break2	Break3	Break4	Mean	STD	95% CI
PL1-1	7051	6020	7409	7171	6912.8	613.5	601.2
L8-1	3282	3156	3161		3199.7	71.3	80.7
L1-1	5892	5605	5752	5316	5641.3	246.5	241.5
L7-1	2646	3143	2644		2811.0	287.5	325.4
L13-1	5310	5412	5490	5070	5320.5	182.5	178.9
L2-1	5530	5662	5332		5508.0	166.1	188.0
L12-1	7115	7218	7218		7183.7	59.5	67.3
L10-1	4559	4443	4467		4489.7	61.2	69.3
L14-1	3932	3900	3826		3886.0	54.4	61.5
PL-2	5527	6161	5925	5894	5876.8	261.9	296.3
PL-3	5982	6383	6203		6189.3	200.8	227.3
L2-2	4918	4701	4705		4774.7	124.1	140.5
L10-2	4486	4471	4557		4504.7	45.9	52.0
L13-2	4566	4965	5054		4861.7	259.9	294.1
L8-2	3193	3366	3376		3311.7	102.9	116.4
L14-2	3380	3317	3191		3296.0	96.2	108.9
L12-2	6783	7034	6981		6932.7	132.3	149.7
L1-2	5794	6017	5963	6496	6067.5	301.0	295.0
L7-2	2796	2390	2840		2675.3	248.1	280.7
PL1-4	5954	5809	5785	5776	5831.0	83.2	81.5
PL1-5	5898	5037	5406	5124	5366.3	387.9	380.1
L2-3	5849	5762	5973		5861.3	106.0	120.0
L7-3	Not done; insufficient line						
L1-3	5764	5614	5213	5514	5526.3	232.7	228.1
L13-3	5226	5191	5422		5279.7	124.5	140.9
L14-3	3276	2830	3022		3042.7	223.7	253.2
L8-3	2791	3172	3185		3049.3	223.8	253.3
L12-3	7028	7153	6858		7013.0	148.1	167.6
L10-3	3726	3362	3569		3552.3	182.6	206.6
PL1-6	5133	4967	4201	4760	4765.3	405.9	397.8
L16-1	5156	5267	4988	4951	5090.5	147.7	144.7
L17-1	5150	5902	5850	6134	5759.0	424.4	415.9
PL1-7	Not completed at time of report						
L17-2	Not completed at time of report						
L16-2	Not completed at time of report						
PL1-8	Not completed at time of report						
L16-3	5002	5046	5277	5215	5135.0	131.9	129.2
L17-3	4595	4520	4586	4412	4528.3	84.4	82.7
PL1-9	Not completed at time of report						

F. Northwest Laboratory-performed tension-test results

Test ID	Break1	Break 2	Break 3	Mean	STD	95% CI
PL1-1	5020	5420	5400	5280.0	225.4	255.0
L8-1	2500	1900	2560	2320.0	365.0	413.0
L1-1	4560	4740	4840	4713.3	141.9	160.6
L7-1	2400	2420	2580	2466.7	98.7	111.6
L13-1	4540	3660	4440	4213.3	481.8	545.2
L2-1	4640	4860	4600	4700.0	140.0	158.4
L12-1	3560	4700	5260	4506.7	866.3	980.3
L10-1	4120	3820	3700	3880.0	216.3	244.8
L14-1	3140	3400	3360	3300.0	140.0	158.4
Pl-2	4120	4040	4700	4286.7	360.2	407.6
PL-3	3860	4840	4340	4346.7	490.0	554.5
L2-2	4020	3820	4120	3986.7	152.8	172.9
L10-2	3860	3960	4360	4060.0	264.6	299.4
L13-2	3840	3660	3440	3646.7	200.3	226.7
L8-2	2100	2620	2500	2406.7	272.3	308.1
L14-2	2620	2320	2420	2453.3	152.8	172.9
L12-2	4980	5160	4640	4926.7	264.1	298.8
L1-2	4180	5200	4580	4653.3	513.9	581.6
L7-2	2780	2820	2780	2793.3	23.1	26.1
PL1-4	4120	4300	4720	4380.0	307.9	348.4
PL1-5	4260	4600	4780	4546.7	264.1	298.8
L2-3	4880	4660	5200	4913.3	271.5	307.3
L7-3	Not done; Insuficient line					
L1-3	4300	4560	4180	4346.7	194.3	219.8
L13-3	4340	4380	4460	4393.3	61.1	69.1
L14-3	2740	2520	2500	2586.7	133.2	150.7
L8-3	2820	2440	2500	2586.7	204.3	231.2
L12-3	4600	4940	4820	4786.7	172.4	195.1
L10-3	2860	3080	3200	3046.7	172.4	195.1
PL1-6	3840	4000	4060	3966.7	113.7	128.7
L16-1	4240	3800		4020.0	311.1	431.2
L17-1	4200	4000		4100.0	141.4	196.0
PL1-7	5280	5000		5140.0	198.0	274.4
L17-2	3580	4100		3840.0	367.7	509.6
L16-2	3800	4000		3900.0	141.4	196.0
PL1-8	4960	4280		4620.0	480.8	666.4
L16-3	3900	3900		3900.0	0.0	0.0
L17-3	3000	3280		3140.0	198.0	274.4
PL1-9	3500.0	4880		4190.0	975.8	1352.4

G. Recorded loads at center roller and calculated in-line loads in pounds

Sample ID	Date Tested	# of rec @ fairlead	Avg Load	Inline load from equation	95% CI
PL1-1	3/24/05	258	216.1	1137.4	31.4
L8-1	3/25/05	3284	215.8	1135.4	65.8
L1-1	3/28/05	8876	218.5	1153.9	79.4
L7-1	3/28/05	5754	219.1	1158.0	49.2
L13-1	3/29/05	9938	219.0	1157.3	57.9
L2-1	3/30/05	10446	221.2	1172.3	51.2
L12-1	3/30/05	9746	215.6	1134.0	65.8
L10-1	3/31/05	9366	216.5	1140.2	61.1
L14-1	3/31/05	4228	218.4	1153.2	71.3
PL1-2	4/1/05	8484	221.5	1174.4	95.7
PL1-3	4/4/05	8977	218.3	1152.5	61.1
L2-2	4/4/05	9142	220.9	1170.3	69.7
L10-2	4/5/05	9631	217.1	1144.3	64.3
L13-2	4/5/05	7724	221.0	1171.0	78.7
L8-2	4/6/05	8308	219.7	1162.1	55.4
L14-2	4/6/05	8791	217.8	1149.1	76.9
L12-2	4/7/05	10220	218.3	1152.5	68.1
L1-2	4/7/05	8964	220.2	1165.5	67.7
L7-2	4/8/05	8132	219.0	1157.3	48.9
PL1-4	4/8/05	7605	211.7	1107.3	122.7
PL1-5	4/11/05	9208	216.1	1137.4	44.2
L2-3	4/11/05	9116	220.4	1166.9	54.7
L7-3	4/18/05				
L1-3	4/12/05	9551	217.0	1143.6	40.3
L13-3	4/12/05	6858	218.2	1151.8	52.3
L14-3	4/13/05	8394	220.3	1166.2	54.8
L8-3	4/14/05	7854	220.4	1166.9	71.2
L12-3	4/14/05	8372	219.6	1161.4	57.4
L10-3	4/15/05	8124	219.0	1157.3	32.7
PL1-6	4/19/05	4539	218.0	1150.4	47.1
L16-1	5/9/05	8079	218.5	1153.9	86.5
L17-1	5/9/05	8269	217.4	1146.3	62.3
PL1-7	5/10/05	8689	216.1	1137.4	50.1
L17-2	5/11/05	8192	218.6	1154.5	56.4
L16-2	5/11/05	11704	219.1	1158.0	66.2
PL1-8	5/12/05	8597	214.4	1125.8	62.2
L16-3	5/12/05	8826	214	1123.1	85.9
L17-3	5/13/05	8984	221.3	1173.0	48.3
PL1-9	5/16/05	7369	210	1095.7	117.2