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Industry Report : Understanding Dredge Performance for a Lined versus Unlined NMFS Sea Scallop Dredge

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Industry Report

Understanding Dredge Performance for a Lined versus Unlined NMFS Sea Scallop Dredge

VIMS Marine Resource Report: 2020-6

Submitted to:

Sea Scallop Fishing Industry

Submitted by:

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VIRGINIA INSTITUTE OF MARINE SCIENCE
MARINE ADVISORY PROGRAM

Project Summary

The Virginia Institute of Marine Science (VIMS) tested a scale model of the sea scallop survey dredge in the flume tank at the Fisheries and Marine Institute of Memorial University over two days in March of 2019. This work was conducted to understand how the liner, survey protocols, and catch volume effect dredge performance. Tow speed, warp tension, maximum bag height, height at the twine top end, wire angle, wheel height of bottom, and dredge angle were measured for the trials. Tow speeds tested ranged from 3-4.5 kts. Video footage of trials was recorded and can be viewed at the VIMS Sea Scallop Program youtube channel: https://www.youtube.com/channel/UCUJpqwOCoiY89gd6Ok0rtxw.

Results indicated the liner did not negatively impact dredge performance compared to an unlined version of the survey dredge. The liner improved overall bag shape, dredge bag height, and twine top height, as well as hydrodynamic flow through the dredge. Other findings indicated catch volume increased dredge angle and the height of the wheel off bottom, especially as speed increased. Tow speeds should be kept under 4.3 kts to improve dredge performance and have the dredge fish more consistently.

Project Description

Survey Dredge and Protocols

The standard National Marine Fisheries Service (NMFS) sea scallop survey dredge used since the 1970s is a New Bedford style dredge, 8 ft. in width and equipped with 2-inch rings, and 3.5-inch diamond mesh twine top (NEFSC, 2018). A 1.5-inch diamond mesh liner is installed in the dredge to retain small scallops that would otherwise pass through the rings. Survey protocols for fishing the dredge include a 15 minute tow duration, tow speed range of 3.8-4 kts and scope to depth ratio of 3:1.

Flume Tank

Flume tank testing was conducted at the Fisheries and Marine Institute of Memorial University of Newfoundland's flume tank in St. John's Newfoundland. The flume tank facility has a data acquisition and flow monitoring system for data collection of dredge performance metrics (Marine Institute Fisheries and Marine Institute of Memorial University of Newfoundland, 2017) (Figure 1).

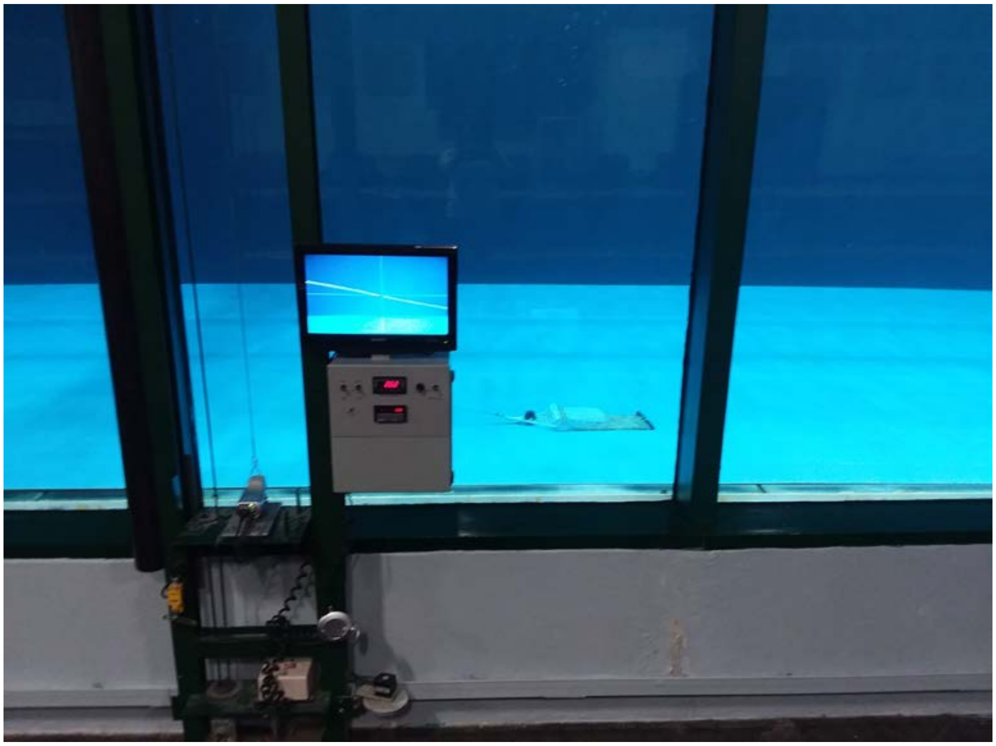

Figure 1. Image of the data acquisition system used to take measurements of the scale survey dredge. In this image the towing wire angle is being measured.

Scale Survey Dredge

Mr. Tor Bendiksen of Reidar's Trawl Gear and Marine Supply Company in New Bedford, MA built a 1:6.65 scale survey dredge with a liner (Figure 2). Two scale towing wire diameters were tested to represent the different diameters used by VIMS (26.6 mm = 2 inch diameter wire) and the NMFS (16 mm = 9/16 inch diameter wire). We only report on trials in this report where the 26 mm tow wire was used since VIMS surveys are conducted on commercial vessels.

Flume Tank Trials

All trials on the first day were conducted with the liner installed and all trials on the second day were completed with the liner removed. Trials on day 2 were identical to day 1 trials to determine the effect of the dredge liner. The following measurements were taken using the data acquisition system for a subset of trials:

- Tow speed (kts). Controlled by the speed of the conveyer belt.
- Warp tension (unit kilogram-force (kgf))
- Maximum bag height (mm) (Figure 2, A)
- Height at the twine top end (mm) (Figure 2, B)
- Wire angle (degrees) (Figure 1)
- Height of the wheel of bottom (mm) (Figure 2, C)

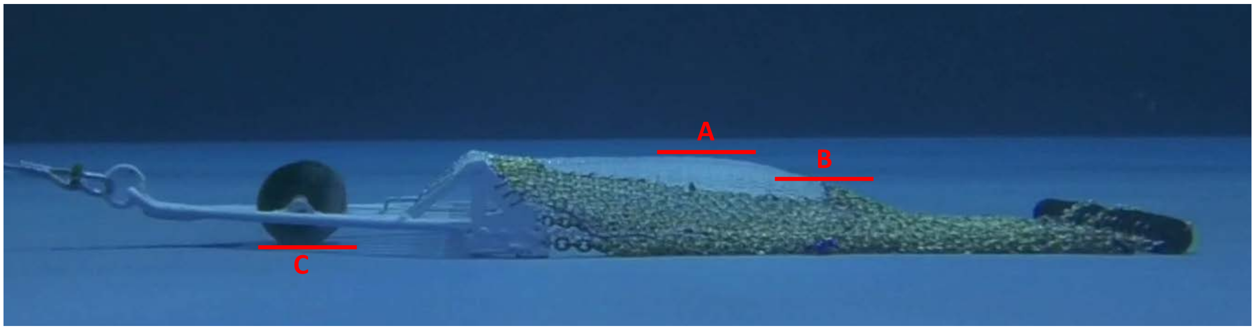

Figure 2. Location of measurements taken for the maximum height of the bag (A), height at the twine top end (B), and height of the wheel of bottom (C).

The following trials were completed for the dredge configuration with the liner installed and again without the liner:

1. Regular Trials
   1.1. Dredge tested at speeds of 3, 3.5, 3.8, 4, and 4.5 kts at a 3:1 scope to depth ratio and 26.6 mm towing wire.
2. Simulated Catch Trials
   2.1. Dredge tested with simulated catch using 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts at a 3:1 scope to depth ratio and 26.6 mm towing wire (Figure 3).
   2.2. Dredge tested with simulated catch of 100 BioRings at intervals of 0.1 kts from 4 to 4.5 kts with 26.6 mm towing wire.

Figure 3. Image of a BioRing used to simulate catch in the scale survey dredge. Each BioRing either had a weight in the center of the ring or weight attached to the outside of the ring, as shown in this picture.

3. Hydrodynamic Catch Trials
   3.1. Dredge tested with simulated catch of 100 BioRings at 3.8 kts at a 3:1 scope to depth ratio and 26.6 mm towing wire. Dye tabs were fixed to the dredge to allow for visual examination of water flow through the dredge (Figure 4).
   3.2. Dredge tested with simulated catch of 100 BioRings at 3.8 kts at a 2.5:1 scope to depth ratio and 26.6 mm towing wire.

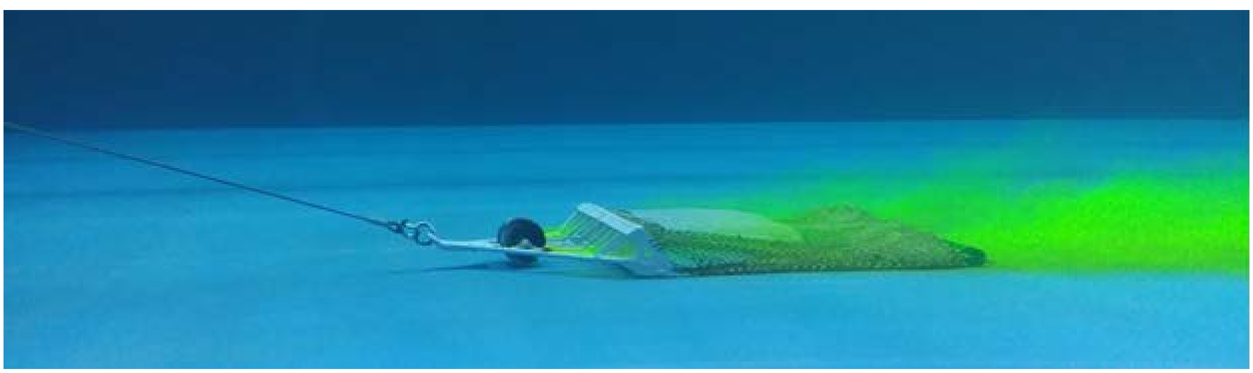

Figure 4. Image of scale survey dredge hydrodynamic trial with dye tabs.

4. Scope to Depth Ratio Trials
   4.1. Dredge tested with a simulated catch of 100 BioRings at a scope to depth ratio of 3.1:1, a speed of 3.8 kts, and 26.6 mm towing wire.
   4.2. Dredge tested with a simulated catch of 100 BioRings at scope to depth ratios of 2.5:1, 3.25:1, and 3.5:1 at a speed of 4.5 kts, and 26.6 mm towing wire.
   4.3. Dredge tested with a simulated catch of 100 BioRings at scope to depth ratios of 2.5:1, 3.25:1, and 3.5:1 at a speed of 4.5kts, and 16 mm towing wire.

Dredge Angle Calculations

Dredge angle was calculated by from still images from each video. The software program ImageJ was used to calculate dredge angle by drawing one line from the goose neck to the back end of the heel of the shoe. A second line was drawn parallel to the flume tank conveyor belt to the back end of the heel of the shoe. The angle calculated from the ImageJ software was recorded as the dredge angle (Figure 5).

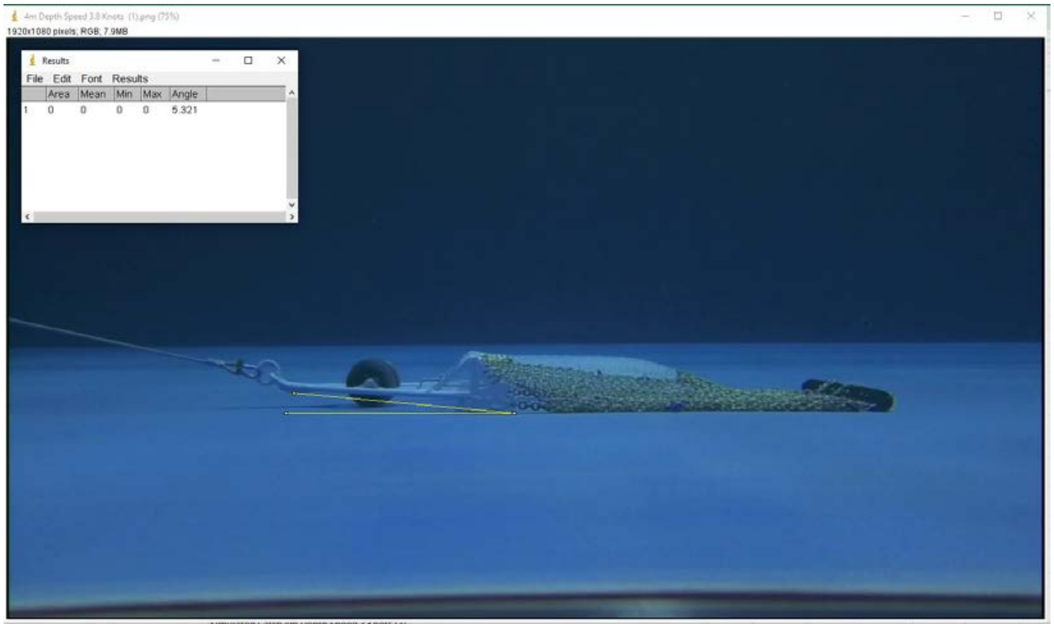

Figure 5. Still image from one flume tank trial with dredge angle lines and angle calculated from the lines (upper left corner) using ImageJ.

Results

Tables 1-2 provide measurement data for trials. Figures 6-13 provide graphical interpretations of the different measurements taken by trial.

Table 1. Measurements taken for trials with no catch, a 26 mm tow wire, and speeds of 3, 3.5, 3.8, 4, and 4.5 kts. Trials were completed with the liner installed and without a liner, indicated by the Liner in Dredge column. Measurements include warp tension (kgf), maximum bag height (mm), height at the twine top end (mm), warp angle (degrees), wheel height of bottom (mm), and dredge angle (degrees).

Liner in Dredge	Tow Speed (kts)	Warp Tension (kgf)	Maximum Bag Height (mm)	Height at Twine Top End (mm)	Warp Angle (degrees)	Wheel Height off Bottom (mm)	Dredge Angle (degrees)
Y	3	431.12	405.65	312.55	11.00	0	4.84
Y	3.5	498.76	418.95	319.20	12.80	0	4.94
Y	3.8	546.99	418.95	339.15	13.70	0	5.39
Y	4	591.98	438.90	352.45	14.70	0	5.29
Y	4.5	684.03	452.20	372.40	16.40	59.85	6.66
N	3	399.95	399.00	219.45	9.30	0	5.16
N	3.5	468.47	405.65	239.40	11.60	0	5.30
N	3.8	522.87	405.65	259.35	13.30	0	5.32
N	4	546.69	405.65	279.30	14.20	0	5.34
N	4.5	622.27	425.60	299.25	15.50	26.6	5.52

Table 2. Measurements taken for trials with simulated catch, 26 mm tow wire, and speeds of 3-4.5 kts. Trials were completed with the liner installed and without a liner, indicated by the Liner in Dredge column. The number of BioRings is indicated in the Catch Volume column. Measurements include warp tension (kgf), maximum bag height (mm), height at the twine top end (mm), warp angle (degrees), wheel height of bottom (mm), and dredge angle (degrees). For the last 12 columns only dredge angle was calculated.

Liner in Dredge	Catch Volume	Tow Speed (kts)	Warp Tension (kgf)	Maximum Bag Height (mm)	Height at Twine Top End (mm)	Warp Angle (degrees)	Wheel Height off Bottom (mm)	Dredge Angle (degrees)
Y	30 BioRings	3	450.53	399.00	266.00	11.00	0	4.72
Y	30 BioRings	3.5	525.81	412.30	292.60	13.20	0	4.96
Y	30 BioRings	3.8	563.46	425.60	319.20	14.00	0	5.57
Y	30 BioRings	4	600.80	418.95	325.85	14.80	0	5.71
Y	30 BioRings	4.5	688.73	445.55	379.05	16.60	66.50	6.60
Y	100 BioRings	3	469.94	399.00	339.15	11.60	0	4.88
Y	100 BioRings	3.5	555.22	405.65	379.05	13.80	0	5.19
Y	100 BioRings	3.8	593.75	418.95	372.40	14.40	0	5.12

Y	100 BioRings	4	625.51	412.30	379.05	14.80	19.95	5.35
Y	100 BioRings	4.5	700.20	445.55	392.35	16.50	66.50	7.05
Y	150 BioRings	3	487.58	405.65	379.05	11.40	0	5.30
Y	150 BioRings	3.5	569.04	418.95	399.00	13.30	0	5.21
Y	150 BioRings	3.8	618.74	438.90	405.65	14.60	0	5.05
Y	150 BioRings	4	644.62	452.20	405.65	15.30	13.30	5.27
Y	150 BioRings	4.5	741.08	478.80	452.20	16.80	99.75	7.84
Y	300 BioRings	3	499.94	538.65	532.00	11.90	0	5.41
Y	300 BioRings	3.5	591.98	585.20	551.95	13.80	0	5.26
Y	300 BioRings	3.8	644.92	585.20	571.90	14.50	0	5.60
Y	300 BioRings	4	677.56	591.85	578.55	15.10	39.90	5.95

Y	300 BioRings	4.5	788.43	625.10	598.50	16.40	106.40	9.08
N	30 BioRings	3	411.12	392.35	246.05	10.30	0	4.99
N	30 BioRings	3.5	488.76	399.00	272.65	12.10	0	5.21
N	30 BioRings	3.8	528.76	405.65	312.55	13.20	0	5.36
N	30 BioRings	4	552.87	412.30	319.20	14.20	0	5.45
N	30 BioRings	4.5	636.09	432.25	345.80	15.70	39.90	5.69
N	100 BioRings	3	446.12	405.65	312.55	10.80	0	5.27
N	100 BioRings	3.5	518.46	405.65	319.20	13.20	0	5.20
N	100 BioRings	3.8	574.34	405.65	345.80	14.40	0	5.25
N	100 BioRings	4	600.80	418.95	365.75	14.60	0	5.56
N	100 BioRings	4.5	679.91	438.90	379.05	0.00	39.90	6.73

N	150 BioRings	3	427.30	438.90	399.00	10.90	0	5.10
N	150 BioRings	3.5	529.93	445.55	412.30	13.70	0	5.43
N	150 BioRings	3.8	567.28	438.90	405.65	14.50	0	5.42
N	150 BioRings	4	614.92	438.90	399.00	15.30	0	5.34
N	150 BioRings	4.5	682.56	438.90	405.65	16.40	33.25	6.17
N	300 BioRings	3	471.41	545.30	545.30	11.60	0	5.43
N	300 BioRings	3.5	580.81	545.30	545.30	13.50	0	5.60
N	300 BioRings	3.8	638.74	551.95	551.95	14.40	19.95	5.57
N	300 BioRings	4	677.56	545.30	545.30	15.10	26.60	5.69
N	300 BioRings	4.5	774.61	571.90	571.90	16.10	59.85	8.96
Y	100 BioRings	4						5.43

Y	100 BioRings	4.1	5.03
Y	100 BioRings	4.2	5.29
Y	100 BioRings	4.3	5.64
Y	100 BioRings	4.4	6.05
Y	100 BioRings	4.5	6.82
N	100 BioRings	4	5.64
N	100 BioRings	4.1	5.77
N	100 BioRings	4.2	5.66
N	100 BioRings	4.3	6.02
N	100 BioRings	4.4	6.68
N	100 BioRings	4.5	6.80

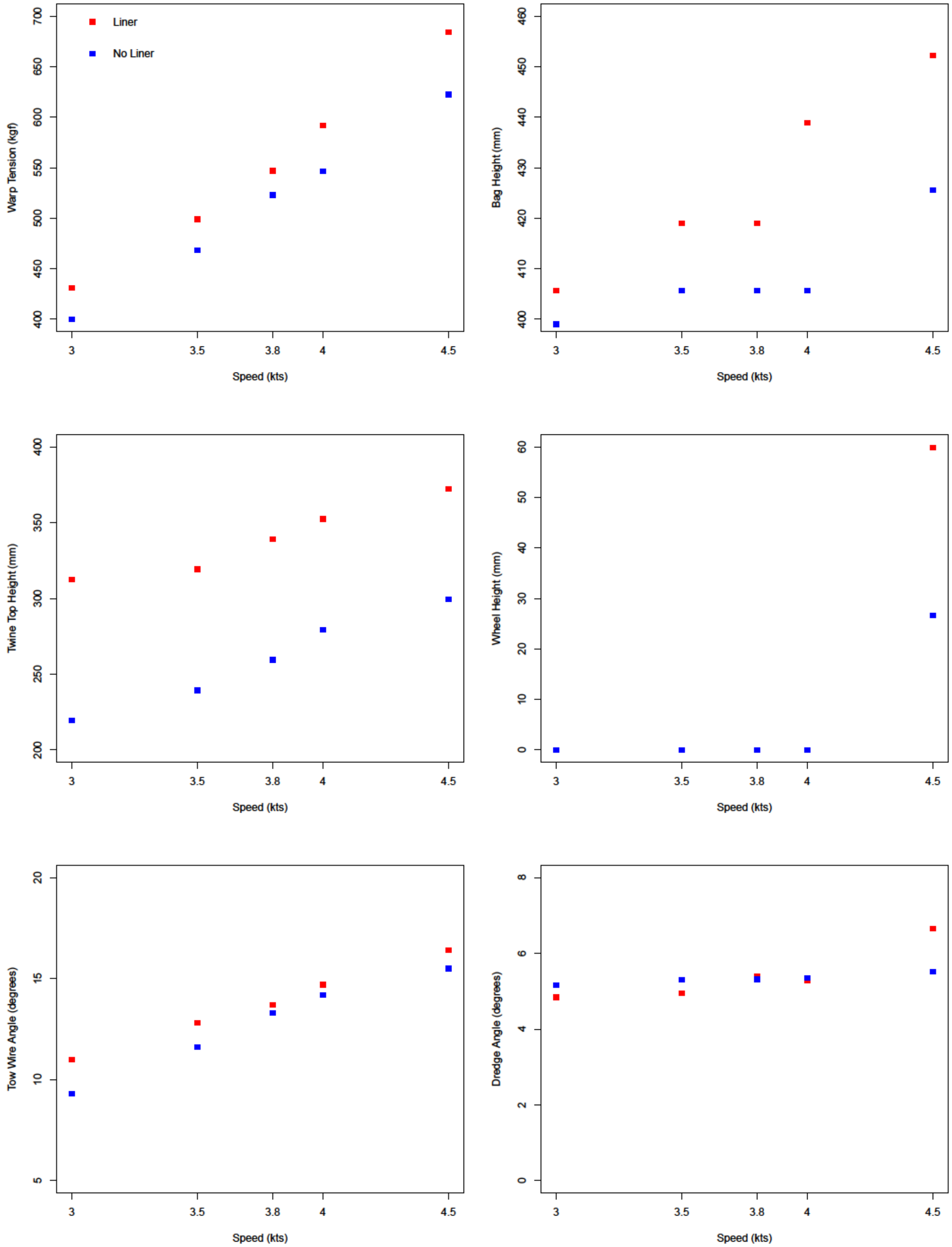

Figure 6. Plots of warp tension (kgf), bag height (mm), twine top height (mm), wheel height (mm), tow wire angle (degrees), and dredge angle (degrees) measurements taken for trials at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, no catch, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

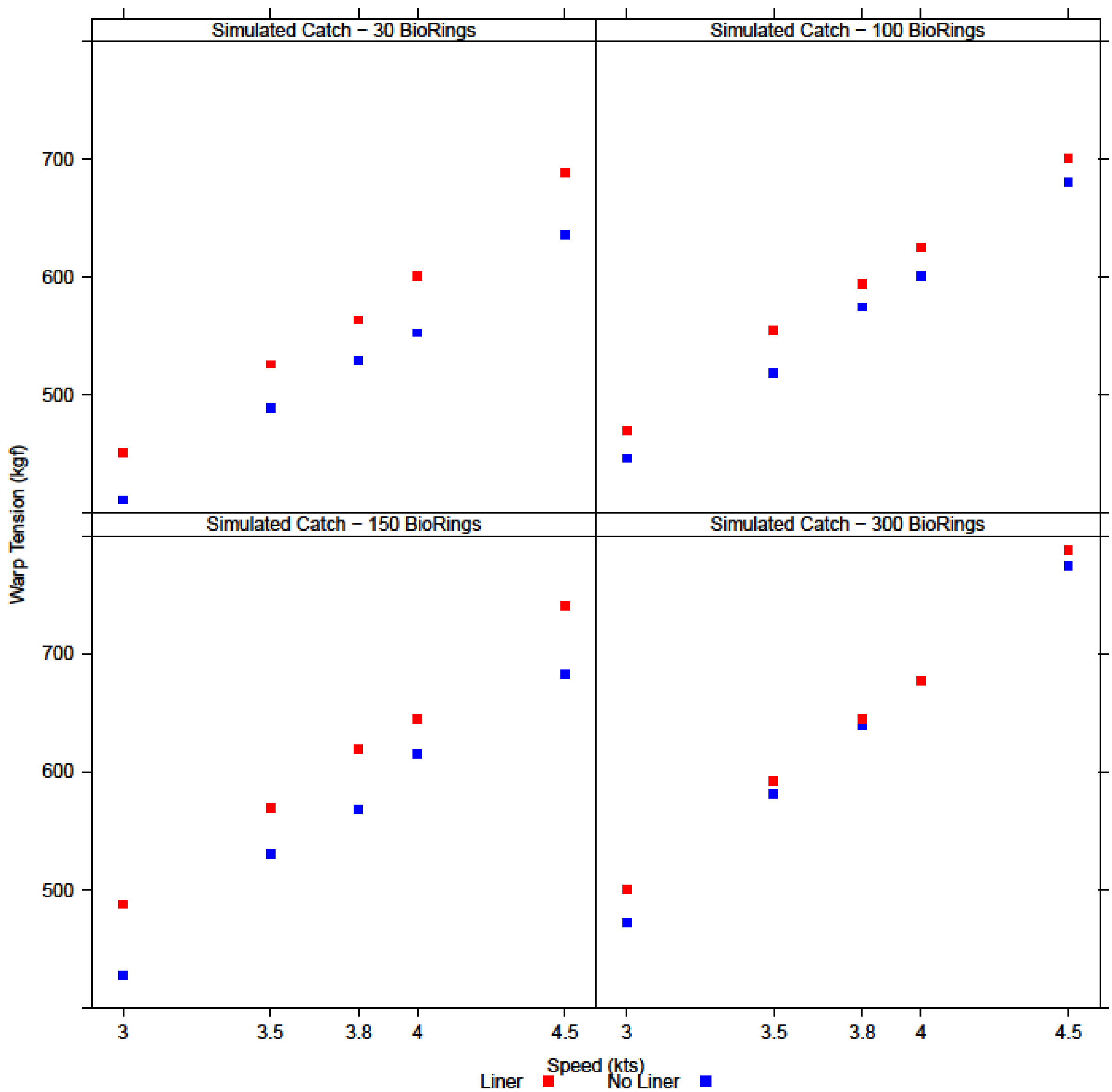

Figure 7. Plots of warp tension (kgf) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

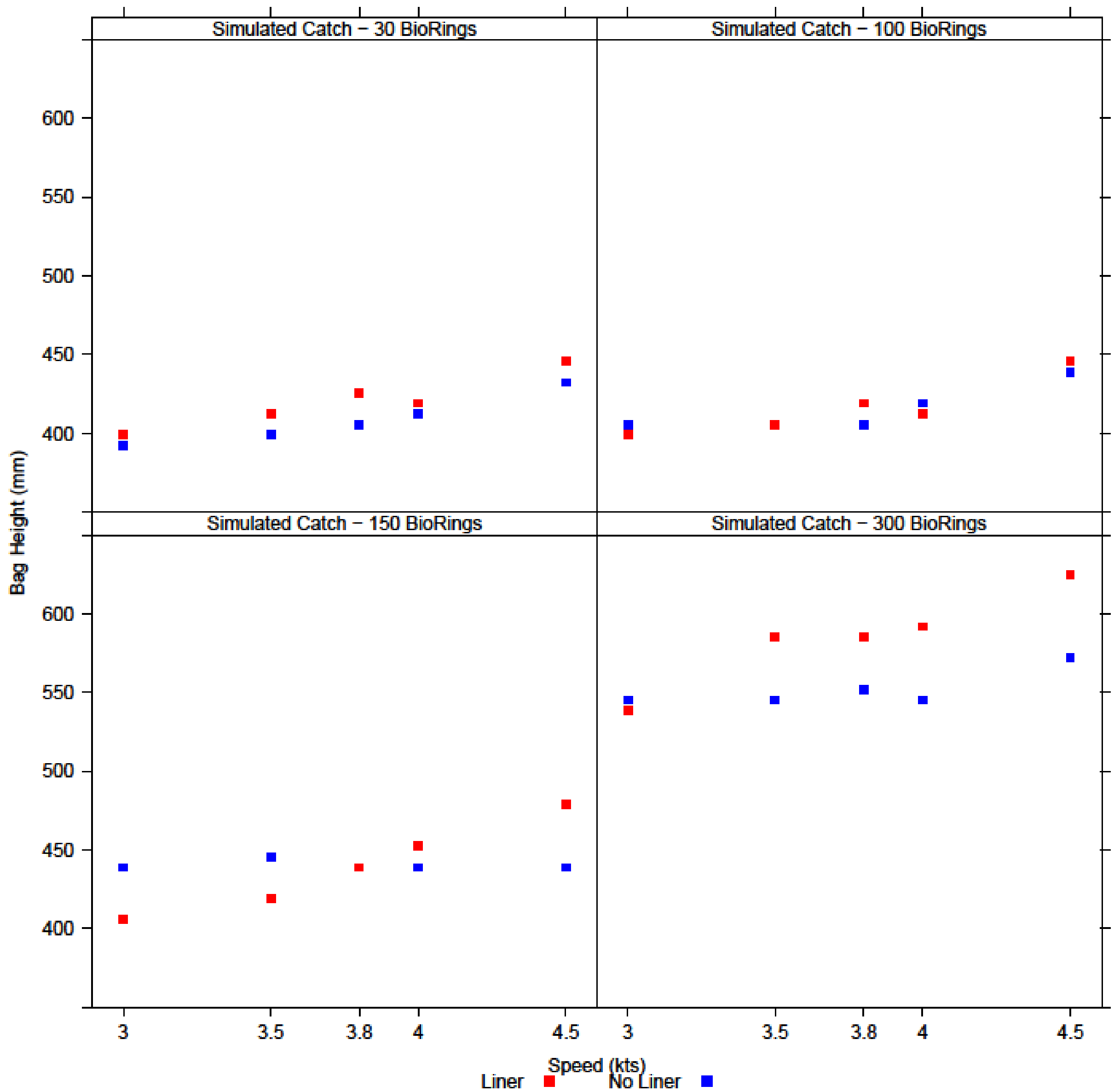

Figure 8. Plots of bag height (mm) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

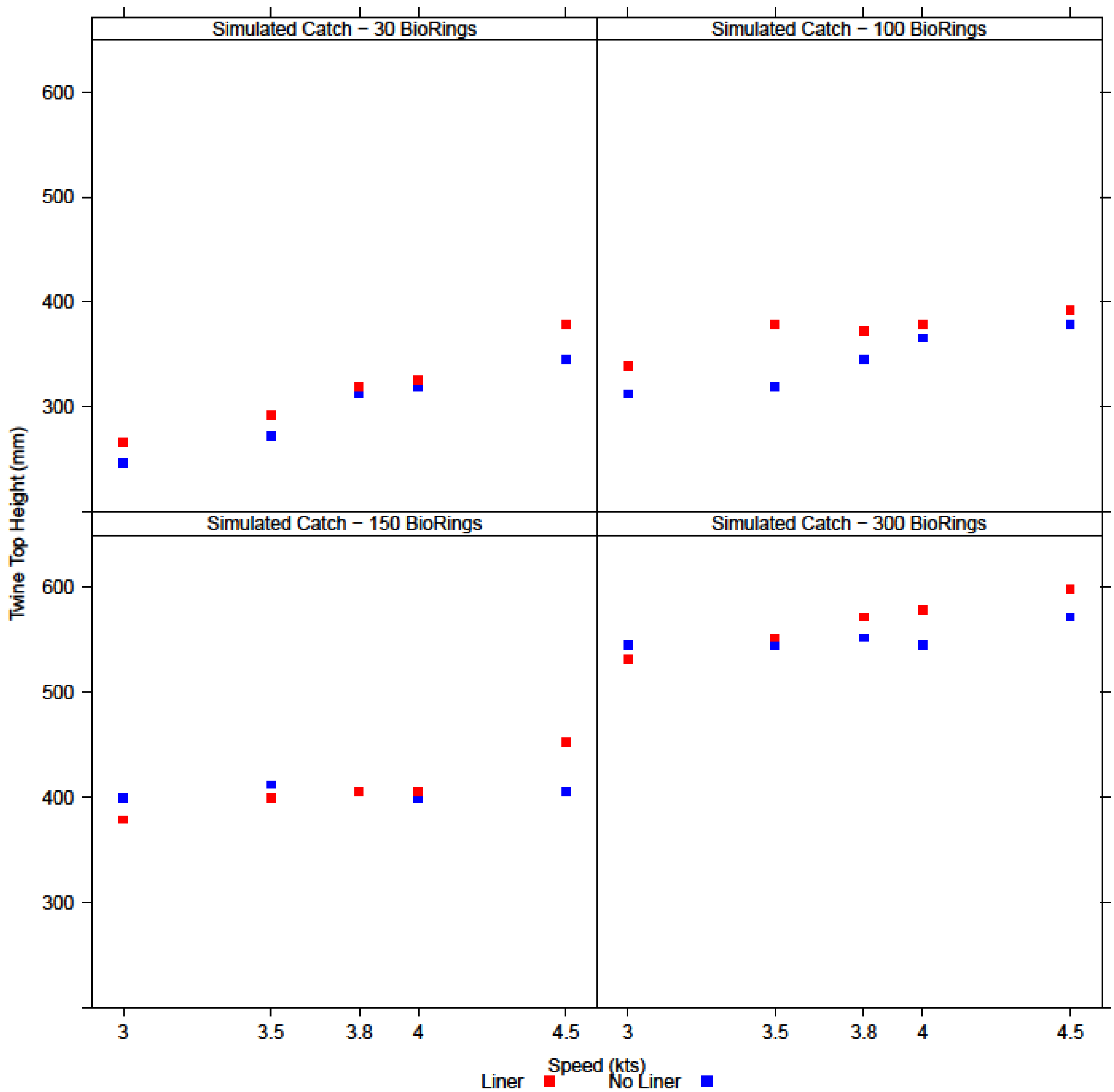

Figure 9. Plots of twine top height (mm) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

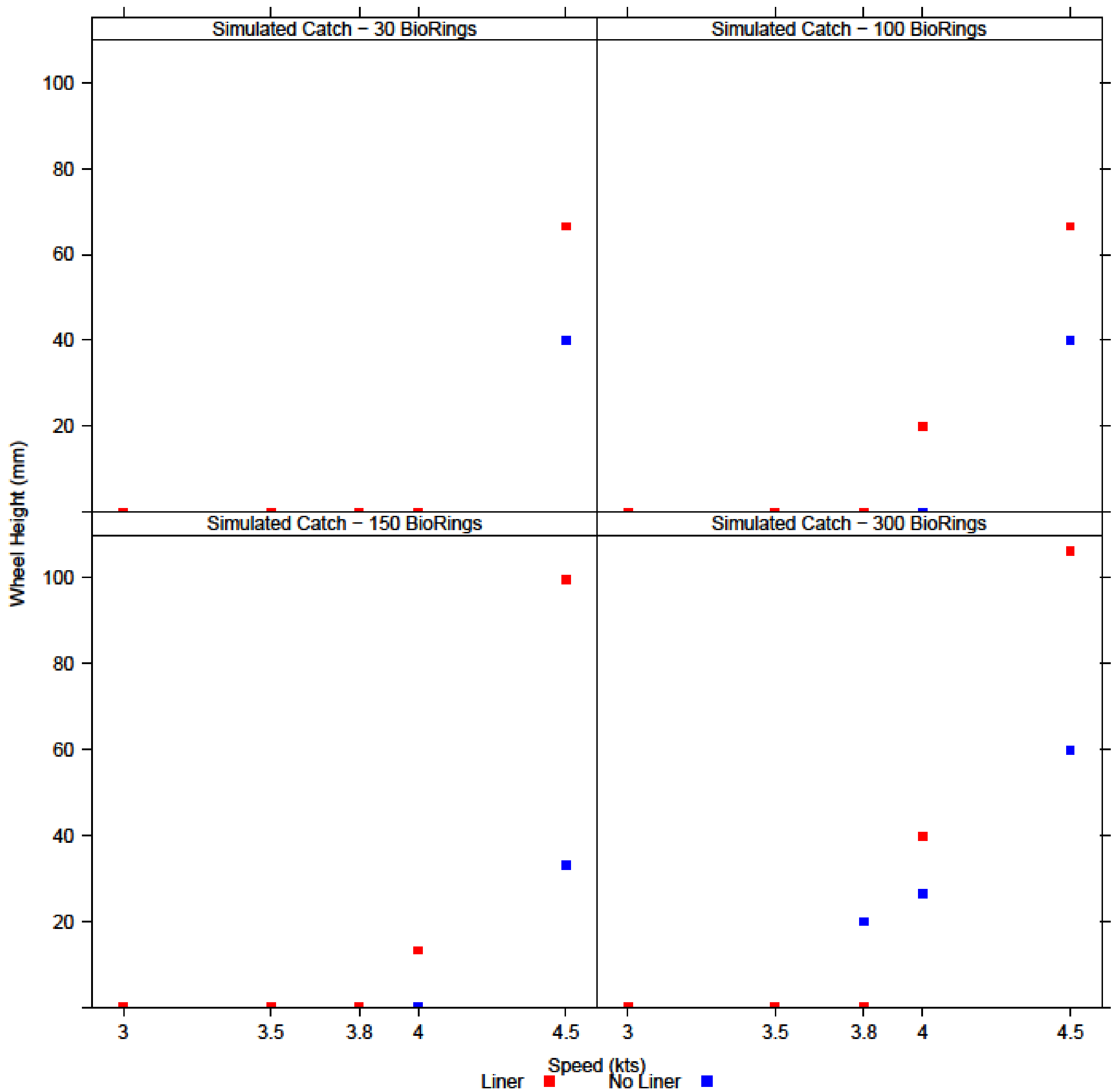

Figure 10. Plots of wheel height (mm) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

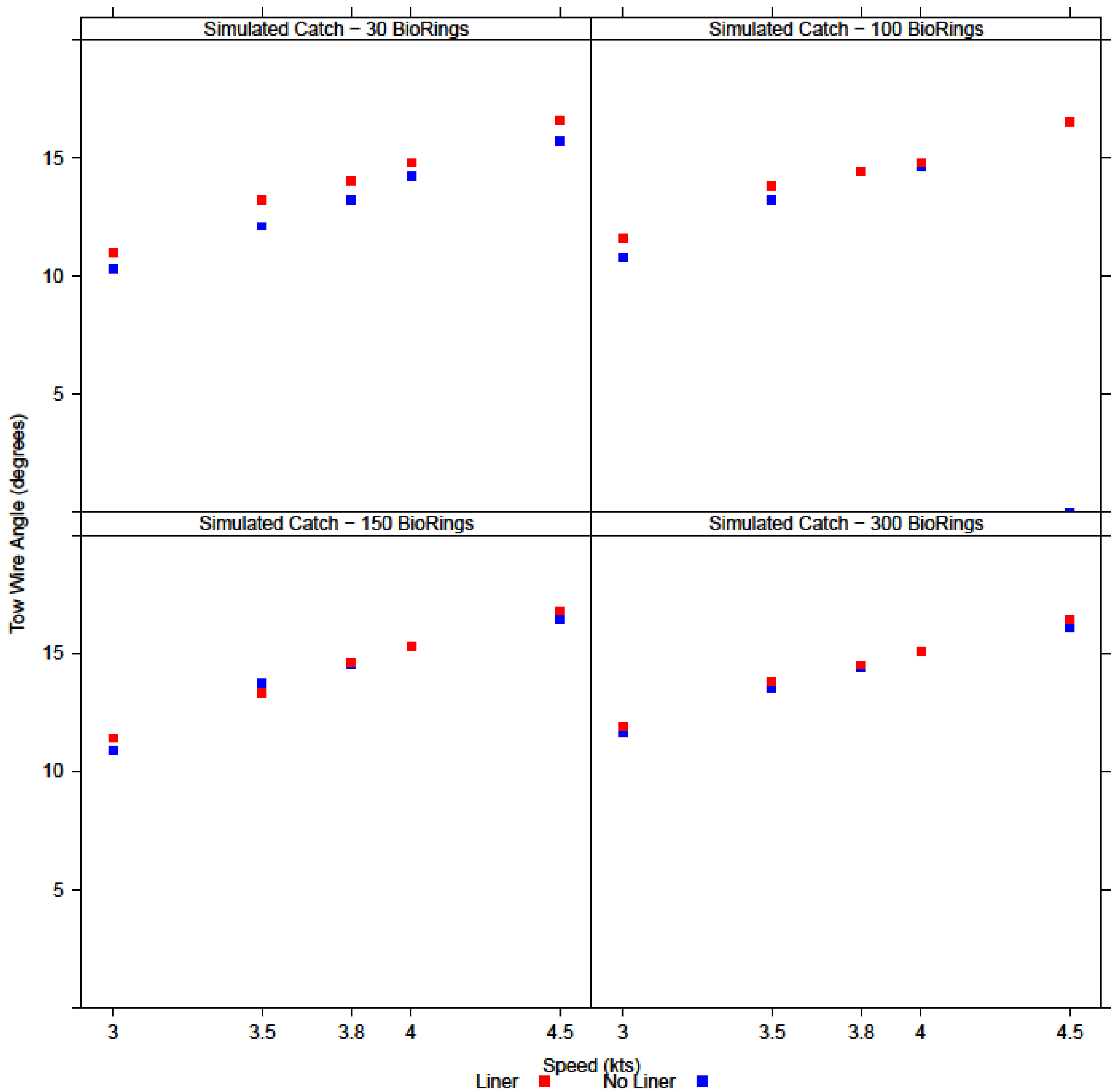

Figure 11. Plots of tow wire angle (degrees) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

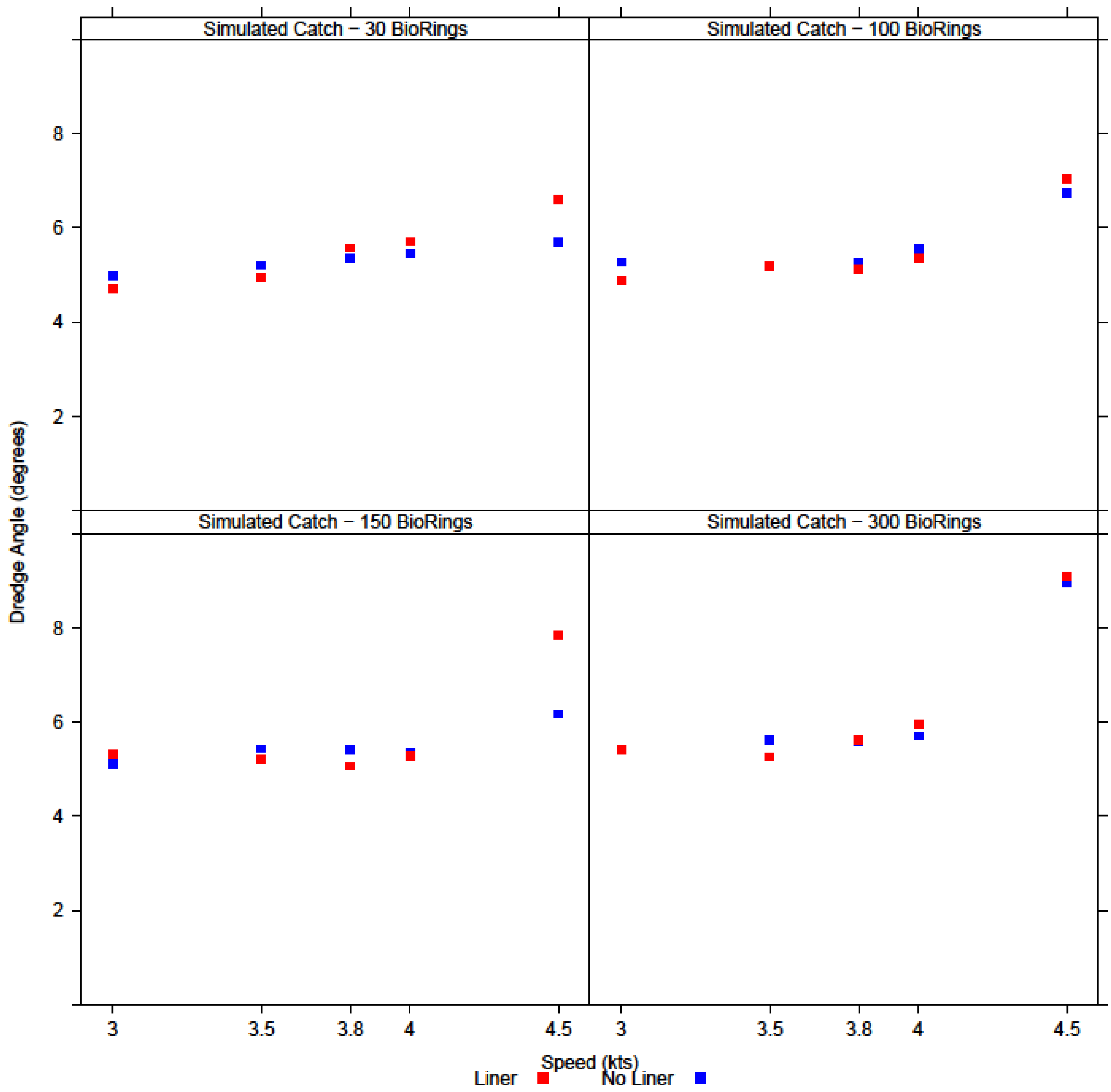

Figure 12. Plots of dredge angle (degrees) measurements taken for the simulated catch trials of 30, 100, 150, and 300 BioRings at speeds of 3, 3.5, 3.8, 4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

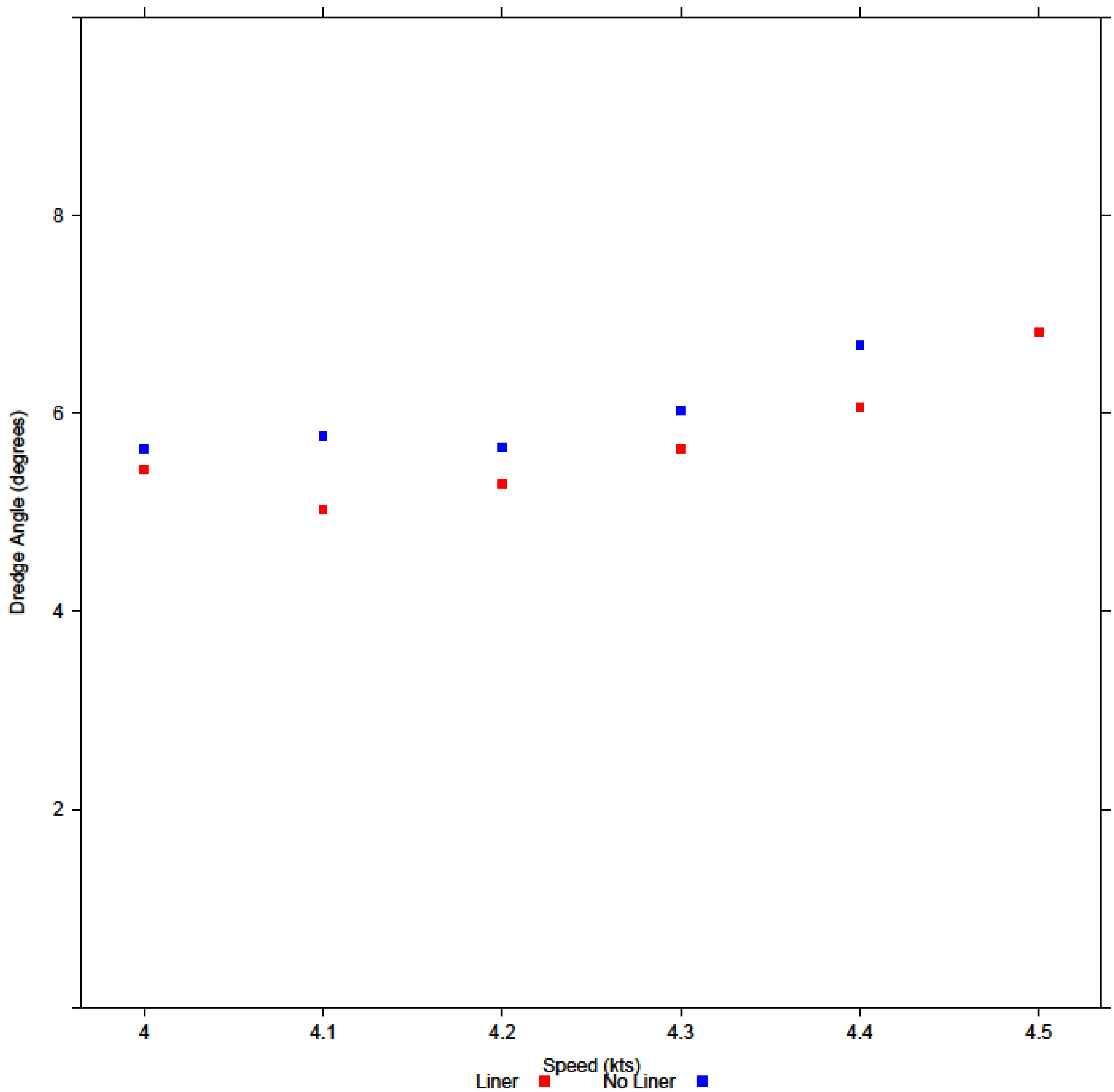

Figure 13. Plot of dredge angle (degrees) measurements taken for the simulated catch trials of 100 BioRings at speeds of 4, 4.1, 4.2, 4.3, 4.4, and 4.5 kts, a 3:1 scope to depth ratio, and a 26 mm tow wire for the lined (red) and unlined (blue) dredge.

Regular Trials

For Regular trials with a 26 mm tow wire, no catch, and a 3:1 scope to depth ratio, most measurements indicated the lined dredge had higher values than the unlined dredge. There was also a generally consistent increase in measurement values as speed increased for both the lined and unlined trials. The wheel was only observed to come off the bottom at the greatest speed of 4.5 kts, otherwise the wheel maintained contact with the conveyer belt. Observations of the dredge shoes at 4.5 kts showed the shoe heels were the only component that had contact with the conveyor belt and that the shoes moved around much more than at lower speeds. The greatest values for the twine top height and bag height increased with speed, but did not correspond to an increase in the wheel height off bottom. Dredge angle was relatively consistent across all speeds, although an increase was observed at 4.5 kts. For the lined dredge the average angle was 6.66 degrees and the unlined dredge the average was 5.52 degrees. At the required tow speed range of 3.8-4 kts, dredge angles for both the lined and unlined dredge were consistent. Average dredge angles were 5.39 and 5.29 for the lined dredge at 3.8 and 4 kts, respectively. For the unlined dredge the average dredge angle at 3.8 kts was 5.32 degrees and at 4 kts was 5.32 degrees.

Simulated Catch Trials

Simulated Catch trials for the 26 mm tow wire and a 3:1 scope to depth ratio indicated catch impacted some dredge measurements. Overall, results were similar to the Regular trial results in terms of the lined dredge versus the unlined dredge. The lined dredge tended to have higher values for all measurements. The lined dredge also had a greater bag height and a better shape compared to the unlined dredge. Twine top height, bag height, and the height of the wheel off bottom all increased for the greatest catch volume of 300 BioRings. Twine top height values tended to have higher values as catch increased, which is in contrast to the bag height measurements, which only increased at the greatest catch volume. The wheel height off bottom value started to increase at 3.8 kts at the greatest catch volume for the unlined dredge. For the lined dredge, the wheel height increased for catch volumes of 100, 150, and 300 BioRings at 4 kts, and the greatest distance off bottom was observed at 4.5 kts. The height off bottom for the greatest catch volume of 300 BioRings at 4 kts was double that of the observed height of bottom at low speeds and catch volumes. Dredge angle increased as speed and catch volume increased for the lowest two catch trials of 30 and 100 BioRings for both dredge configurations. For all catch volumes, the greatest dredge angle was observed at 4.5 kts for both the lined and unlined dredge trials. At the required speeds of 3.8 and 4 kts the difference in dredge angle between the two configurations was minimal across all catch volumes.

Simulated catch trials looking at a simulated catch of 100 BioRings, with a 26 mm tow wire, and speeds from 4-4.5 kts at 0.1 kt intervals indicated the lined dredge configuration had higher dredge angle values compared to the unlined dredge across all speeds except at 4.5 kts. At 4.5 kts dredge angles were similar. Dredge angle for both configurations was relatively consistent for speeds of 4-4.2 kts. Dredge angle began to increase at 4.3 kts, and again at 4.4 and 4.5 kts for both dredge configurations. For the lined dredge, dredge angle increased to 5.64 degrees at 4.3 kts, 6.05 degrees at 4.4 kts, and 6.82 degrees at 4.5 kts. For the unlined dredge, dredge angle increased to 6.02 degrees at 4.3 kts, 6.68 degrees at 4.4 kts, and 6.80 degrees at 4.5 kts. While the height of the wheel of the conveyor belt was not measured, video indicated that at 4.2 kts for both dredge configurations the wheel did not always remain in contact with the conveyor belt. At 4.3 kts the wheel was completely off bottom, and the greatest height off bottom was observed at 4.5 kts.

Hydrodynamic Trials

Hydrodynamic trials with 100 BioRings, a 26 mm tow wire, and the liner installed, indicated water flowed through the dredge and exited at the back of the bag near the club stick. The same trial with no liner showed water flowed mainly out of the dredge through the twine top and not through the entire dredge. This difference in hydrodynamic flow should explain why the lined dredge has a better shape while being towed.

Scope to Depth Ratio Trials

Scope to depth ratio trials were assessed with video observations only. For lined dredge trials, a shorter scope to depth ratio of 2.5:1 showed that the dredge angle increased, the wheel was completely of bottom, and only the heels of the shoes were in contact with the conveyor belt. Increased scope to depth ratios did not impact dredge angle or dredge contact with the conveyor belt at speeds of 3.8-4 kts. At 4.5 kts, a greater scope to depth ratio of 3.25 or 3.5:1 improved shoe and wheel contact with the conveyor belt. This will likely reduce dredge angle. Results for the unlined scope to depth ratio trials were similar to the lined dredge configurations.