Numerical Simulation of an Inshore Shrimp Trawl Using Dyneema Netting

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Fisheries and Marine Institute of

Memorial University of Newfoundland

Centre for Sustainable Aquatic Resources

P.O. Box 4920, St. John's, NL, A1C 5R3

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Numerical Simulation of an Inshore Shrimp Trawl Using Dyneema Netting

Report Prepared by

Centre for Sustainable Aquatic Resources

Fisheries and Marine Institute of Memorial University

and

Crimond Enterprises Ltd.

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1.0 INTRODUCTION

Dyneema® fibers are used to make low-diameter twines with reduced towing resistance through the water, creating lower drag, thus saving energy and reducing fuel consumption. Benefits from this include towing a larger net or sweeping more fishing ground area using the same net size.

Apart from steel, there is no product used in trawl gear that can compete with Dyneema. For instance the diameter of Dyneema twine at the same strength is always 50% lower.

Wet knot strength is crucial, Dyneema hardly loses its tenacity when wet. This is in contrast with the knots in Polyethylene, which lose about 20% of their dry knot strength.

Dyneema netting in a trawl can be 50% thinner than comparable Polyethylene, and this has a major impact on the efficiency of the net.

The weight reduction is also substantial. A Dyneema based net should weigh no more than about one third of a Polyamide or regular Polyethylene net.

The use of Dyneema twines in the whole net or in sections of the net will substantially reduce the resistance and the drag, and thus save energy.

2.0 METHODOLOGY

The fishing gear development cycle often uses numerical simulation during the early stages of new trawl design (Winger et al., 2006). It typically precedes physical modeling in flume tanks and is a fast and convenient method for validating new design ideas. In addition to simulating geometry and basic drag forces, recent advances in numerical simulation also permit the estimation of mechanical forces of fishing gears on the seabed, if desired. For this project the DynamiT numerical simulation software from Ifremer was used.

> **DynamiT** developed by the French national research institute for the exploitation of the sea (IFREMER).
> Web: http://www.ifremer.fr/dynamit/en/
>
> **The DynamiT software should be used as a comparative tool, and the results should not be considered as an absolute value.**

The following activities were included in the testing plan:

1) Upon receipt of the net plan from Crimond Enterprises Ltd., the Marine Institute parameterized the trawl into individual components and inserted the corresponding values into the DynamiT software.

2) Once the trawl was properly characterized within the software, simulations were conducted at towing speeds of 2.1, 2.2, 2.3 and 2.4 knots. The water depth was set at 175 fathoms, with a total of 450 fathoms of warp out for all runs. This base line trawl used primarily polyethylene netting throughout the design. The trawl doors used in the base line simulation were # 12.5 Bison as recommended by Crimond. Output parameters recorded included:

    a. Door Spread
    b. Wing Spread
    c. Headline Height
    d. Mouth Area
    e. Total Warp Tension
    f. Bridle Tension
    g. Swept Water Volume

3) Repeated item 2 using Dyneema netting in all panels of the trawl except the wing tips, extensions and codend.

4) Repeated item 3 using # 10.5 Bison Trawl Doors®. Only 2 runs were completed with this rig. Towing speeds of 2.2 and 2.4 knots were tested.

3.0 RESULTS

The following section provides:

- Tables of trawl geometry and warp/bridle tension for various towing speeds.
- Comparative graphs illustrating geometry and tension results for the Standard and Dyneema trawls at different towing speeds and door selections.

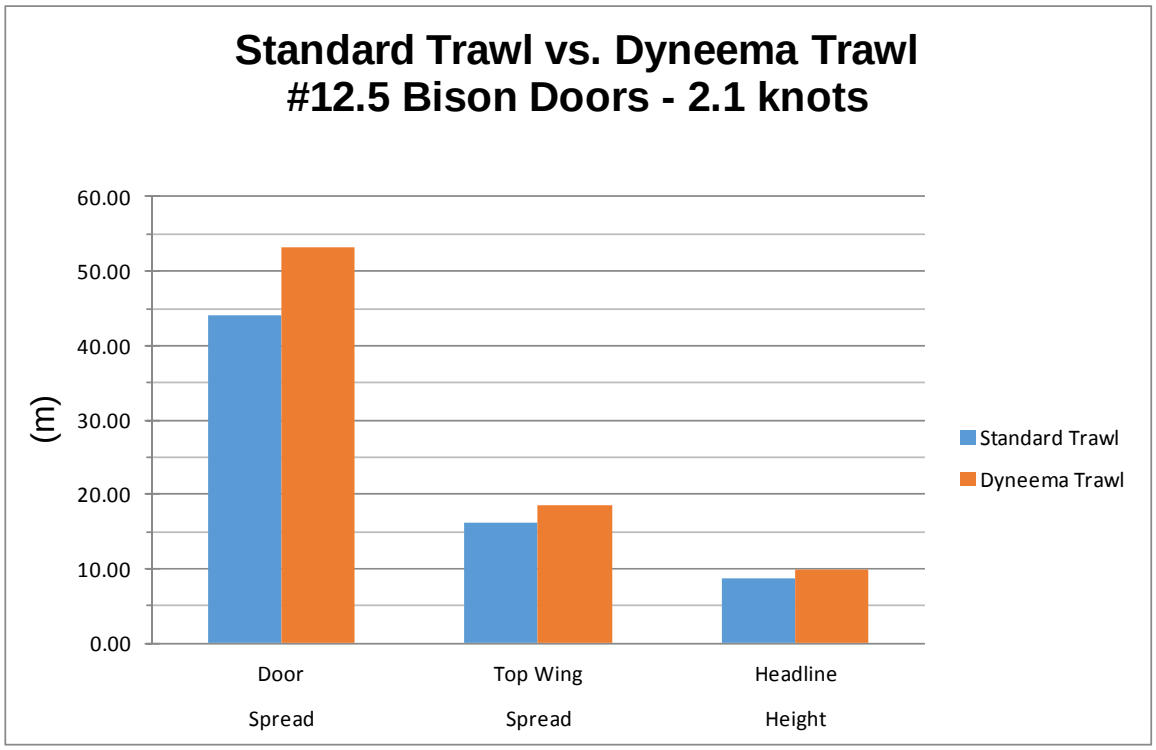
For further results and images of the simulations, please see Appendix.

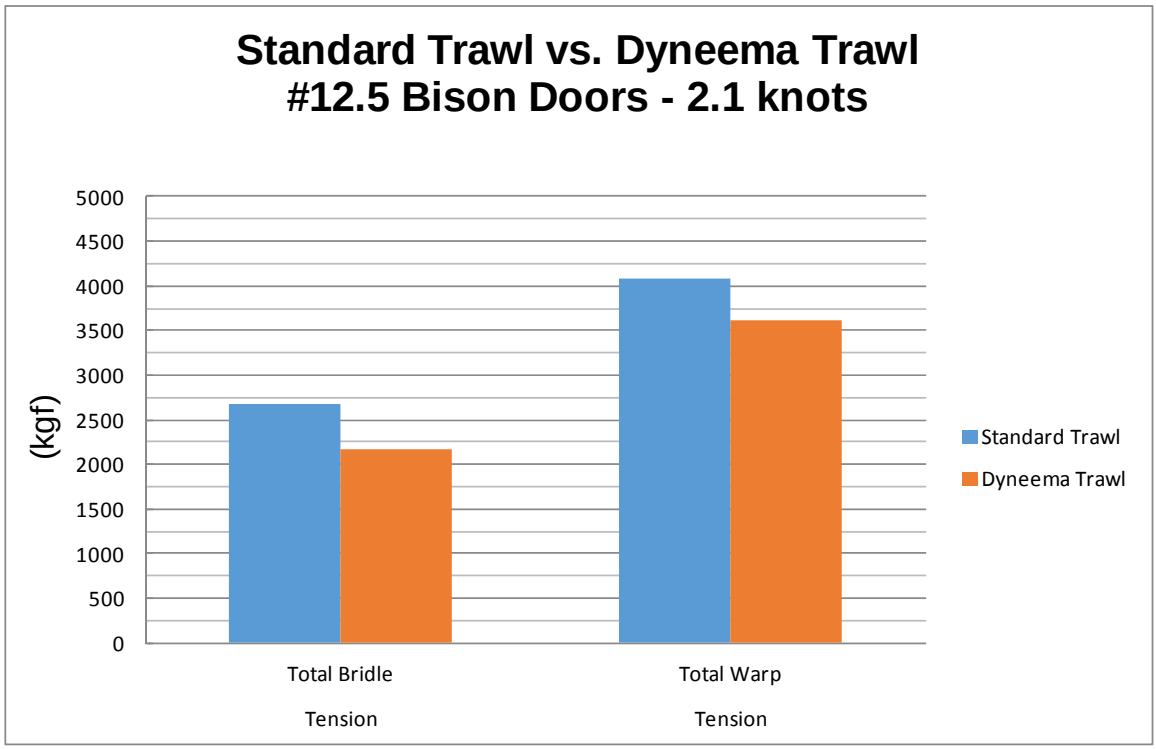
Standard Trawl - #12.5 Bison Doors							
Towing Speed (knots)	Door Spread (m)	Top Wing Spread (m)	Headline Height (m)	Total Bridle Tension (kgf)	Total Warp Tension (kgf)	Mouth Area (m^2)	Swept Water Volume (m^3/sec)
2.1	44.1	16.2	8.7	2685.4	4077.4	141.7	154.3
2.2	44.7	16.3	8.2	2901.8	4291.8	134.5	153.8
2.3	45.2	16.4	7.6	3091.1	4496.7	127.9	151.9
2.4	45.7	16.5	7.2	3447.9	4720.9	122.2	145.2

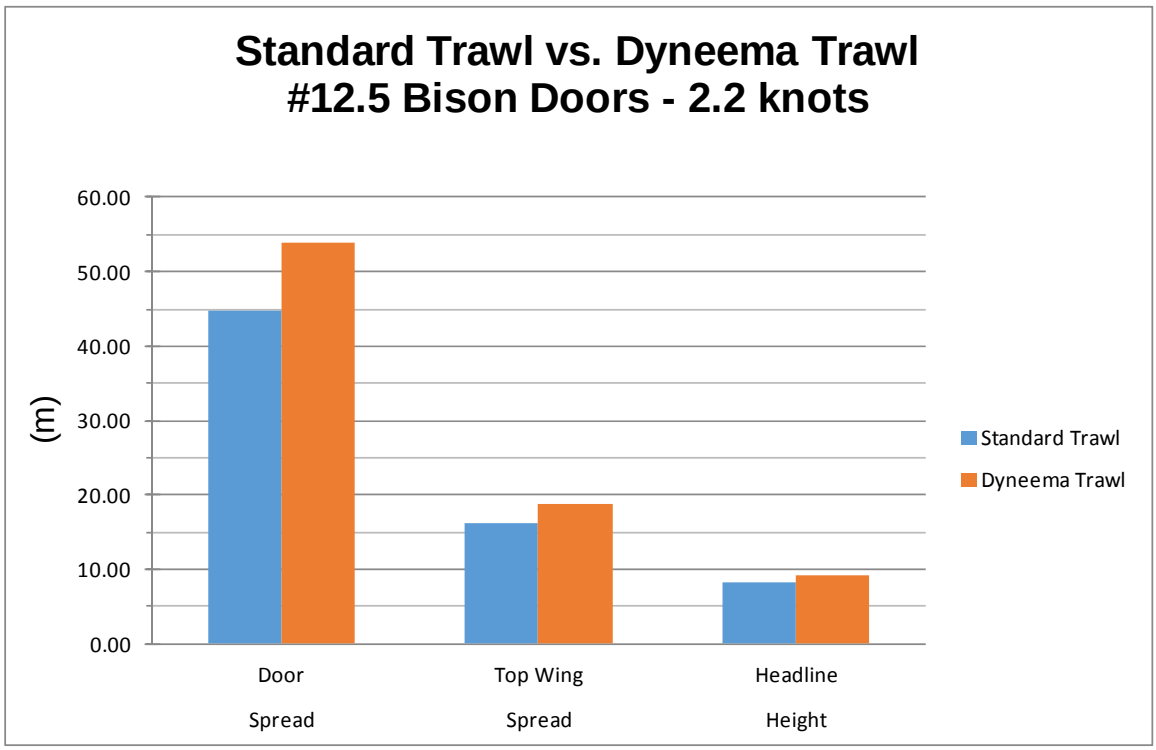
Dyneema Trawl - #12.5 Bison Doors							
Towing Speed (knots)	Door Spread (m)	Top Wing Spread (m)	Headline Height (m)	Total Bridle Tension (kgf)	Total Warp Tension (kgf)	Mouth Area (m^2)	Swept Water Volume (m^3/sec)
2.1	53.1	18.6	9.8	2166.2	3614.3	185.4	202.1
2.2	53.9	18.7	9.2	2328.4	3783.3	176.9	201.5
2.3	54.5	18.8	8.7	2494.8	3959.8	169.7	201.4
2.4	55.1	18.9	8.2	2696.4	4145.9	162.8	199.7

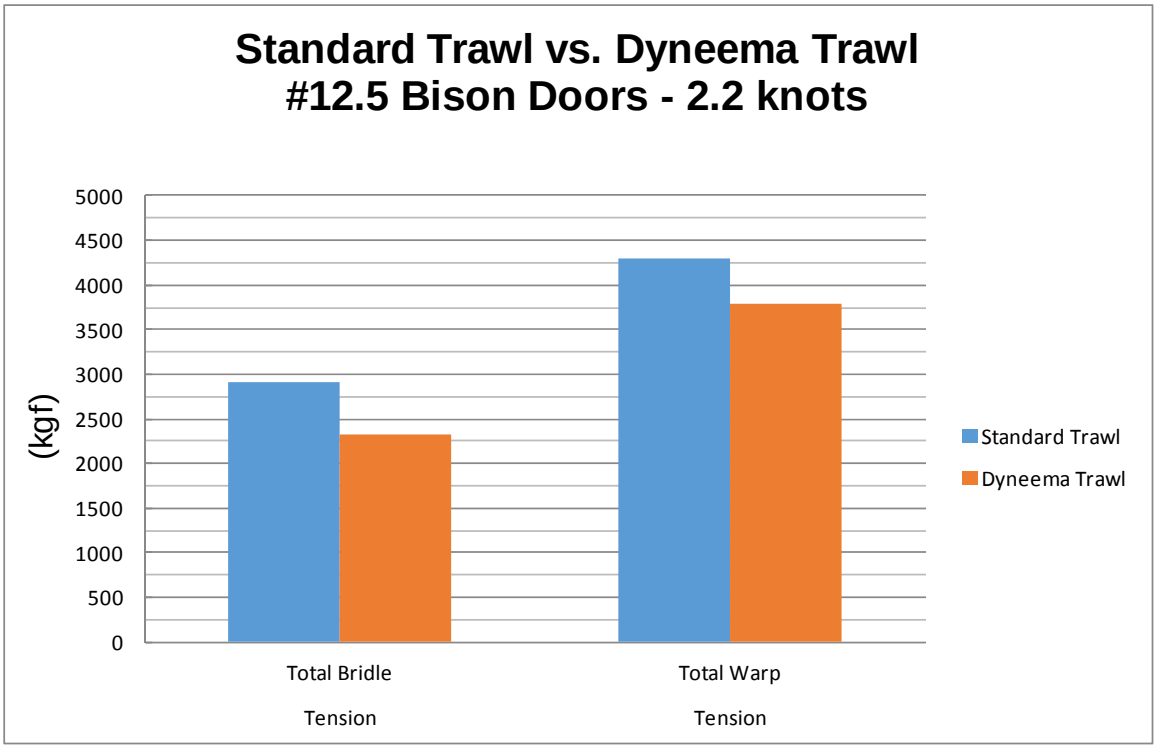
Dyneema Trawl - #10.5 Bison Doors							
Towing Speed (knots)	Door Spread (m)	Top Wing Spread (m)	Headline Height (m)	Total Bridle Tension (kgf)	Total Warp Tension (kgf)	Mouth Area (m^2)	Swept Water Volume (m^3/sec)
2.2	45.4	16.8	9.9	2214.4	3479.2	165.9	189.0
2.4	46.6	17.0	8.8	2525.3	3799.8	152.9	189.0

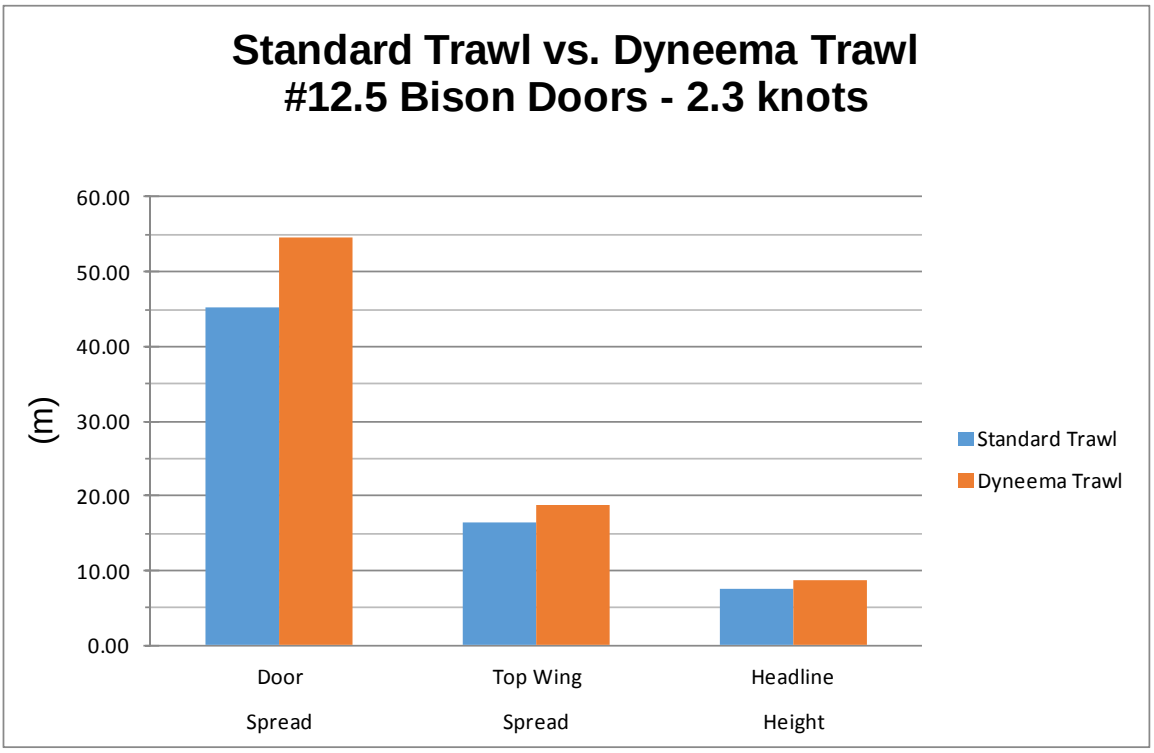
Note: All simulations were conducted at a water Depth of 175ftm (320m) with 450 ftm (823.5m) of warp out.

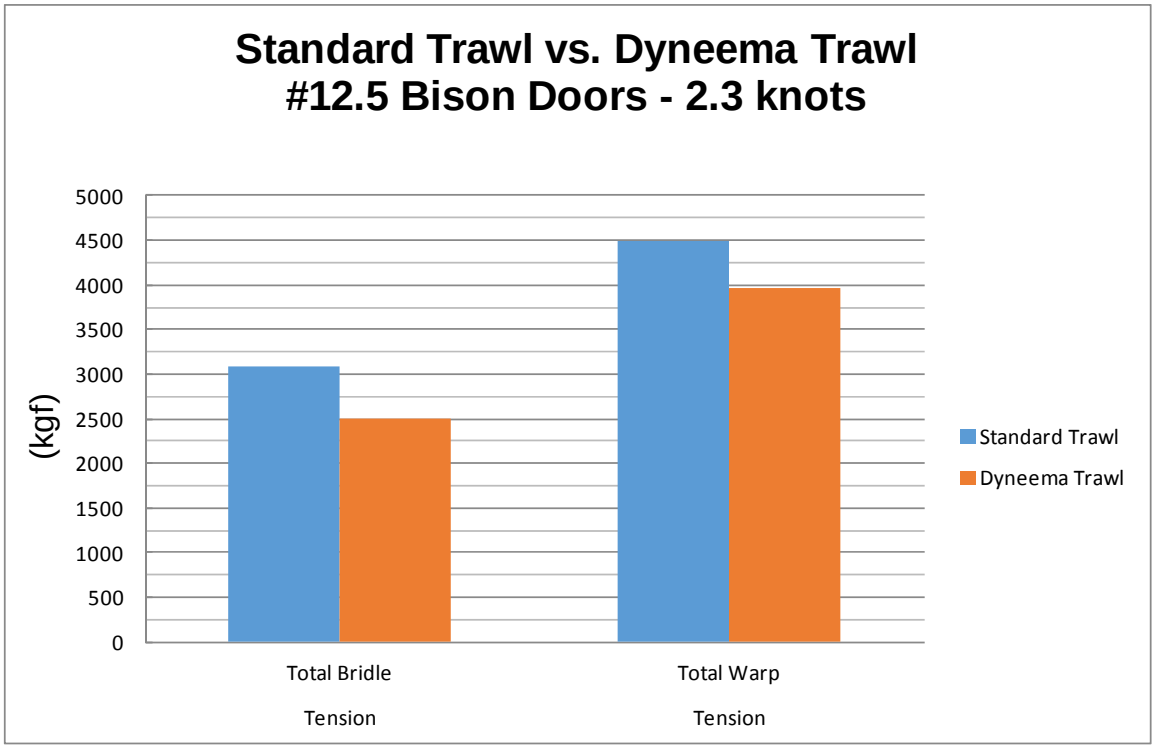

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.1 knots
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(m)
Door Spread
Top Wing Spread
Headline Height
Standard Trawl
Dyneema Trawl

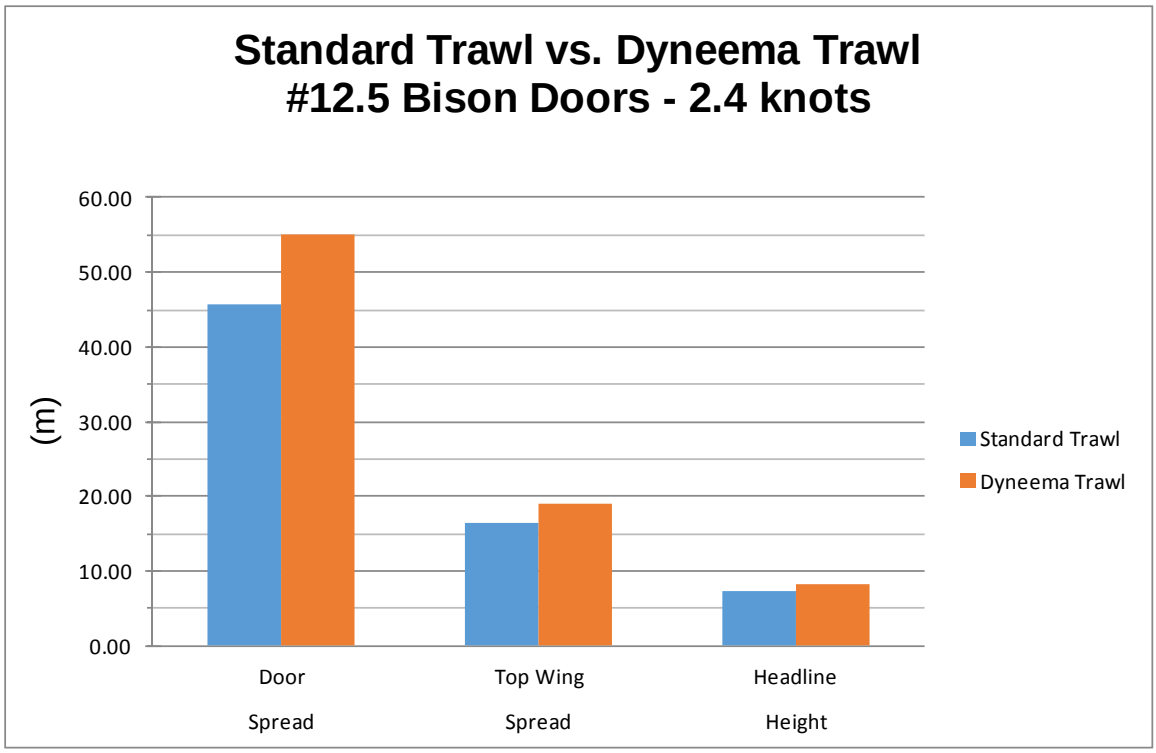

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.1 knots
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
(kgf)
Total Bridle Tension
Total Warp Tension
Standard Trawl
Dyneema Trawl

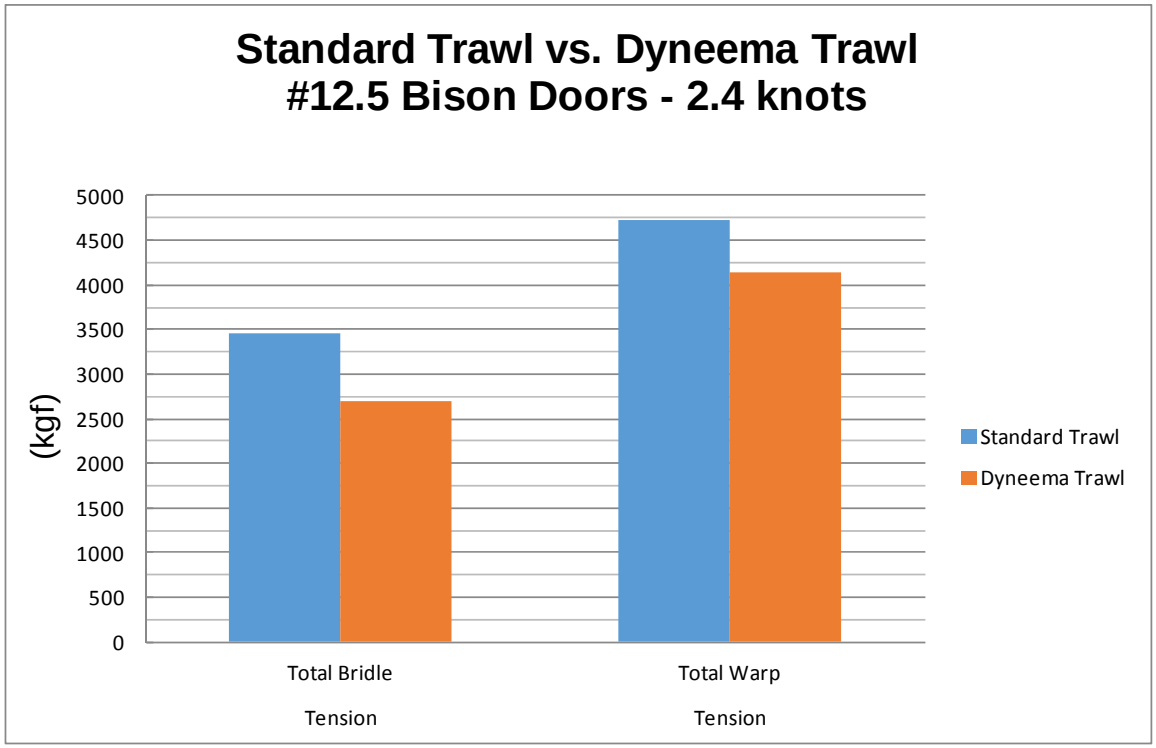

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.2 knots
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(m)
Door Spread
Top Wing Spread
Headline Height
Standard Trawl
Dyneema Trawl

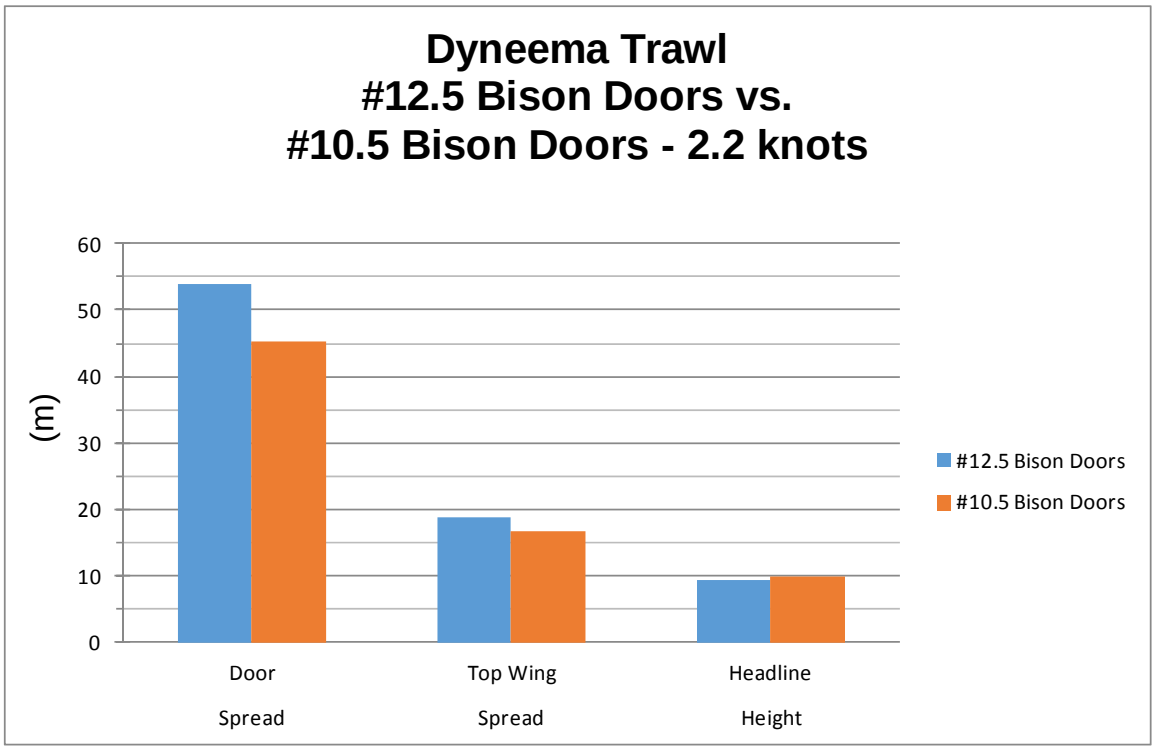

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.2 knots
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
(kgf)
Total Bridle Tension
Total Warp Tension
Standard Trawl
Dyneema Trawl

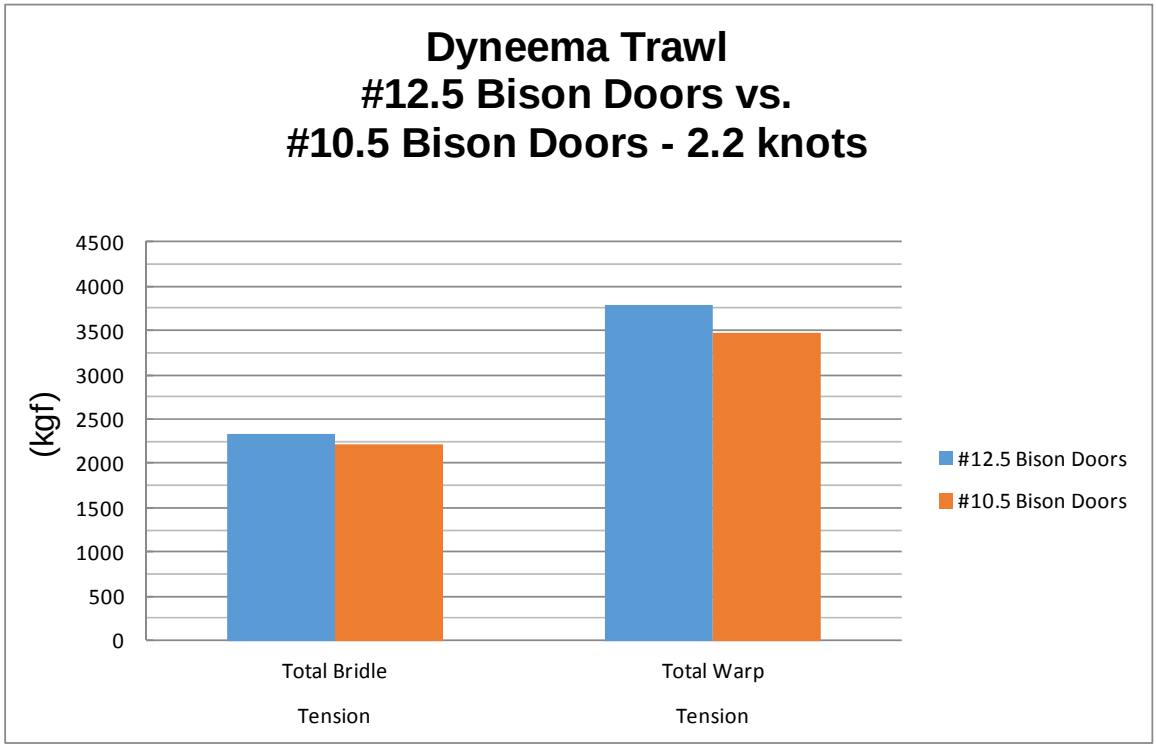

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.3 knots
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(m)
Door Spread
Top Wing Spread
Headline Height
Standard Trawl
Dyneema Trawl

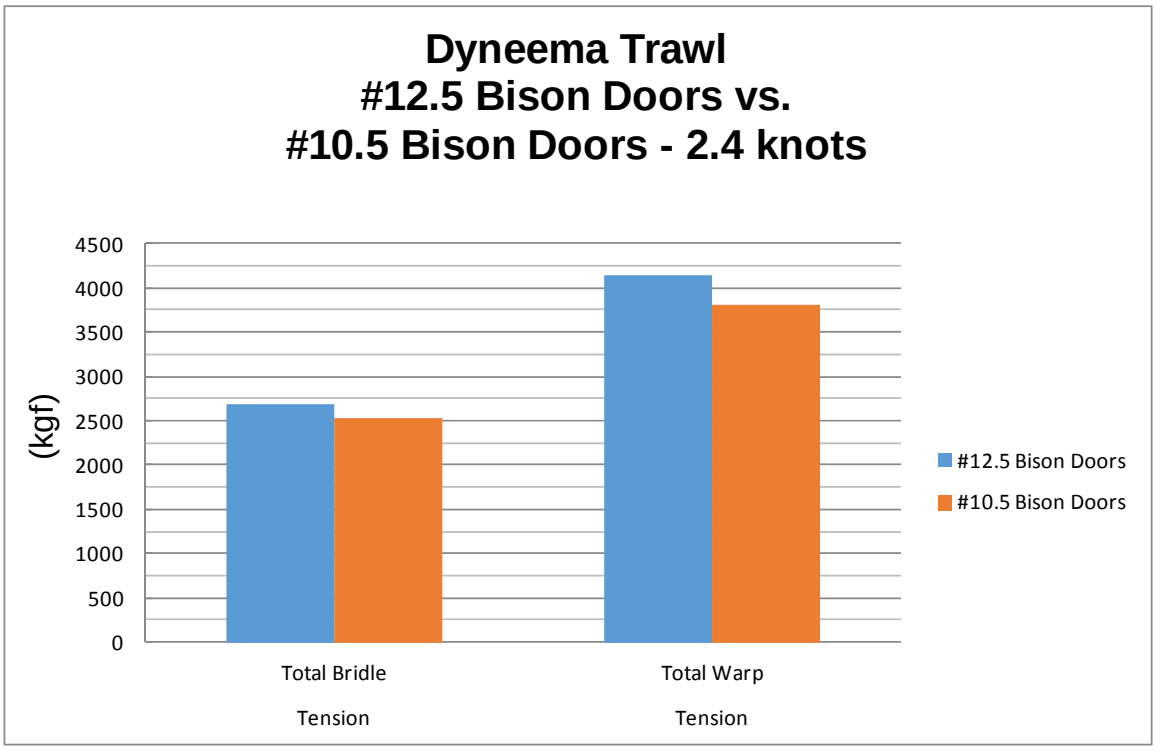

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.3 knots
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
(kgf)
Total Bridle Tension
Total Warp Tension
Standard Trawl
Dyneema Trawl

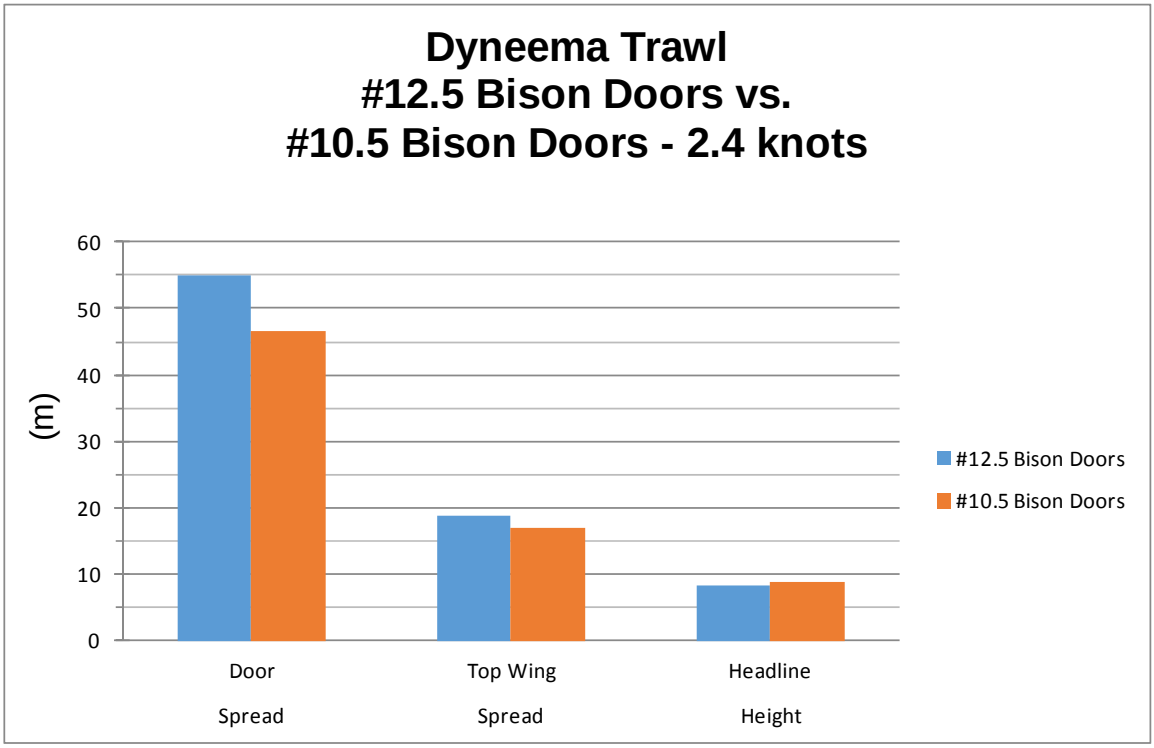

Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.4 knots
60.00
50.00
40.00
30.00
20.00
10.00
0.00
(m)
Door Spread
Top Wing Spread
Headline Height
Standard Trawl
Dyneema Trawl


Standard Trawl vs. Dyneema Trawl
#12.5 Bison Doors - 2.4 knots
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
(kgf)
Total Bridle Tension
Total Warp Tension
Standard Trawl
Dyneema Trawl


Dyneema Trawl
#12.5 Bison Doors vs.
#10.5 Bison Doors - 2.2 knots
(m)
60
50
40
30
20
10
0
Door Spread
Top Wing Spread
Headline Height
#12.5 Bison Doors
#10.5 Bison Doors


Dyneema Trawl
#12.5 Bison Doors vs.
#10.5 Bison Doors - 2.2 knots
(kgf)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Total Bridle Tension
Total Warp Tension
#12.5 Bison Doors
#10.5 Bison Doors


Dyneema Trawl
#12.5 Bison Doors vs.
#10.5 Bison Doors - 2.4 knots
(kgf)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Total Bridle Tension
Total Warp Tension
#12.5 Bison Doors
#10.5 Bison Doors


Dyneema Trawl
#12.5 Bison Doors vs.
#10.5 Bison Doors - 2.4 knots
(m)
60
50
40
30
20
10
0
Door Spread
Top Wing Spread
Headline Height
#12.5 Bison Doors
#10.5 Bison Doors

4.0 SUMMARY

Comparison of Dyneema Trawl to Standard Trawl Using #12.5 Bison Doors

- At 2.1 knots
  - The door spread of the Dyneema trawl was 20.4 % larger than that of the standard trawl.
  - The wing spread of the Dyneema trawl was 14.8 % larger than that of the standard trawl.
  - The headline height of the Dyneema trawl was 12.6 % larger than that of the standard trawl.
  - The bridle tension of the Dyneema trawl was 19.3 % less than that of the standard trawl.
  - The warp tension of the Dyneema trawl was 11.4 % less than that of the standard trawl.
  - The mouth area of the Dyneema trawl was 30.8 % larger than that of the standard trawl.

- At 2.2 knots
  - The door spread of the Dyneema trawl was 20.6 % larger than that of the standard trawl.
  - The wing spread of the Dyneema trawl was 14.7 % larger than that of the standard trawl.
  - The headline height of the Dyneema trawl was 12.2 % larger than that of the standard trawl.
  - The bridle tension of the Dyneema trawl was 19.8 % less than that of the standard trawl.
  - The warp tension of the Dyneema trawl was 11.9 % less than that of the standard trawl.
  - The mouth area of the Dyneema trawl was 31.5 % larger than that of the standard trawl.

- At 2.3 knots
    - The door spread of the Dyneema trawl was 20.6 % larger than that of the standard trawl.
    - The wing spread of the Dyneema trawl was 14.6 % larger than that of the standard trawl.
    - The headline height of the Dyneema trawl was 14.5 % larger than that of the standard trawl.
    - The bridle tension of the Dyneema trawl was 19.3 % less than that of the standard trawl.
    - The warp tension of the Dyneema trawl was 11.9 % less than that of the standard trawl.
    - The mouth area of the Dyneema trawl was 32.7 % larger than that of the standard trawl.

- At 2.4 knots
    - The door spread of the Dyneema trawl was 20.6 % larger than that of the standard trawl.
    - The wing spread of the Dyneema trawl was 14.6 % larger than that of the standard trawl.
    - The headline height of the Dyneema trawl was 13.9 % larger than that of the standard trawl.
    - The bridle tension of the Dyneema trawl was 21.8 % less than that of the standard trawl.
    - The warp tension of the Dyneema trawl was 12.2 % less than that of the standard trawl.
    - The mouth area of the Dyneema trawl was 33.2 % larger than that of the standard trawl.

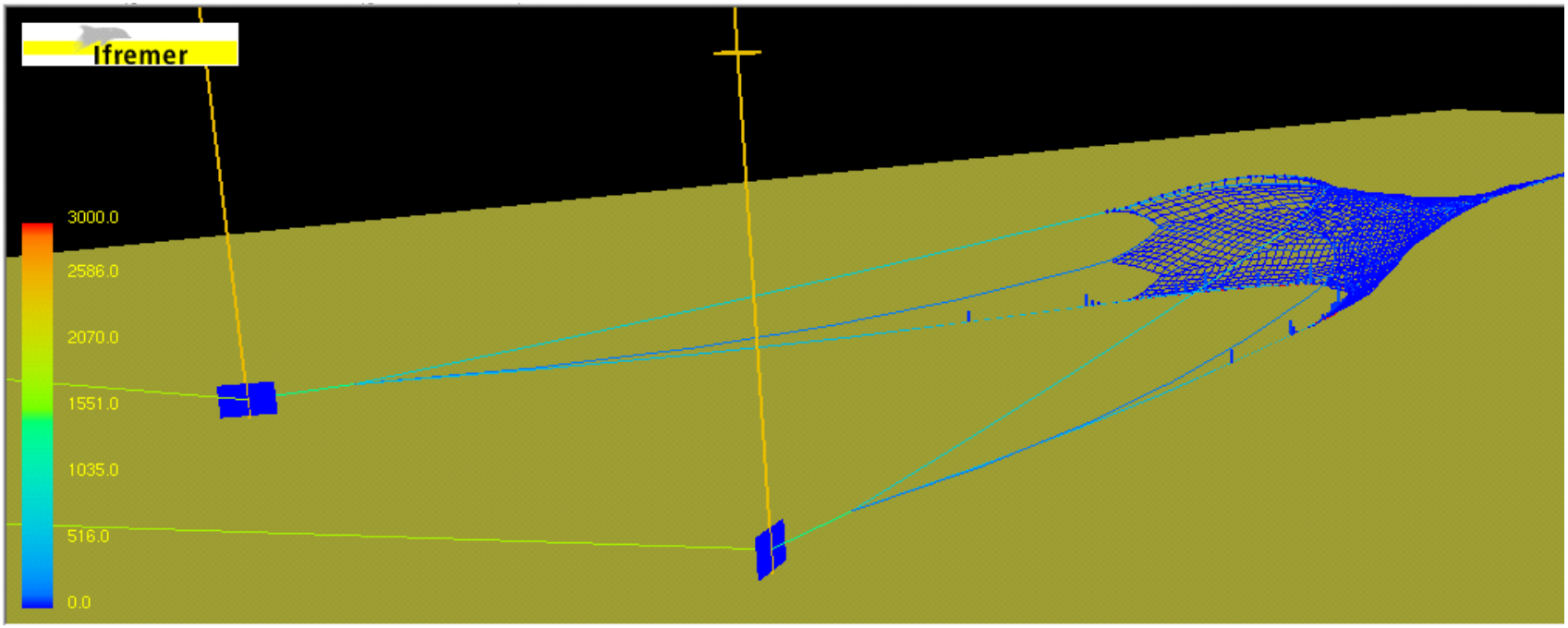
Comparison of #10.5 Bison Trawl Doors to #12.5 Bison Trawl Doors using Dyneema Trawl

- At 2.2 knots
  - The door spread of the Dyneema trawl using the #10.5 Bison Door was 15.8 % smaller than when using the #12.5 Bison door.
  - The wing spread of the Dyneema trawl using the #10.5 Bison Door was 10.2 % smaller than when using the #12.5 Bison door.
  - The headline height of the Dyneema trawl using the #10.5 Bison Door was 7.6 % larger than when using the #12.5 Bison door.
  - The bridle tension of the Dyneema trawl using the #10.5 Bison Door was 4.9 % less than when using the #12.5 Bison door.
  - The warp tension of the Dyneema trawl using the #10.5 Bison Door was 8.0 % less than when using the #12.5 Bison door.
  - The mouth area of the Dyneema trawl using the #10.5 Bison Door was 6.2 % smaller than when using the #12.5 Bison door.

- At 2.4 knots
  - The door spread of the Dyneema trawl using the #10.5 Bison Door was 15.4 % smaller than when using the #12.5 Bison door.
  - The wing spread of the Dyneema trawl using the #10.5 Bison Door was 10.1 % smaller than when using the #12.5 Bison door.
  - The headline height of the Dyneema trawl using the #10.5 Bison Door was 7.3 % larger than when using the #12.5 Bison door.
  - The bridle tension of the Dyneema trawl using the #10.5 Bison Door was 6.4 % less than when using the #12.5 Bison door.
  - The warp tension of the Dyneema trawl using the #10.5 Bison Door was 8.4 % less than when using the #12.5 Bison door.
  - The mouth area of the Dyneema trawl using the #10.5 Bison Door was 6.1 % smaller than when using the #12.5 Bison door.

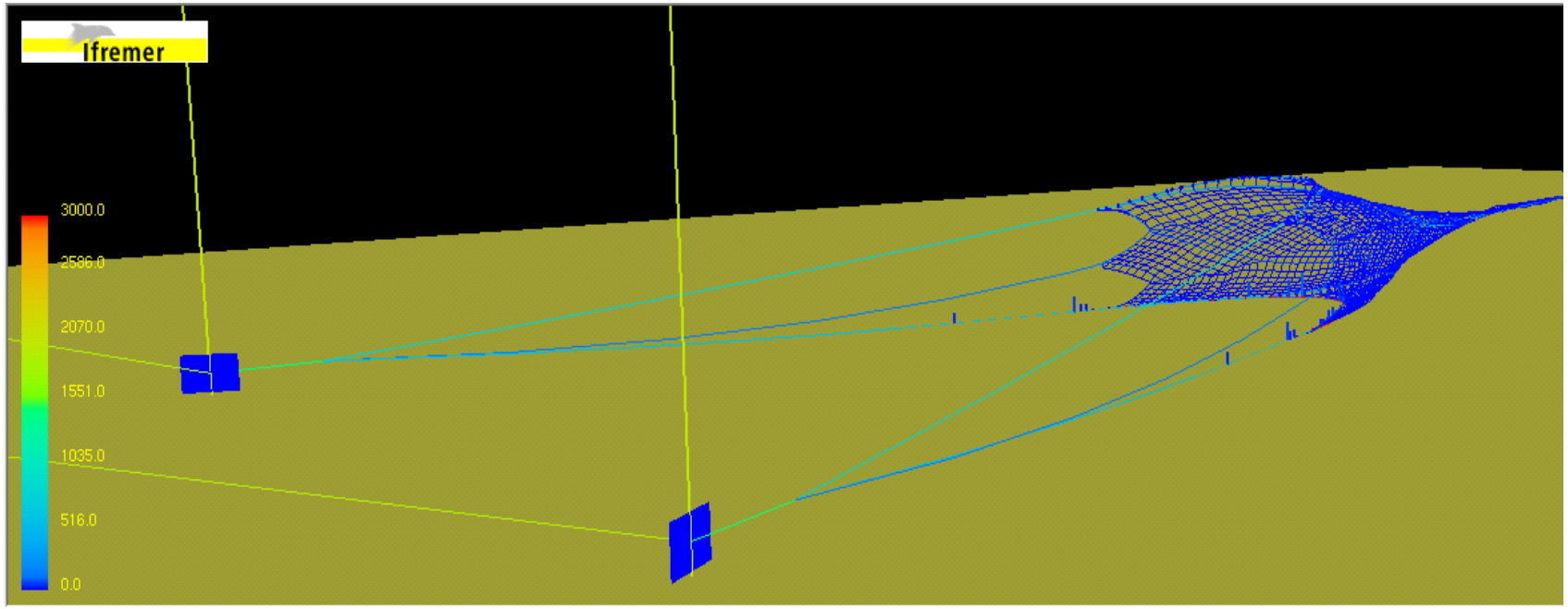
APPENDIX

Figure 1 - Standard Trawl - #12.5 Bison Doors



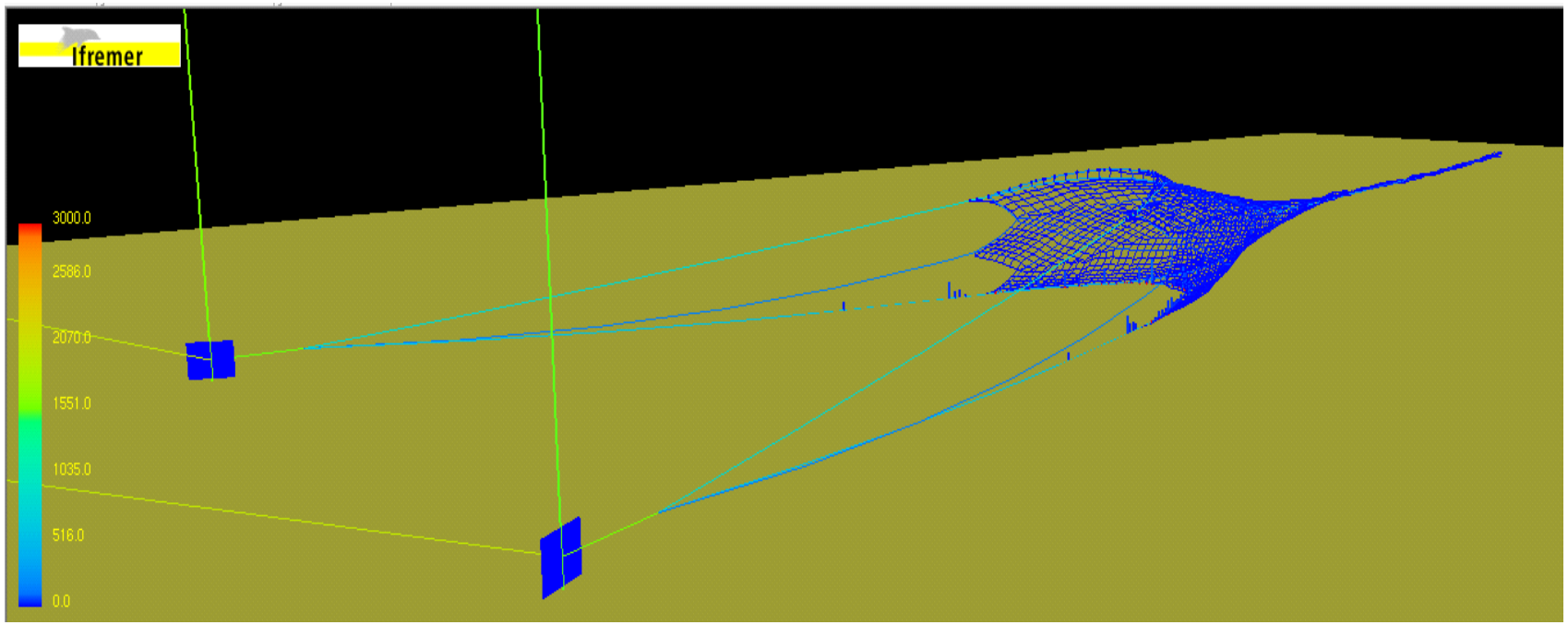
Speed (knots):	2.1	Total Bridle Tension (kgf):	2685.4
Door Spread (m):	44.1	Total Warp Tension (kgf):	4077.4
Top Wing Spread (m):	16.2	Swept Water Volume (m^3/sec):	154.3
Headline Height (m):	8.7	Water Depth (m):	320.0
Mouth Area (m^2):	141.7	Warp Out (m):	823.5

Figure 2 - Standard Trawl - #12.5 Doors



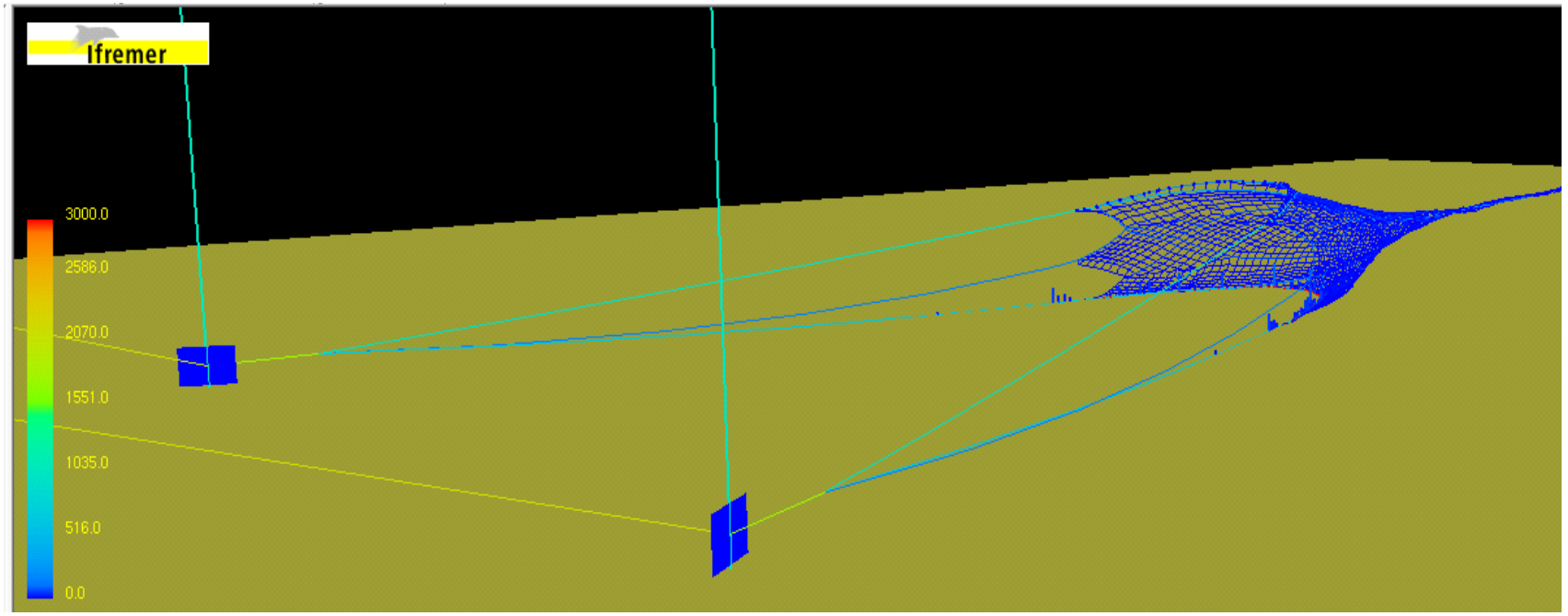
Speed (knots):	2.2	Total Bridle Tension (kgf):	2901.8
Door Spread (m):	44.7	Total Warp Tension (kgf):	4291.8
Top Wing Spread (m):	16.3	Swept Water Volume (m^3/sec):	153.8
Headline Height (m):	8.2	Water Depth (m):	320.0
Mouth Area (m^2):	134.5	Warp Out (m):	823.5

Figure 3 - Standard Trawl - #12.5 Doors



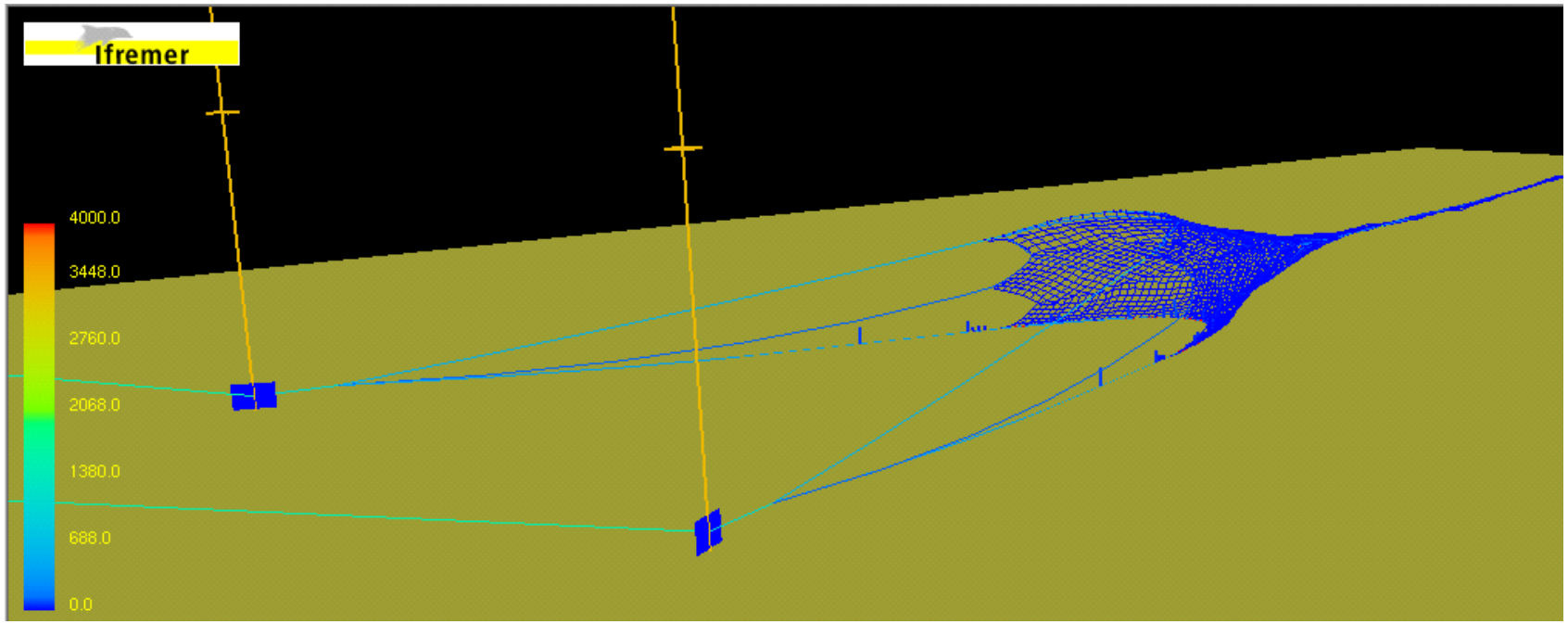
Speed (knots):	2.3	Total Bridle Tension (kgf):	3091.1
Door Spread (m):	45.2	Total Warp Tension (kgf):	4496.7
Top Wing Spread (m):	16.4	Swept Water Volume (m^3/sec):	151.9
Headline Height (m):	7.6	Water Depth (m):	320.0
Mouth Area (m^2):	127.9	Warp Out (m):	823.5

Figure 4 - Standard Trawl - #12.5 Doors



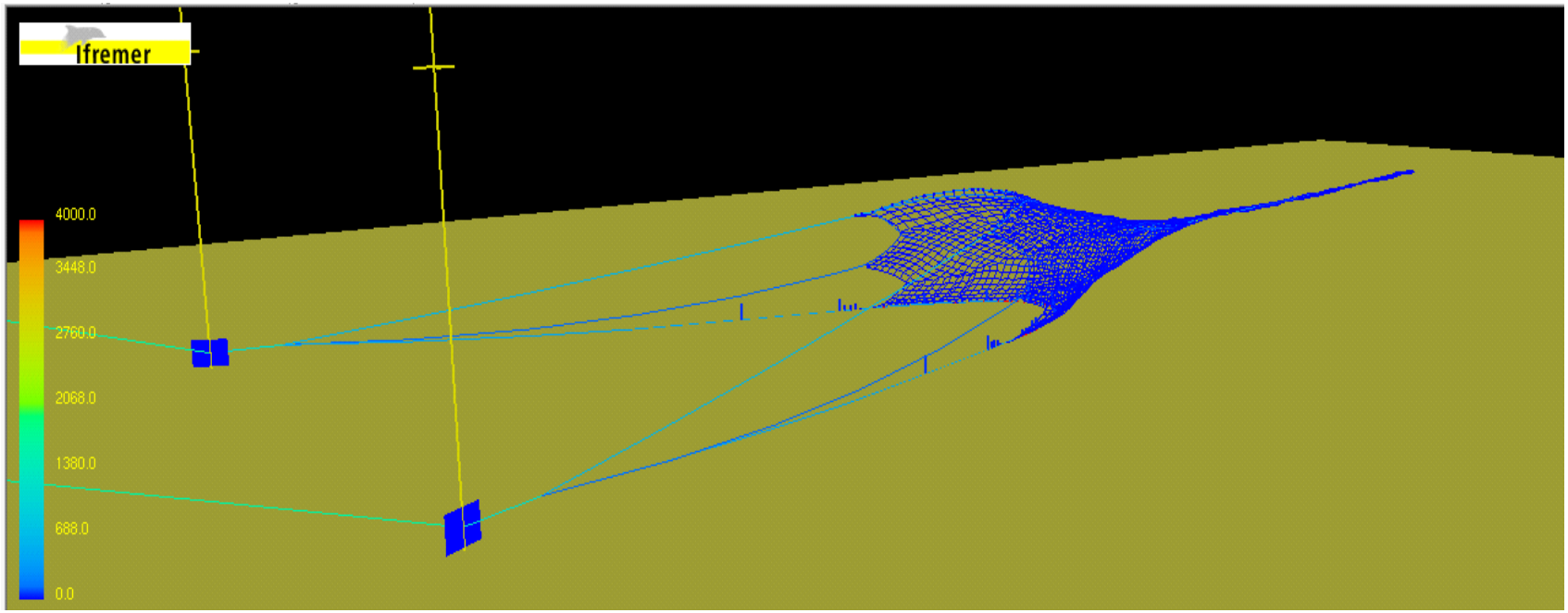
Speed (knots):	2.4	Total Bridle Tension (kgf):	3447.9
Door Spread (m):	45.7	Total Warp Tension (kgf):	4720.9
Top Wing Spread (m):	16.5	Swept Water Volume (m^3/sec):	145.2
Headline Height (m):	7.2	Water Depth (m):	320.0
Mouth Area (m^2):	122.2	Warp Out (m):	823.5

Figure 5 - Dyneema Trawl - #12.5 Doors



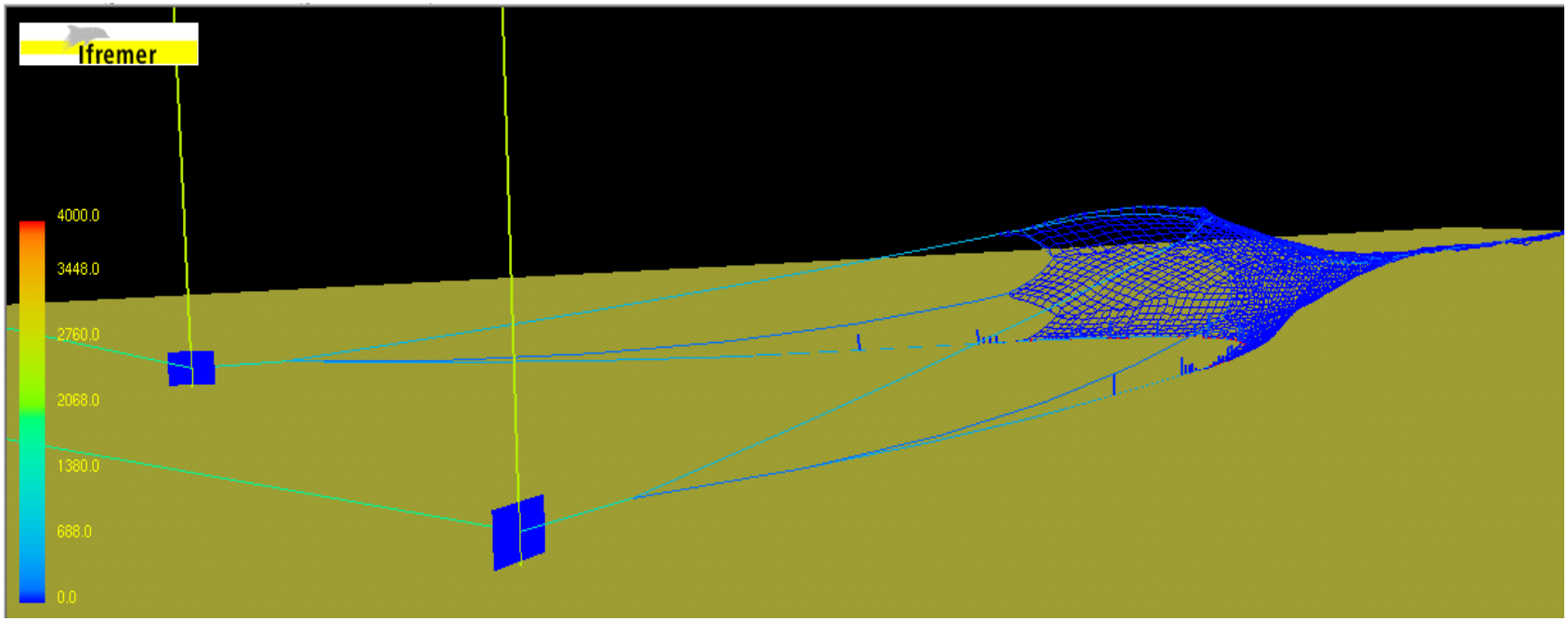
Speed (knots):	2.1	Total Bridle Tension (kgf):	2166.2
Door Spread (m):	53.1	Total Warp Tension (kgf):	3614.3
Top Wing Spread (m):	18.6	Swept Water Volume (m^3/sec):	202.1
Headline Height (m):	9.8	Water Depth (m):	320.0
Mouth Area (m^2):	185.4	Warp Out (m):	823.5

Figure 6 - Dyneema Trawl - #12.5 Doors



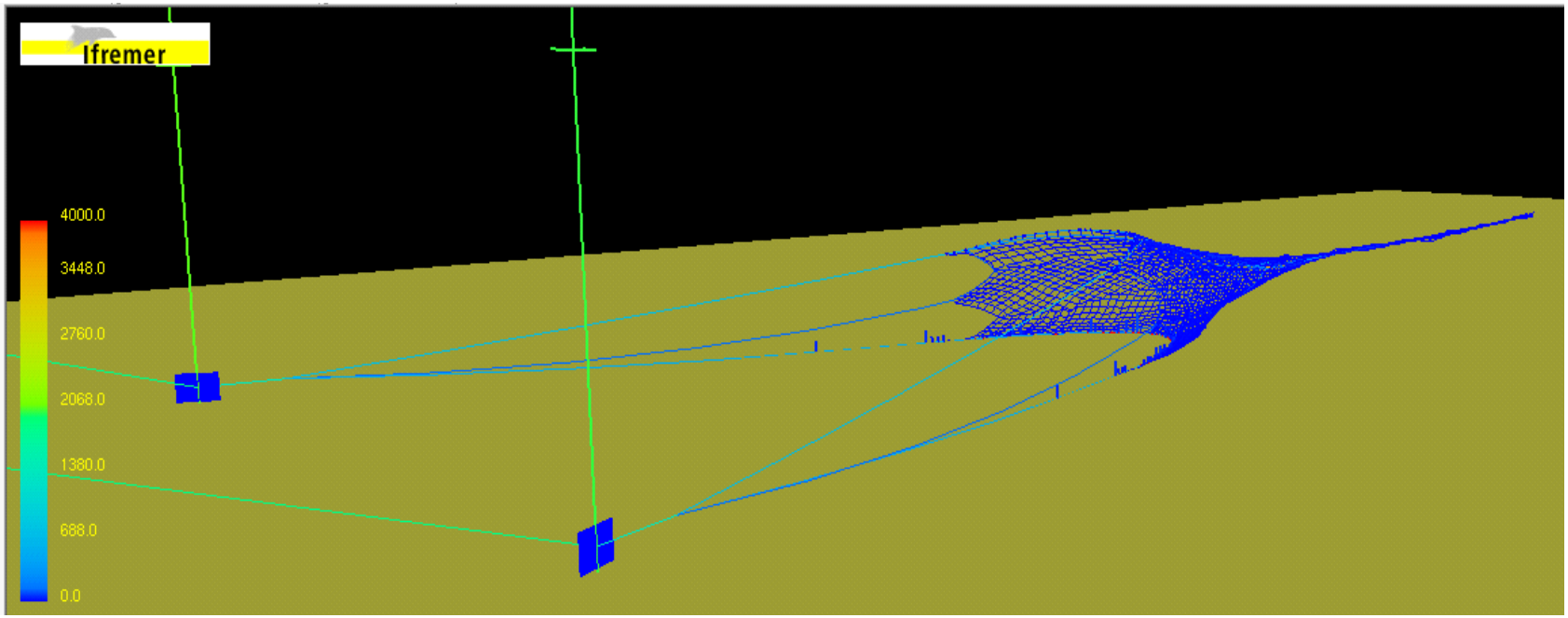
Speed (knots):	2.2	Total Bridle Tension (kgf):	2328.4
Door Spread (m):	53.9	Total Warp Tension (kgf):	3783.3
Top Wing Spread (m):	18.7	Swept Water Volume (m^3/sec):	201.5
Headline Height (m):	9.2	Water Depth (m):	320.0
Mouth Area (m^2):	176.9	Warp Out (m):	823.5

Figure 7 - Dyneema Trawl - #12.5 Doors



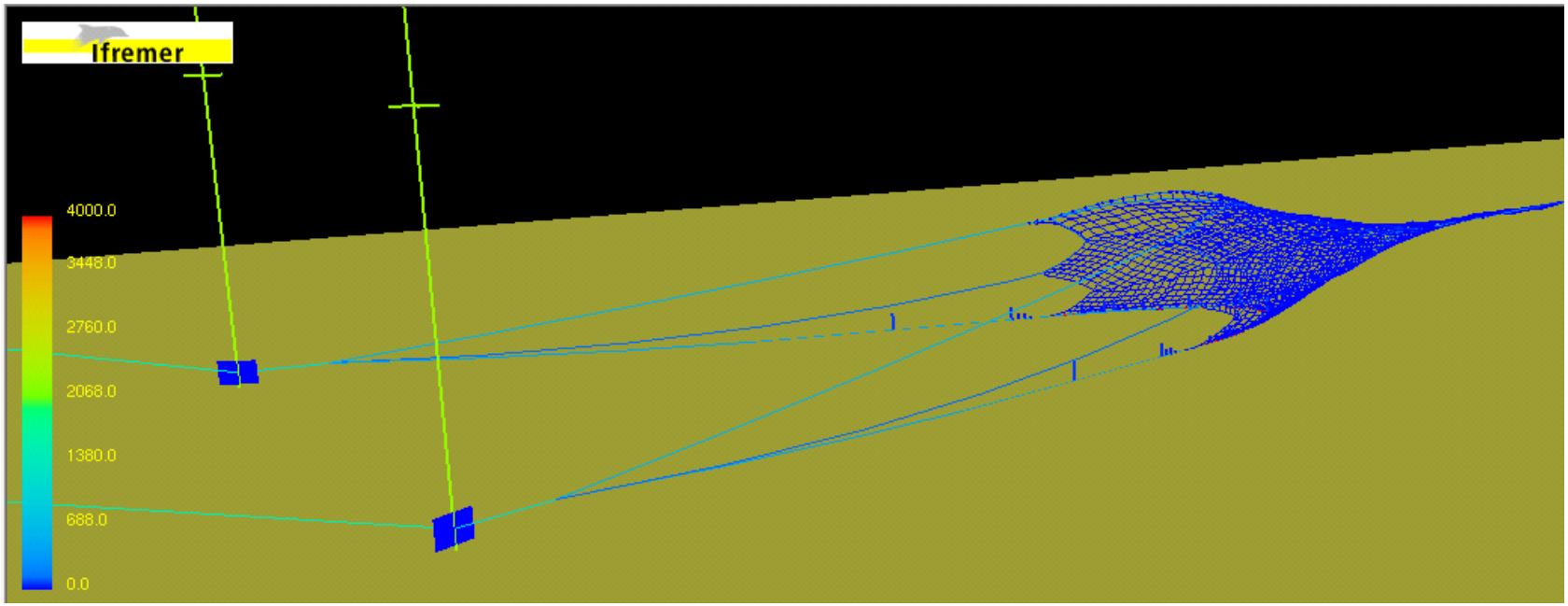
Speed (knots):	2.3	Total Bridle Tension (kgf):	2494.8
Door Spread (m):	54.5	Total Warp Tension (kgf):	3959.8
Top Wing Spread (m):	18.8	Swept Water Volume (m^3/sec):	201.4
Headline Height (m):	8.7	Water Depth (m):	320.0
Mouth Area (m^2):	169.7	Warp Out (m):	823.5

Figure 8 - Dyneema Trawl - #12.5 Doors



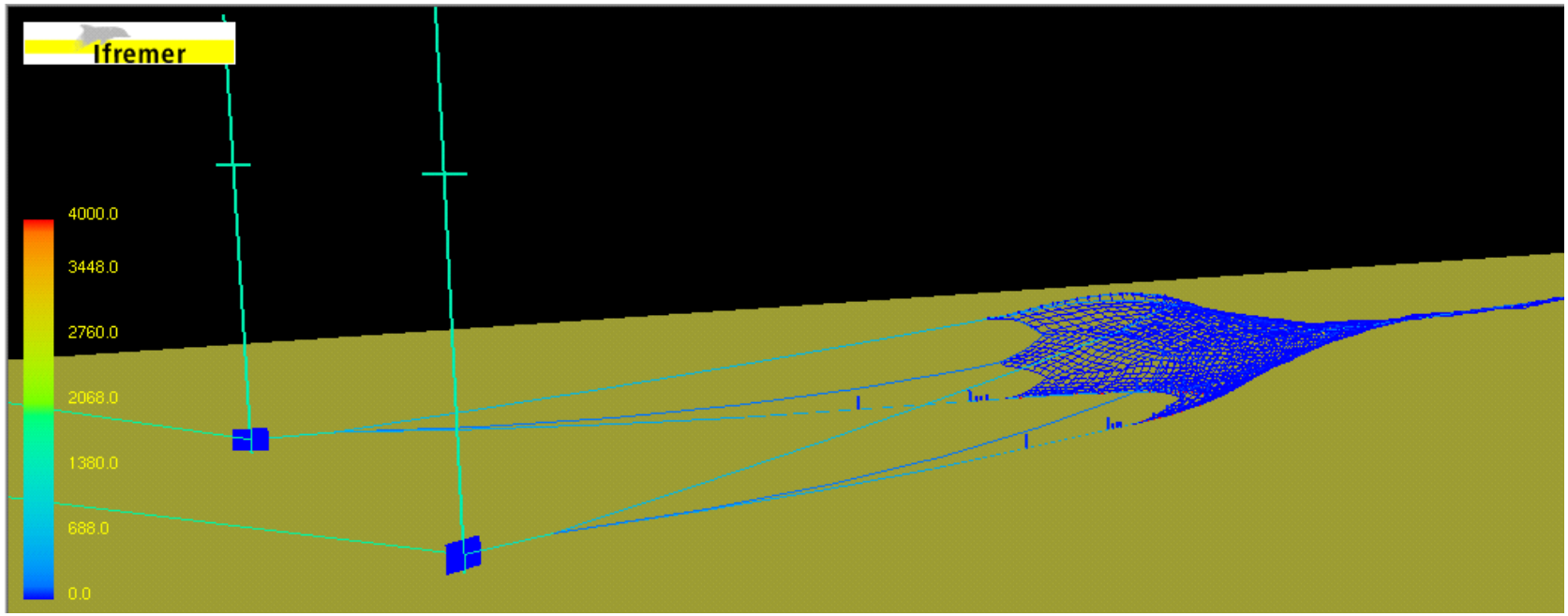
Speed (knots):	2.4	Total Bridle Tension (kgf):	2696.4
Door Spread (m):	55.1	Total Warp Tension (kgf):	4145.9
Top Wing Spread (m):	18.9	Swept Water Volume (m^3/sec):	199.7
Headline Height (m):	8.2	Water Depth (m):	320.0
Mouth Area (m^2):	162.8	Warp Out (m):	823.5

Figure 9 - Dyneema Trawl - #10.5 Doors



Speed (knots):	2.2	Total Bridle Tension (kgf):	2214.4
Door Spread (m):	45.4	Total Warp Tension (kgf):	3479.2
Top Wing Spread (m):	16.8	Swept Water Volume (m^3/sec):	189.0
Headline Height (m):	9.9	Water Depth (m):	320.0
Mouth Area (m^2):	165.9	Warp Out (m):	823.5

Figure 10 - Dyneema Trawl - #10.5 Doors



Speed (knots):	2.4	Total Bridle Tension (kgf):	2525.3
Door Spread (m):	46.6	Total Warp Tension (kgf):	3799.8
Top Wing Spread (m):	17.0	Swept Water Volume (m^3/sec):	189.0
Headline Height (m):	8.8	Water Depth (m):	320.0
Mouth Area (m^2):	152.9	Warp Out (m):	823.5