Supplementary Material: Resolution of biodiversity and assemblage structure in demersal fisheries surveys: the role of tow duration

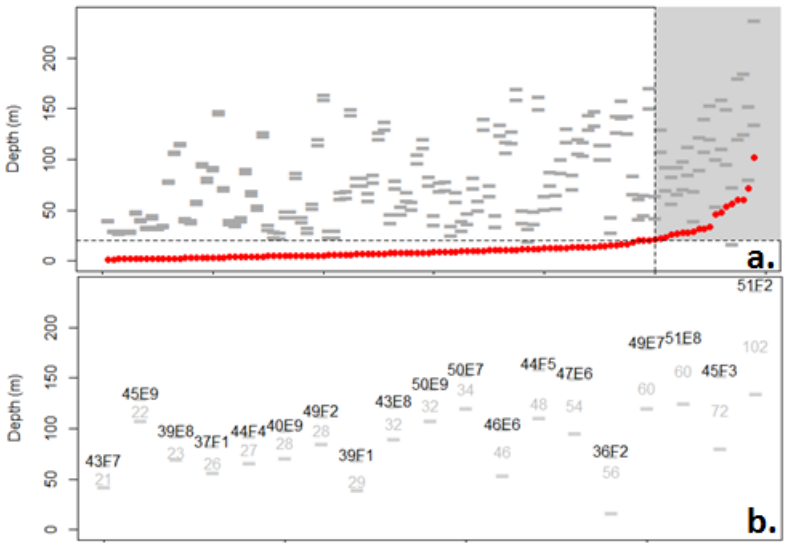

Figure S1. (a.) Differences in depth of paired long and short tows. The majority of rectangles (84%) have paired tows with depth difference of 20m or less. The red dots show the spread of the depths and the grey lines show the actual depths recorded. (b.) This graph highlights the rectangles of paired tows of more than 20m depth differences (grey box in top graph).

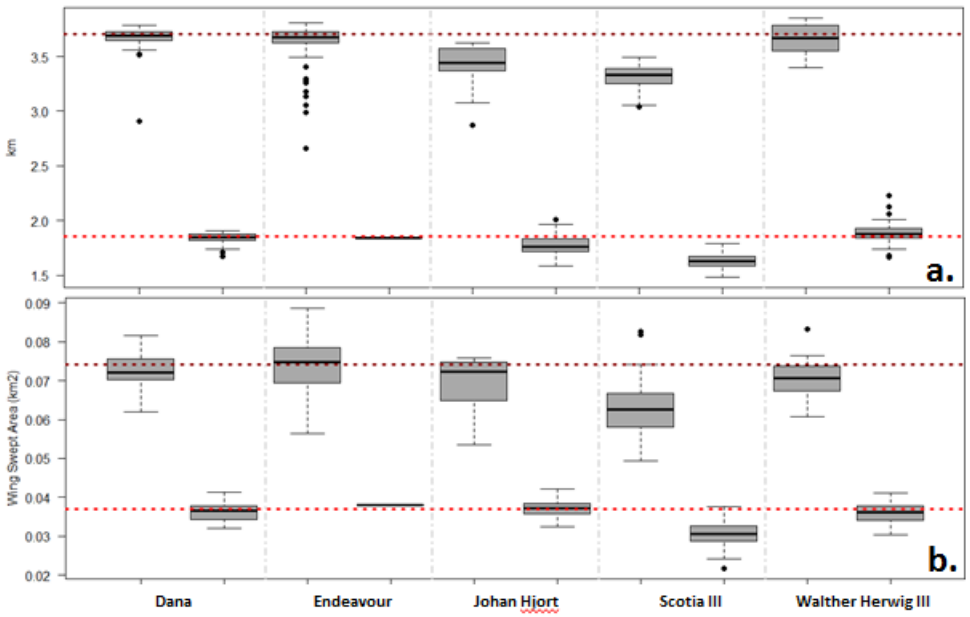

Figure S2 (a.) The top boxplot shows the distance towed for long and short tows the dark red line shows the expected distance towed for 30min at 4 knots (3.7km) the light red line shows the expected distance towed in 15mins at 4 knots (1.85km) for the 2015 and 2016 sample area. (b.) The bottom boxplot shows the wing swept area estimates (km^2) for long and short tow durations at a mean wingspread of 20m. Analysis of variance shows that ship is a significant factor for explaining differences in distance and speed. The mean speed in the long group is 3.86 knots while in the short group it is 3.76 knots.

Table S1: Species occurrence in each tow category and in each year in the study area. Over the two-year period 89 species where collected in long tows, 80 species where recorded in short tows. 95 different species where recorded in total. Resolution of taxonomic discrepancies carried out by Moriarty et al., (2017) are noted below the table.

	Common Name	long, 2015	long, 2016	short, 2015	short, 2016	% of occurrence in survey for both years
Actinopterygii						
Beloniformes						
Belone belone	Garfish	0	1	0	0	0.24
Clupeiformes[1]						
Alosa alosa	Allis shad	1	0	1	0	0.49
Alosa fallax	Twaite shad	3	1	1	0	1.22
Clupea harengus	Herring	88	93	74	78	81.02
Engraulis encrasicolus	Anchovy	12	6	8	3	7.06
Sardina pilchardus	Pilchard	5	4	2	2	3.16
Sprattus sprattus	Sprat	53	49	44	37	44.53
Gadiformes						
Ciliata mustela	Five-bearded rockling	0	0	0	1	0.24
Enchelyopus cimbrius	Four-bearded rockling	17	19	7	11	13.14
Gadiculus argenteus	Silvery pout	3	9	5	12	7.06
Gadiculus thori	Pout	2	2	2	1	1.70
Gadus morhua	Cod	52	59	54	65	55.96
Melanogrammus aeglefinus	Haddock	67	74	59	81	68.37
Merlangius merlangus	Whiting	92	102	92	108	95.86

Merluccius merluccius	Hake	39	46	37	42	39.90
Micromesistius poutassou	Blue whiting	15	8	13	13	11.92
Molva molva	Ling	14	14	15	20	15.33
Phycis blennoides	Greater forkbeard	2	0	1	0	0.73
Pollachius pollachius	Pollack	0	1	1	1	0.73
Pollachius virens	Saithe	35	42	32	33	34.55
Trisopterus esmarkii	Norway pout	46	53	45	57	48.91
Trisopterus luscus	Bib	1	3	3	1	1.95
Trisopterus minutus	Poor cod	19	24	18	27	21.41
Lophiiformes						
Lophius budegassa	Black bellied angler	3	4	0	1	1.95
Lophius piscatorius	Angler	34	45	27	27	32.36
Osmeriformes[2/3]						
Argentina silus	Greater argentine	12	8	12	11	10.46
Argentina sphyraena	Lesser argentine	33	39	31	45	36.01
Perciformes						
Ammodytidae[4]	Sandeels	23	16	20	20	19.22
Anarhichas lupus	Catfish	3	8	2	4	4.14
Callionymus lyra	Dragonet	39	40	30	39	36.01
Callionymus maculatus	Spotted dragonet	24	32	17	24	23.60
Callionymus reticulatus	Reticulated dragonet	0	4	1	0	1.22
Capros aper	Boarfish	3	4	3	5	3.65
Echiichthys vipera[5]	Lesser weever	13	12	13	11	11.92
Gobiidae[6]	Gobies	2	8	3	13	6.33
Leptoclinus maculatus	Spotted snake blenny	1	0	0	0	0.24
Lumpenus lampretaeformis	Snake blenny	2	0	5	2	2.19
Lycodes gracilis	Eelpout	1	0	2	1	0.97
Lycodes vahlii	Eelpout	0	1	0	0	0.24
Mullus surmuletus	Striped red mullet	17	14	13	7	12.41
Pholis gunnellus	Butterfish	1	2	0	4	1.70
Sarda sarda	Atlantic bonito	1	0	0	0	0.24
Scomber colias	Atlantic chub mackerel	1	0	0	0	0.24
Scomber scombrus	Mackerel	76	73	63	52	64.23
Trachinus draco	Greater weever	0	0	1	1	0.49
Trachurus trachurus	Horse mackerel	60	71	32	43	50.12
Pleuronectiformes						
Arnoglossus laterna	Scaldfish	18	16	9	11	13.14
Buglossidium luteum	Solenette	24	25	19	23	22.14
Glyptocephalus cynoglossus	Witch	23	18	15	15	17.27
Hippoglossoides platessoides	Long rough dab	75	74	69	81	72.75

Hippoglossus hippoglossus	Halibut	2	3	3	2	2.43
Lepidorhombus whiffiagonis	Megrim	18	16	12	19	15.82
Limanda limanda	Common dab	87	93	82	96	87.10
Microchirus variegatus	Thickback sole	2	2	0	2	1.46
Microstomus kitt	Lemon sole	85	84	72	87	79.81
Phrynorhombus norvegicus	Norwegian topknot	1	0	0	0	0.24
Platichthys flesus	Flounder	3	4	6	1	3.41
Pleuronectes platessa	Plaice	85	86	77	86	81.27
Scophthalmus maximus	Turbot	7	12	7	8	8.27
Scophthalmus rhombus	Brill	4	4	3	6	4.14
Solea solea	Dover sole	6	9	6	3	5.84
Zeugopterus punctatus[7]	Topknot	0	1	0	0	0.24
Salmoniformes						
Salmo trutta trutta	Sea trout	0	1	0	0	0.24
Scorpaeniformes						
Agonus cataphractus	Hooknose	14	18	10	11	12.90
Chelidonichthys cuculus[8]	Red gurnard	5	5	6	10	6.33
Chelidonichthys lucerna[8]	Tub gurnard	7	9	10	9	8.52
Cyclopterus lumpus	Lumpsucker	1	1	1	0	0.73
Eutrigla gurnardus[9]	Grey gurnard	98	102	95	105	97.32
Helicolenus dactylopterus	Bluemouth	1	2	0	0	0.73
Liparis liparis liparis	Striped seasnail	0	1	0	0	0.24
Myoxocephalus scorpius	Bullrout	11	4	7	1	5.60
Sebastes viviparus[10]	Norway haddock	8	11	10	4	8.03
Trigla lyra[11]	Piper gurnard	7	7	0	0	3.41
Triglops murrayi	Moustache sculpin	1	2	0	0	0.73
Stomiiformes						
Maurolicus muelleri	Pearlside	0	4	2	1	1.70
Syngnathiformes						
Entelurus aequoreus	Snake pipefish	0	0	0	1	0.24
Syngnathus acus[12]	Great pipefish	0	0	0	1	0.24
Zeiformes						
Zeus faber	John dory	3	2	1	1	1.70
Chondrichthyes						
Lamniformes						
Cetorhinus maximus	Basking shark	0	1	0	0	0.24
Elasmobranchii						
Carcharhiniformes						
Galeorhinus galeus	Tope	0	3	0	1	0.97
Mustelus asterias	Starry smooth hound	3	2	3	3	2.68
Mustelus mustelus	Smooth hound	0	0	2	3	1.22
Scyliorhinus canicula	Lesser spotted dogfish	23	40	22	28	27.49

Rajiformes						
Amblyraja radiata	Starry ray	34	37	22	28	29.44
Dipturus batis[13]	Blue skate	2	0	1	2	1.22
Leucoraja fullonica	Shagreen ray	1	1	0	0	0.49
Leucoraja naevus	Cuckoo ray	9	13	6	12	9.73
Raja brachyura	Blond ray	0	0	0	3	0.73
Raja clavata	Thornback ray	4	3	2	2	2.68
Raja montagui	Spotted ray	3	4	1	5	3.16
Squaliformes						
Etmopterus spinax	Velvet belly	0	0	1	0	0.24
Squalus acanthias	Spurdog	12	9	2	5	6.81
Myxini						
Myxiniformes						
Myxine glutinosa	Hagfish	6	8	6	8	6.81
Petromyzonti						
Petromyzontiformes						
Lampetra fluviatilis	European river lamprey	1	0	0	0	0.24
Petromyzon marinus	Sea lamprey	0	1	0	0	0.24

[1] Clupeidae reported on 5 occasions by England resolved to species level using k-NN (Moriarty et al., 2017), This resulted in 4 Clupeidae estimated as *C. harengus* and 3 Clupeidae estimated as *S. sprattus*

[2] Argentinidae reported on 36 occasions by England resolved to species level using k-NN. This resulted in 416 species level estimations.

[3] *Argentina* reported on 1 occasion by Norway resolved to species level using k-NN.

[4] Ammodytidae (Sandeels) are grouped to family level.

[5] England uses the genus *Echiichthys* to report *E. vipera*, all occurrences changed to reflect species level.

[6] All Gobiidae are grouped to family level.

[7] England uses the genus *Zeugopterus* to report Z. punctatus, all occurrences (n=2) changed to reflect species level.

[8] Chelidonichthys reported by England resolved to species level using k-NN. This resulted in 19 species level estimations.

[9] England uses the genus *Eutrigla* to report *E. gurnardus*, all occurrences changed to reflect species level.

[10] England uses the genus *Sebastes* to report *S. viviparous*, all occurrences (n=3) changed to reflect species level.

[11] England uses the genus *Trigla* to report *T. lyra*, all occurrences changed to reflect species level.

[12] One occurrence of *Syngnathus,* by Germany has been changed to *S. acus.*

[13] One occurrence of *Dipturus,* by England has been changed to *D. batis.*

Table S2. The number of stations (s) carried out by each nation and the number of days(d) at sea during the Greater North Sea Q3 survey from 2011 to 2016.

	2011		**2012**		**2013**		**2014**		**2015**		**2016**	
Country/Ship	**s**	**d**	**s**	**d**	**s**	**d**	**s**	**d**	**s**	**d**	**s**	**d**
Denmark (Dana)	49	15	49	15	50	17	50	17	59	17	59	17
Sweden (Dana)	45	13	45	11	45	11	45	11	45	11	45	11
England (CEFAS Endeavour)	75	25	75	24	76	25	73	26	76	24	78	26
Norway (Johan Hjort)	45	17	37	15	46	19	46	19	48	23	67	20
Scotland (Scotia III)	84	19	84	20	84	18	84	21	91	20	99	19

Germany (Walther Herwig III)	29	13	29	13	17	9	29	13	33	13	33	12
Total number of stations	**327**		**319**		**318**		**327**		**352**		**381**	

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41 *Table S3. Summary of best fitting model for explaining variance in species richness in a haul. During*
42 *model selection 208 model combinations of fixed effects were tested. Importance was ranked from 0-*
43 *1. For Example: Ship scored an importance (I) of 1 and was present in 128 models. Ship (I=0.1, N=128),*
44 *Tow Duration (I=1, N=144), Year(I=0.86, N=123), Time of Day(I=0.53,N=104), Julian Day(I=0.50,*
45 *N=104), Speed(I=0.35, N=104), Depth(I=1, N=104), Tow Duration : Year (I=0.23, N=48), Tow Duration :*
46 *Ship (I=0.24,N=48).*

Best Fit Model Richness ~ Year + Julian Days + Ship + Depth + Tow Duration + Time of day + (1|ICESStSq)			
AIC (best fit) 2015.8		**AIC (global fit)** 2021.4	
Random effects:	Variance	Std.Dev.	
ICESStSq	3.141	1.772	
Residual	5.595	2.365	
Number of obs: 411, groups: ICESStSq, 97			
Fixed effects:	Estimate	Std. Error	t value
(Intercept)	15.9720	0.4459	35.82
Year (2016)	0.6654	0.2643	2.52
Julian Day	-0.3825	0.2522	-1.52
Depth (m)	2.1952	0.2361	9.30
Ship (CEFAS Endeavour)	0.7962	0.5600	1.42
Ship (Johan Hjort)	-2.2949	0.7118	-3.22
Ship (Scotia III)	0.6044	0.4683	1.29
Ship (Walther Herwig III)	-1.4575	0.4985	-2.92
Tow Duration (short)	-1.6257	0.3061	-5.31
Time of Day	-0.1957	0.1316	-1.49

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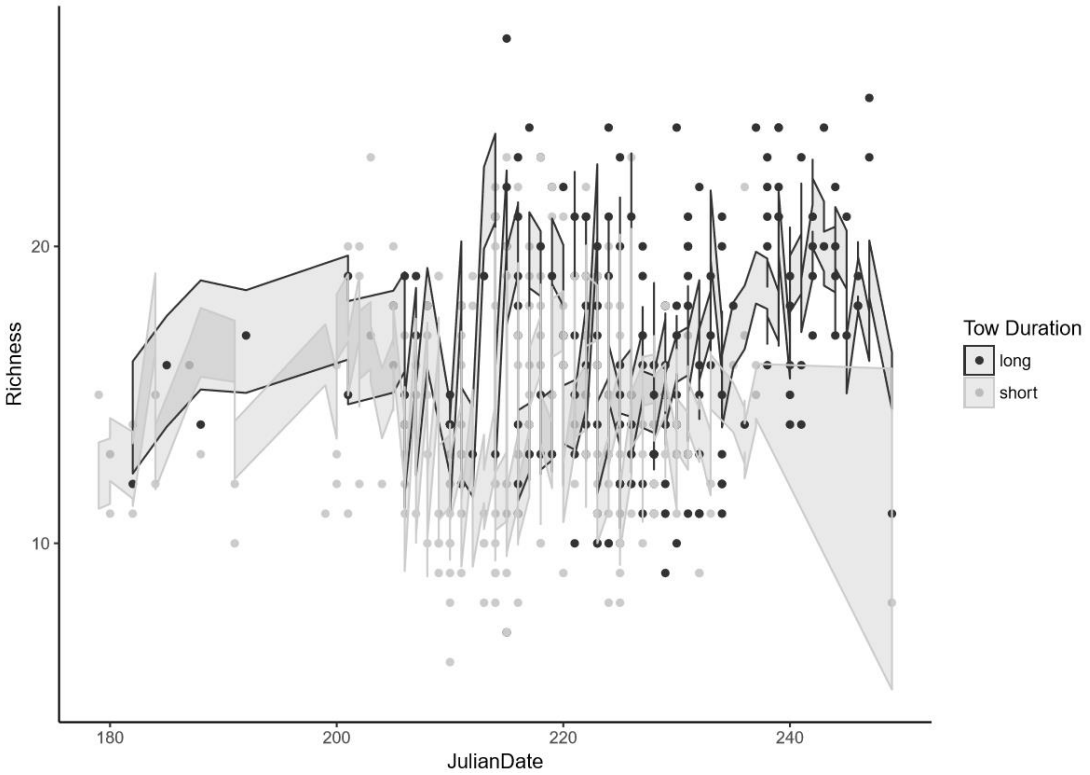

Figure S3. Model Prediction of best fit model for explaining variance in species richness in each haul. The long tows have a higher species richness on average than the short tows.

Table S4. Summary of best fitting model for explaining variance in abundance by haul. During model selection 208 model combinations of fixed effects were tested. Importance was ranked from 0-1. For Example: Ship scored an importance (I) of 1 and was present in 128 models. Ship (I=1, N=128), Tow Duration (I=0.89, N=144), Year(I=0.72, N=128), Time of Day(I=0.63,N=104), Julian Day(I=0.57, N=104), Speed(I=0.50, N=104), Depth(I=0.41, N=104), Tow Duration : Year (I=0.21, N=48), Tow Duration : Ship (I=0.19, N=48).

Best Fit Model log(Abundance) ~ Julian Days + Ship + Tow Duration + Time of day + (1 | ICESStSq)			
AIC (best fit) 1263.8		**AIC (global fit) 1268.2**	
Random effects:	Variance	Std.Dev.	
ICESStSq	0.3339	0.5779	
Residual	0.9781	0.9890	
Number of obs: 411, groups: ICESStSq, 97			

Fixed effects:	Estimate	Std. Error	t value
(Intercept)	6.77396	0.16356	41.42
Julian Day	-0.19024	0.08999	-2.11
Ship (CEFAS Endeavour)	-0.19752	0.21967	-0.90
Ship (Johan Hjort)	-1.27258	0.24803	-5.13
Ship (Scotia III)	-0.11734	0.17963	-0.65
Ship(Walther Herwig III)	-0.44640	0.20229	-2.21
Tow Duration (short)	0.28700	0.12616	2.27
Time of Day	0.09384	0.05399	1.74

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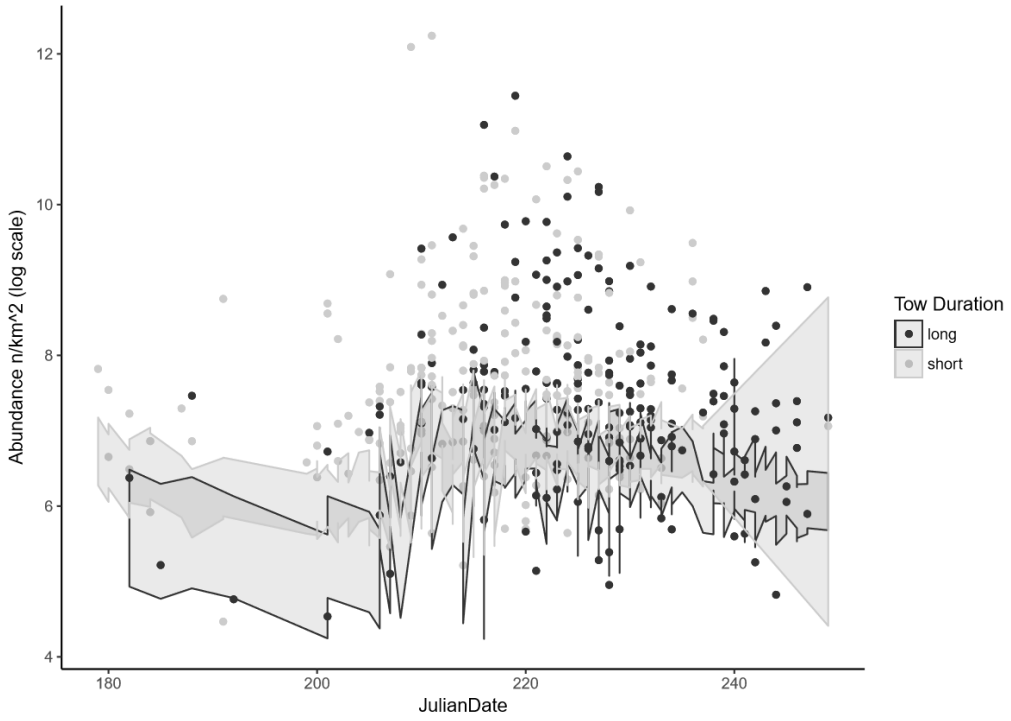

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59 *Figure S4. Model Prediction of best fitting model for explaining variance in haul abundance (n/km^2).*

60 *The short tows have a higher abundance (n/km^2) on average than the long tows.*

61

62 *Table S5. Summary of best fitting model for predicting biomass. During model selection 208 model*

63 *combinations of fixed effects were tested. Importance was ranked from 0-1. For Example: Ship scored*

an importance (I) of 0.87 and was present in 128 models. Ship (I=0.87, N=128), Tow Duration (I=0.94, N=144), Year(I=1, N=123), Time of Day(I=0.53,N=104), Julian Day(I=0.32, N=104), Speed(I=0.28, N=104), Depth(I=0.31, N=104), Tow Duration : Year (I=0.25, N=48), Tow Duration : Ship (I=0.07,N=48).

Best Fit Model log(Biomass) ~ Year + Ship + Tow Duration + Time of day + (1 | ICESStSq)			
AIC (best fit) 973.5		**AIC (global fit) 985.6**	
Random effects:	Variance	Std.Dev.	
ICESStSq	0.1919	0.4381	
Residual	0.4704	0.6858	
Number of obs: 411, groups: ICESStSq, 97			
Fixed effects:	Estimate	Std. Error	t value
(Intercept)	4.150e+00	1.434e-01	28.947
Year (2016)	-2.918e-01	6.821e-02	-4.278
Ship (CEFAS Endeavour)	-1.374e-01	1.402e-01	-0.980
Ship (Johan Hjort)	-4.726e-01	1.469e-01	-3.218
Ship (Scotia III)	-2.363e-01	1.252e-01	-1.887
Ship (Walther Herwig III)	-4.047e-01	1.400e-01	-2.891
Tow Duration (short)	2.332e-01	8.786e-02	2.655
Time of Day	1.259e-04	8.487e-05	1.483

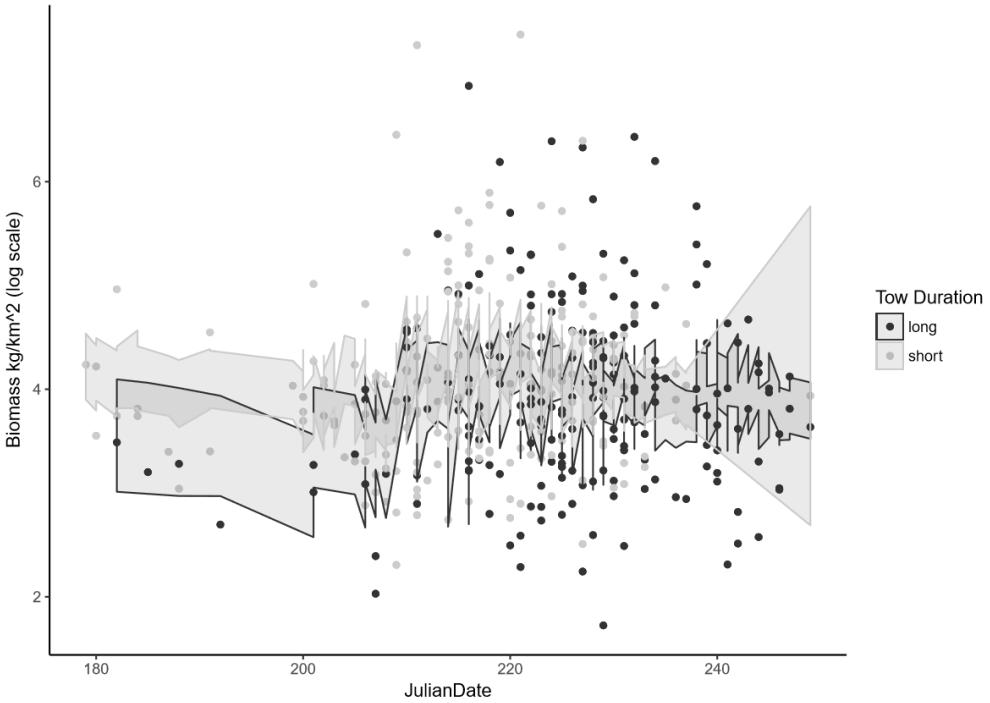

Figure S5. Model prediction of best fit model for explaining variance in haul biomass (kg/km^2). The short tows have a higher biomass (kg/km^2) on average than the long tows.