Selected Supplemental Results for An Individual-Based Model of Basking Sharks in Ireland (P1.18)

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SENSITIVITY AND ROBUSTNESS ANALYSIS

Table 1: Results of Sensitivity and Robustness analysis

Number of Aggregations								
	S+ Per Model Version				R+ Per Model Version			
Parameter	Random	Food/ Social	Social	Food	Random	Food/ Social	Social	Food
threshold_zp	-0.32	-0.04	-1.04	0.47	-0.48	0.05	-0.32	0.12
sense-distance	0.45	-0.95	-0.01	-0.59	0.02	-0.49	0.11	-0.36
Swim-Speed	-0.61	-0.01	-0.07	-0.12	0.01	0.00	-0.03	-0.02
No_eat_min	3.79	-0.17	3.02	0.12	3.77	-0.04	4.36	0.11
return-season	-1.37	-0.17	-0.23	0.03	-0.18	-0.13	-0.04	-0.13
Cal_%	1.37	-0.13	1.20	0.04	0.99	-0.10	1.21	-0.02
other_zp_%	0.81	-0.16	0.12	-0.15	0.45	-0.05	0.23	-0.04
friend_min	-0.02	0.11	-0.05	0.01	-0.14	0.08	0.01	0.01

Max Aggregation size								
	S+ Per Model Version				R+ Per Model Version			
Parameter	Random	Food/ Social	Social	Food	Random	Food/ Social	Social	Food
threshold_zp	-0.77	0.07	0.00	-0.51	0.05	-0.02	0.05	-0.04
sense-distance	1.20	0.03	0.00	0.37	0.06	0.00	0.05	0.03
Swim-Speed	-0.32	-0.07	0.00	0.08	-0.09	-0.01	0.04	0.08
No_eat_min	1.22	0.19	0.47	0.22	0.27	0.02	0.05	0.04
return-season	0.77	-0.26	0.00	-0.83	-0.16	-0.01	0.00	0.00
Cal_%	-0.69	0.01	0.00	-0.44	-0.25	0.01	0.00	-0.03
other_zp_%	0.87	-0.03	0.17	0.03	0.00	0.00	0.00	0.01
friend_min	-0.36	-0.01	-0.16	0.17	0.00	0.00	-0.04	0.04

Table 1: Sensitivity Analysis (S+) was +/- 5% of each parameter setting
Robustness Analysis (R+) was +/- 70% of each parameter setting
The total number of aggregations and the maximum aggregation size were compared
Ten trials were run under each parameter setting and the number of aggregations or maximum aggregation size averaged
Random = sharks do not seek any food or sharks
Food/Social = Seek zooplankton, retain memory of past high zooplankton patches, and seek other sharks
Social = only seek other sharks

Table 2: Parameter Settings for Sensitivity and Robustness Analysis.

	Parameter setting						
Parameter	S-	C	S+	R+	R-	R+++	R--
threshold_zp	9.5E+10	1E+11	1.1E+11	1.7E+11	3E+10	3E+12	3000
sense-distance	9	10	11	17	3	20	1
Swim-Speed	8	9	10	16	2	30	na
No_eat_min	13	14	15	23	4	30	na
return-season	19	20	21	34	6	60	na
Cal_%	9	10	11	17	3	50	na
other_zp_%	9	10	11	17	3	50	na
friend_min	4	5	6	9	2	20	na

Table 2: C was determined as the settings that give the most realistic results through preliminary experimentation. S+/- and R+/- were calculated from C. R+++ and R-- = testing extreme highs and lows

Sensitivity Analysis (S) was +/- 5% of each parameter setting

Robustness Analysis (R) was +/- 70% of each parameter setting

STATISTCAL RESULTS

Table 3: Statistics for Total Aggregations

	All of Ireland			Inishowen			Parameter Settings							
Model Version	**ME**	**RMSE**	**MAE**	**ME**	**RMSE**	**MAE**	**Cal (Calanus)**	**Otherzp (Psuedo calanus)**	**Threshold ZP (Population size)**	**Sense Distance (km)**	**Swim Speed (km)**	**Friend Min (# sharks)**	**No Eat (# Days)**	**Return (# Days)**
Food	0.14	0.28	0.19	0.16	0.29	0.20	10	10	1.00E+11	10	**8**	5	14	20
Food/Social	0.16	0.28	0.21	0.17	0.29	0.21	10	10	1.00E+11	10	**8**	5	14	20
Random	0.40	0.49	0.40	0.41	0.51	0.42	10	10	1.00E+11	10	**8**	5	14	20
Social	0.63	0.71	0.63	0.64	0.73	0.65	10	10	1.00E+11	10	**8**	5	14	20
Food	0.07	0.20	0.13	0.09	0.21	0.13	10	10	**9.50E+10**	10	9	5	14	20
Food/Social	0.15	0.27	0.20	0.16	0.28	0.20	10	10	**9.50E+10**	10	9	5	14	20
Random	0.38	0.47	0.39	0.39	0.49	0.41	10	10	**9.50E+10**	10	9	5	14	20
Social	0.61	0.70	0.62	0.63	0.72	0.64	10	10	**9.50E+10**	10	9	5	14	20
Food	0.15	0.28	0.20	0.17	0.29	0.20	10	10	1.00E+11	10	9	5	14	20
Food/Social	0.16	0.28	0.21	0.17	0.29	0.21	10	10	1.00E+11	10	9	5	14	20
Food/Social	0.18	0.31	0.23	0.20	0.32	0.24	10	10	1.00E+11	10	9	5	14	20
Random	0.38	0.48	0.38	0.39	0.50	0.40	10	10	1.00E+11	10	9	5	14	20
Social	0.60	0.69	0.60	0.62	0.71	0.62	10	10	1.00E+11	10	9	5	14	20
Food	0.14	0.27	0.19	0.15	0.28	0.19	10	10	1.00E+11	10	9	5	14	20
Social	0.61	0.71	0.62	0.63	0.73	0.64	10	10	1.00E+11	10	9	5	14	20
Random	0.41	0.52	0.43	0.43	0.53	0.44	10	10	1.00E+11	10	9	5	14	20
Food/Social	0.10	0.21	0.14	0.12	0.22	0.15	10	10	**3.00E+12**	10	9	5	14	20
Food	0.27	0.33	0.28	0.28	0.34	0.30	10	10	**3.00E+12**	10	9	5	14	20
Random	0.49	0.57	0.49	0.50	0.59	0.51	10	10	**3.00E+12**	10	9	5	14	20
Social	0.57	0.64	0.57	0.59	0.66	0.59	10	10	**3.00E+12**	10	9	5	14	20

Food	0.14	0.26	0.19	0.16	0.27	0.20	**17**	10	1.00E+11	10	9	5	14	20
Food/Social	0.20	0.33	0.24	0.22	0.34	0.25	**17**	10	1.00E+11	10	9	5	14	20
Random	0.48	0.59	0.49	0.50	0.60	0.50	**17**	10	1.00E+11	10	9	5	14	20
Social	0.71	0.79	0.71	0.73	0.81	0.73	**17**	10	1.00E+11	10	9	5	14	20
Food	0.14	0.27	0.19	0.15	0.28	0.19	10	**11**	1.00E+11	10	9	5	14	20
Food/Social	0.18	0.31	0.23	0.20	0.31	0.23	10	**11**	1.00E+11	10	9	5	14	20
Random	0.37	0.46	0.38	0.39	0.48	0.40	10	**11**	1.00E+11	10	9	5	14	20
Social	0.62	0.70	0.62	0.64	0.73	0.64	10	**11**	1.00E+11	10	9	5	14	20
Food/Social	0.12	0.24	0.16	0.13	0.25	0.17	10	11	1.00E+11	10	9	5	**4**	20
Food	0.14	0.26	0.18	0.15	0.27	0.19	10	11	1.00E+11	10	9	5	**4**	20
Random	0.16	0.24	0.18	0.18	0.27	0.20	10	11	1.00E+11	10	9	5	**4**	20
Social	0.24	0.33	0.26	0.26	0.37	0.29	10	11	1.00E+11	10	9	5	**4**	20
Food/Social	0.13	0.27	0.19	0.15	0.27	0.19	10	10	1.00E+11	**20**	9	5	14	20
Food	0.05	0.19	0.12	0.07	0.20	0.12	10	10	1.00E+11	**20**	9	5	14	20
Random	0.38	0.47	0.39	0.40	0.49	0.41	10	10	1.00E+11	**20**	9	5	14	20
Social	0.64	0.73	0.64	0.65	0.75	0.66	10	10	1.00E+11	**20**	9	5	14	20
Food	0.14	0.27	0.19	0.16	0.28	0.19	10	10	1.00E+11	10	**10**	5	14	20
Food/Social	0.17	0.31	0.22	0.19	0.31	0.23	10	10	1.00E+11	10	**10**	5	14	20
Random	0.40	0.50	0.41	0.42	0.52	0.43	10	10	1.00E+11	10	**10**	5	14	20
Social	0.62	0.71	0.62	0.64	0.73	0.64	10	10	1.00E+11	10	**10**	5	14	20
Food	0.12	0.25	0.17	0.13	0.26	0.17	10	10	1.00E+11	10	9	**9**	14	20
Food/Social	0.19	0.33	0.24	0.21	0.33	0.24	10	10	1.00E+11	10	9	**9**	14	20
Random	0.39	0.49	0.40	0.41	0.51	0.42	10	10	1.00E+11	10	9	**9**	14	20
Social	0.63	0.72	0.64	0.65	0.74	0.66	10	10	1.00E+11	10	9	**9**	14	20

Table 3: Statistical results for total aggregations for the ten settings that gave the most realistic results out of the sensitivity and robustness tests for the total aggregations. Total Aggregations include all groups of 2 or more sharks in each day of the model.

Table 4: Statistics for Pseudo Sightings Reports

	All of Ireland			Inishowen			Parameter Settings							
Model Version	**ME**	**RMSE**	**MAE**	**ME**	**RMSE**	**MAE**	**Cal (Calanus copepods)**	**Otherzp (Psuedo calanus)**	**Threshold ZP (Population size)**	**Sense Distance (km)**	**Swim Speed (km)**	**Friend Min (# sharks)**	**No Eat (# Days)**	**Return (# Days)**
Food	0.02	0.15	0.09	0.04	0.16	0.09	10	10	1.00E+11	10	**8**	5	14	20
Food/Social	0.05	0.19	0.12	0.07	0.20	0.12	10	10	1.00E+11	10	**8**	5	14	20
Random	0.47	0.54	0.47	0.49	0.57	0.50	10	10	1.00E+11	10	**8**	5	14	20
Social	0.48	0.56	0.49	0.51	0.59	0.52	10	10	1.00E+11	10	**8**	5	14	20
Food/Social	0.03	0.16	0.10	0.05	0.17	0.10	10	10	**9.50E+10**	10	9	5	14	20
Food	0.09	0.23	0.15	0.12	0.24	0.16	10	10	**9.50E+10**	10	9	5	14	20
Random	0.44	0.52	0.45	0.46	0.54	0.47	10	10	**9.50E+10**	10	9	5	14	20
Social	0.49	0.56	0.49	0.51	0.59	0.52	10	10	**9.50E+10**	10	9	5	14	20
Food	0.01	0.15	0.09	0.04	0.16	0.09	10	10	1.00E+11	10	9	5	14	20
Food	0.05	0.17	0.10	0.07	0.18	0.11	10	10	1.00E+11	10	9	5	14	20
Food/Social	0.07	0.22	0.13	0.09	0.23	0.13	10	10	1.00E+11	10	9	5	14	20
Food/Social	0.08	0.23	0.14	0.10	0.24	0.15	10	10	1.00E+11	10	9	5	14	20
Random	0.47	0.54	0.47	0.49	0.56	0.50	10	10	1.00E+11	10	9	5	14	20
Social	0.47	0.54	0.47	0.49	0.57	0.50	10	10	1.00E+11	10	9	5	14	20
Random	0.47	0.54	0.47	0.49	0.57	0.50	10	10	1.00E+11	10	9	5	14	20
Social	0.48	0.54	0.48	0.50	0.57	0.51	10	10	1.00E+11	10	9	5	14	20
Food	0.02	0.14	0.08	0.04	0.15	0.09	**17**	10	1.00E+11	10	9	5	14	20
Food/Social	0.06	0.21	0.13	0.09	0.22	0.14	**17**	10	1.00E+11	10	9	5	14	20
Random	0.54	0.62	0.55	0.56	0.64	0.57	**17**	10	1.00E+11	10	9	5	14	20
Social	0.54	0.61	0.55	0.56	0.64	0.57	**17**	10	1.00E+11	10	9	5	14	20
Food/Social	0.02	0.17	0.10	0.05	0.17	0.10	10	**11**	1.00E+11	10	9	5	14	20
Food	0.04	0.17	0.10	0.06	0.17	0.11	10	**11**	1.00E+11	10	9	5	14	20
Random	0.45	0.52	0.45	0.47	0.54	0.48	10	**11**	1.00E+11	10	9	5	14	20
Social	0.45	0.52	0.46	0.48	0.55	0.49	10	**11**	1.00E+11	10	9	5	14	20
Food/Social	0.01	0.15	0.08	0.03	0.15	0.08	10	10	**3.00E+12**	10	9	5	14	20

Food	0.10	0.21	0.15	0.12	0.22	0.16	10	10	**3.00E+12**	10	9	5	14	20
Random	0.28	0.35	0.30	0.30	0.37	0.32	10	10	**3.00E+12**	10	9	5	14	20
Social	0.36	0.42	0.37	0.38	0.44	0.39	10	10	**3.00E+12**	10	9	5	14	20
Food/Social	0.00	0.16	0.09	0.02	0.16	0.08	10	10	1.00E+11	**20**	9	5	14	20
Food	0.01	0.16	0.09	0.04	0.17	0.09	10	10	1.00E+11	**20**	9	5	14	20
Social	0.46	0.54	0.46	0.48	0.56	0.49	10	10	1.00E+11	**20**	9	5	14	20
Random	0.47	0.54	0.48	0.50	0.57	0.50	10	10	1.00E+11	**20**	9	5	14	20
Food	0.04	0.17	0.11	0.06	0.18	0.11	10	10	1.00E+11	10	**10**	5	14	20
Food/Social	0.08	0.23	0.14	0.10	0.24	0.15	10	10	1.00E+11	10	**10**	5	14	20
Random	0.48	0.56	0.49	0.51	0.59	0.52	10	10	1.00E+11	10	**10**	5	14	20
Social	0.50	0.58	0.50	0.52	0.60	0.53	10	10	1.00E+11	10	**10**	5	14	20
Food/Social	0.04	0.18	0.11	0.06	0.18	0.11	10	10	1.00E+11	10	9	**9**	14	20
Food	0.09	0.23	0.15	0.11	0.24	0.15	10	10	1.00E+11	10	9	**9**	14	20
Random	0.49	0.56	0.50	0.52	0.59	0.53	10	10	1.00E+11	10	9	**9**	14	20
Social	0.50	0.57	0.50	0.52	0.60	0.53	10	10	1.00E+11	10	9	**9**	14	20
Food/Social	0.03	0.18	0.10	0.06	0.19	0.11	10	11	1.00E+11	10	9	5	**4**	20
Social	0.30	0.37	0.32	0.32	0.40	0.34	10	11	1.00E+11	10	9	5	**4**	20
Food	0.04	0.17	0.10	0.06	0.18	0.11	10	11	1.00E+11	10	9	5	**4**	20
Random	0.26	0.33	0.27	0.28	0.36	0.31	10	11	1.00E+11	10	9	5	**4**	20

Table 4: Statistical results for total aggregations for the ten settings that gave the most realistic results out of the sensitivity and robustness tests for the pseudo sightings reports. Pseudo sightings reports are randomly sample 10 patches every day and report how many shark(s) were found in each patch.

SENSE DISTANCE TESTS

These results for the following settings:

Cal	Otherzp	Threshold ZP	Sense Distance	Swim Speed	Friend Min	No Eat	Return
10	10	1.00E+11	20	9	5	14	20

Results were calculated by averaging the monthly output of each submodel from 10 trials.

Every day, the model reports Total Aggregations, or *all* aggregations of sharks of two or more. The model also samples 10 random patches each day, and reports how many sharks are in each patch (Pseudo Sighting Reports). This includes single sharks and aggregations of two or more. Pseudo Sighting Reports are meant to represent the sightings reports that make up the IBSG/IWDG sightings database.

The average number of aggregations (2+ sharks) was 1,771 for the Social submodel, 56,714 for the Food submodel, 33,970 for the food/social submdoel, and 3,073 for the Random submodel.

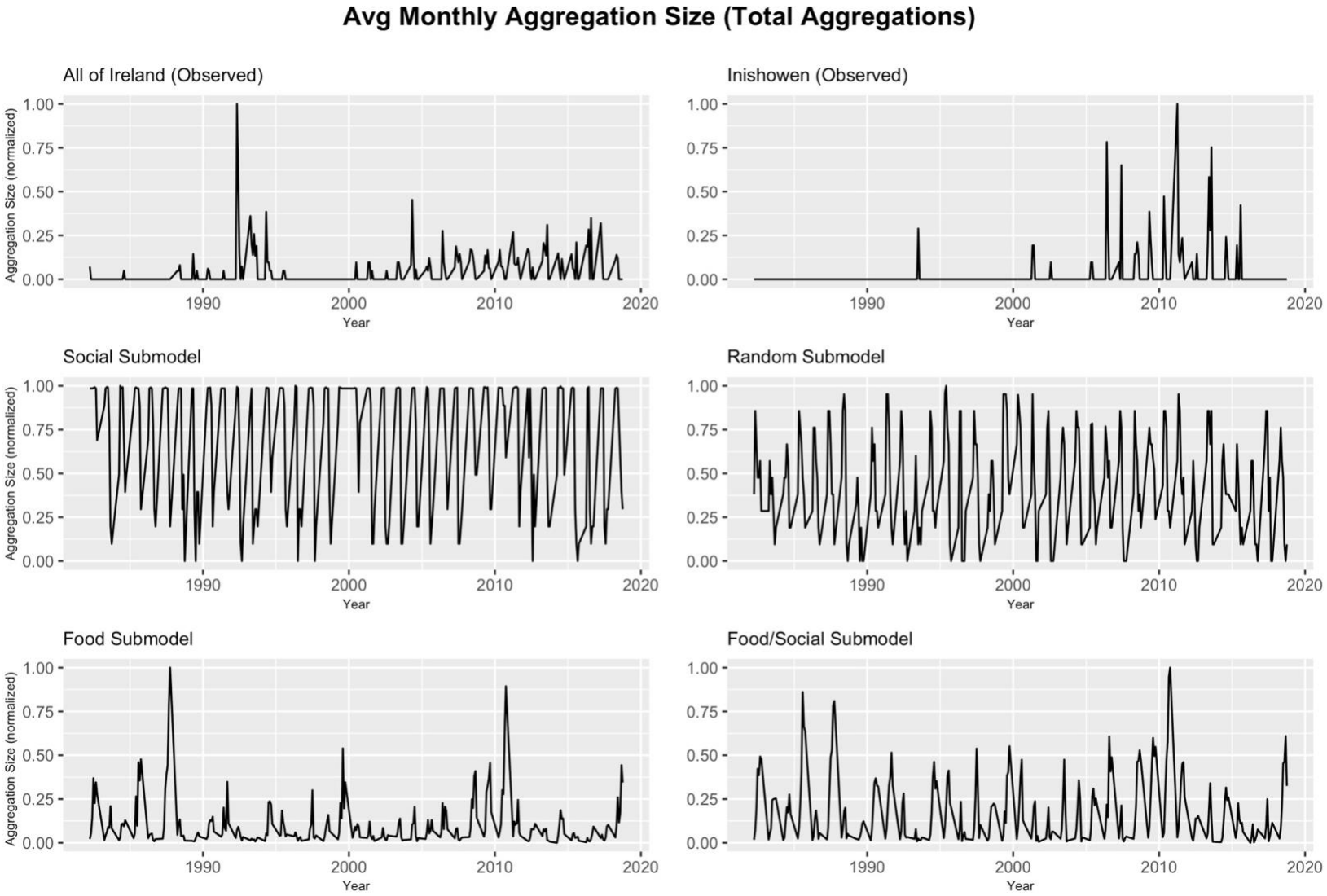

Figure 1: Times series data from Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization.

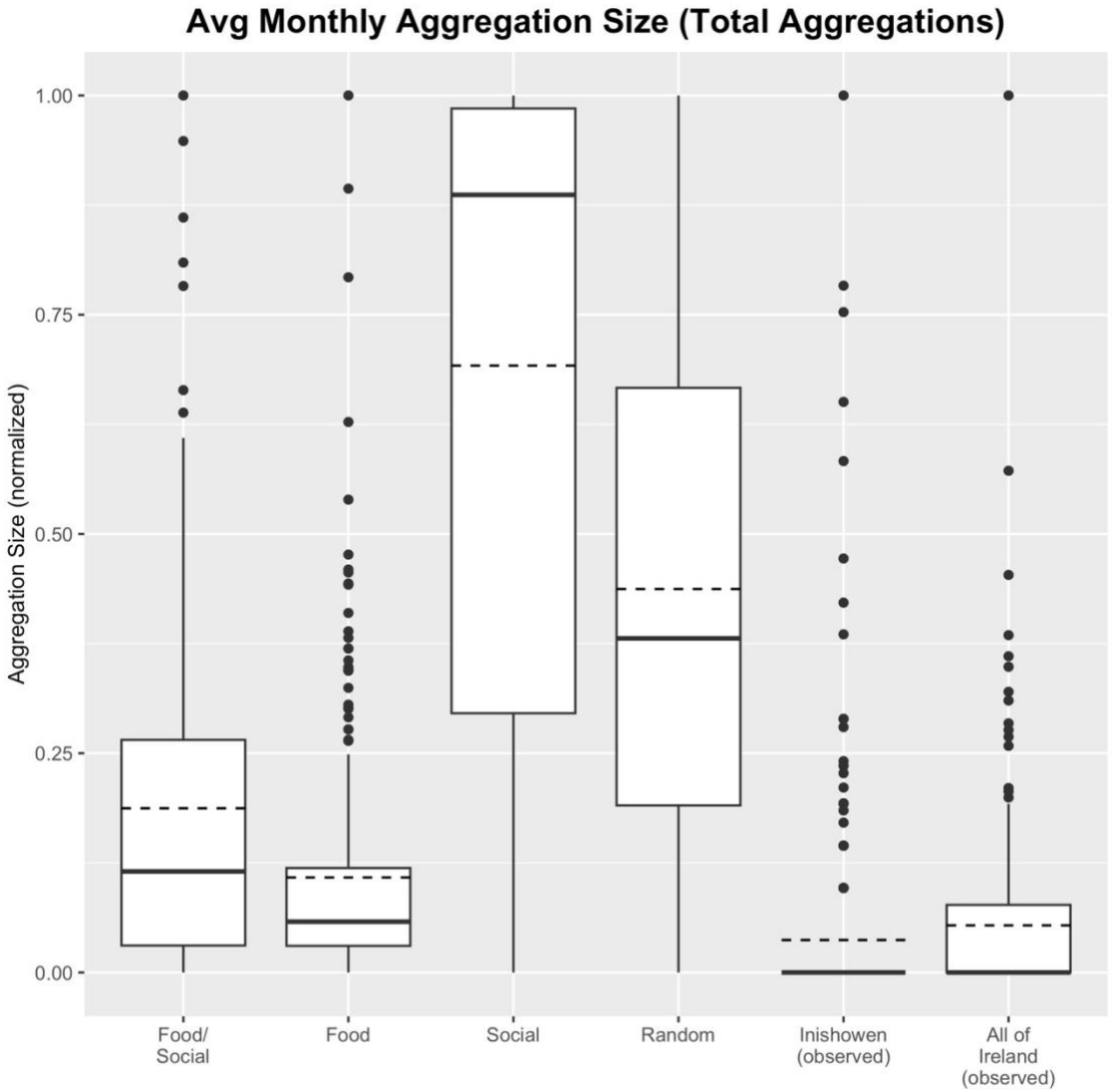

Figure 2: Boxplot of Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

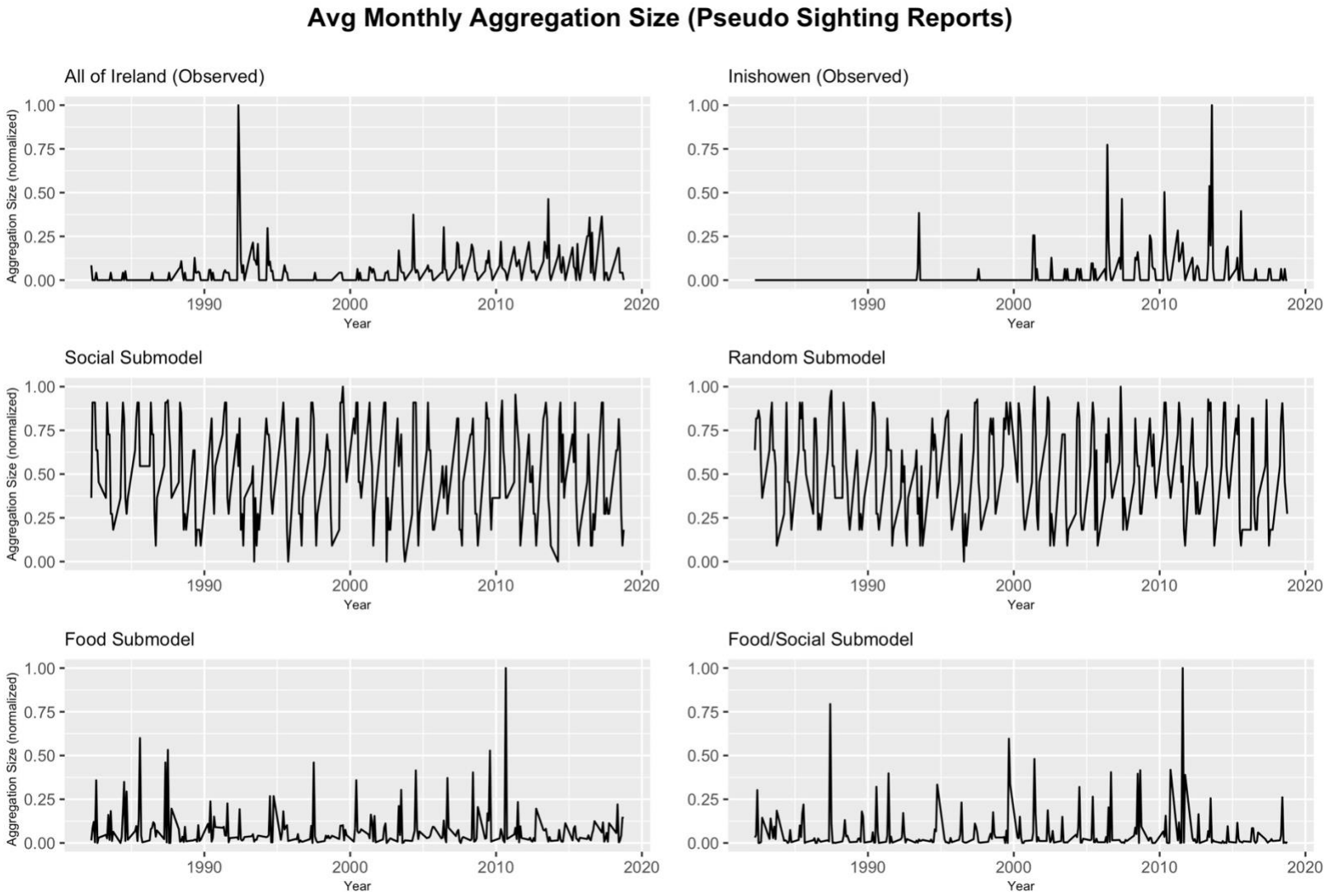

Figure 3:Time series Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports include single sharks and groups of 2+ sharks). Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

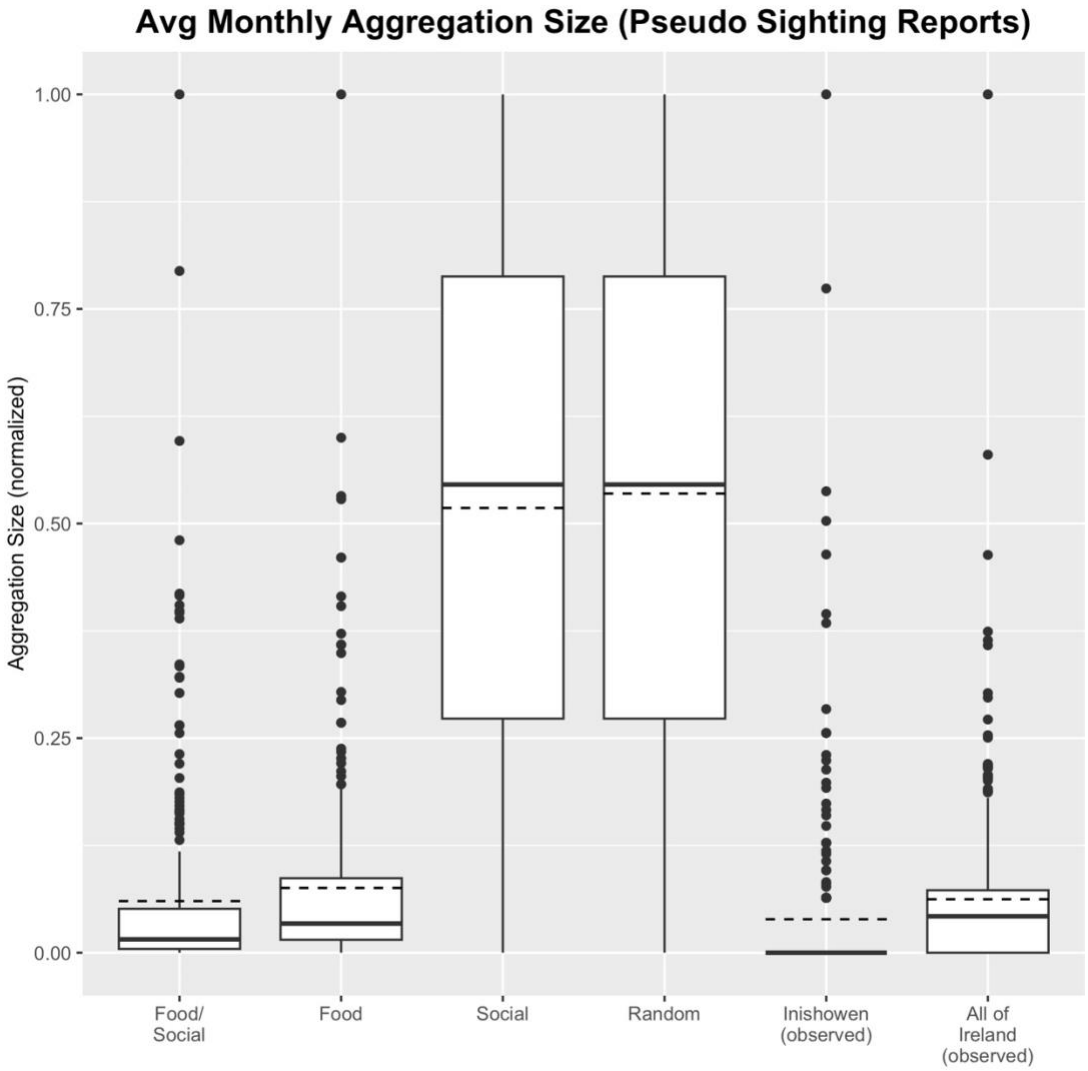

Figure 4: Boxplot of Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports incl

THRESHOLD ZOOPLANTON TESTS

The following are results for the following settings:

Cal	Otherzp	Threshold ZP	Sense Distance	Swim Speed	Friend Min	No Eat	Return
10	10	3.00E+12	10	9	5	14	20

Results were calculated by averaging the monthly output of each submodel from 10 trials.

Every day, the model reports Total Aggregations, or *all* aggregations of sharks of two or more. The model also samples 10 random patches each day, and reports how many sharks are in each patch (Pseudo Sighting Reports). This includes single sharks and aggregations of two or more. Pseudo Sighting Reports are meant to represent the sightings reports that make up the IBSG/IWDG sightings database.

The average number of aggregations (2+ sharks) was 459 for the Social submodel, 10,903 for the Food submodel, 10,627 for the food/social submdoel, and 536 for the Random submodel.

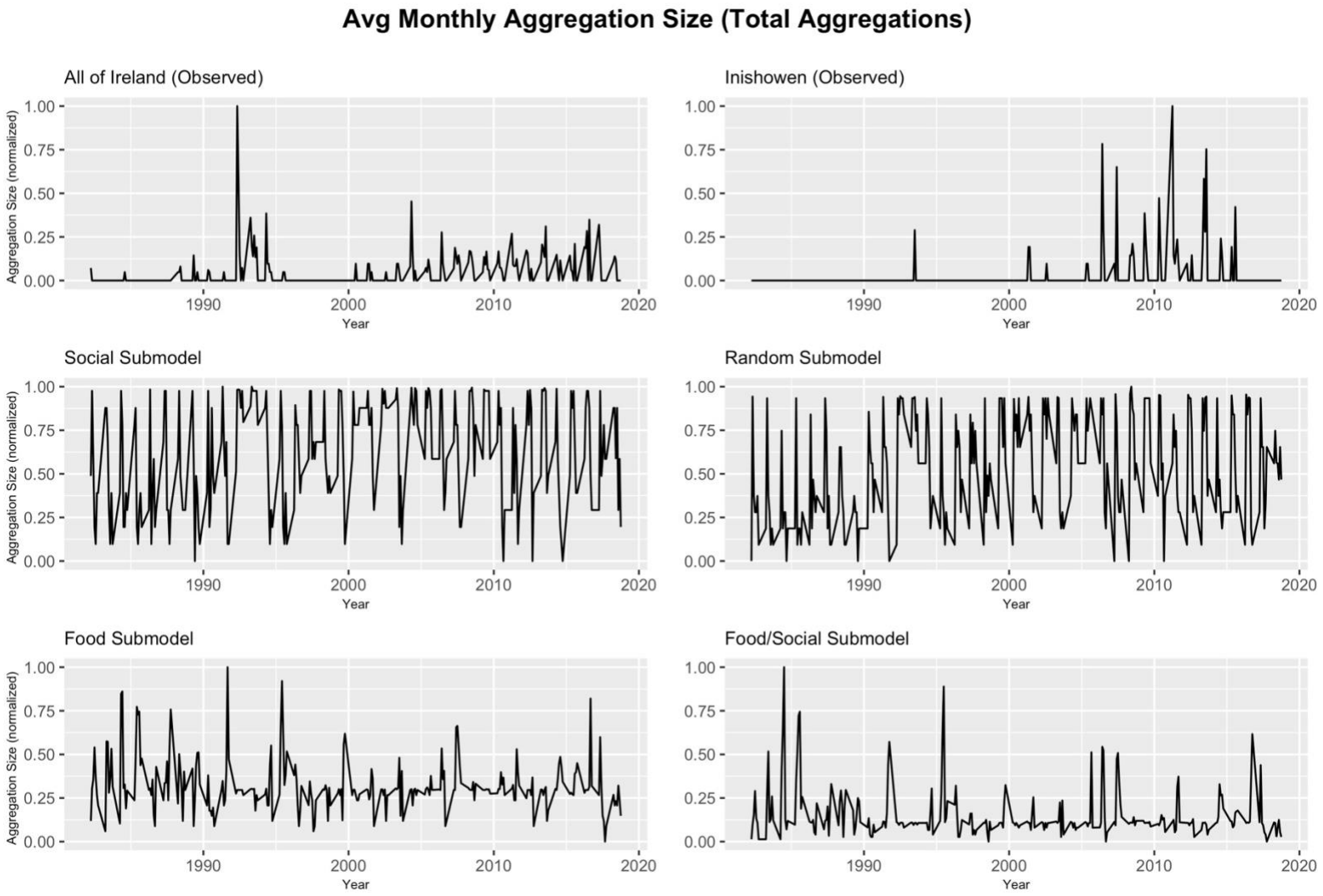

Figure 5: Times series data from Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization.

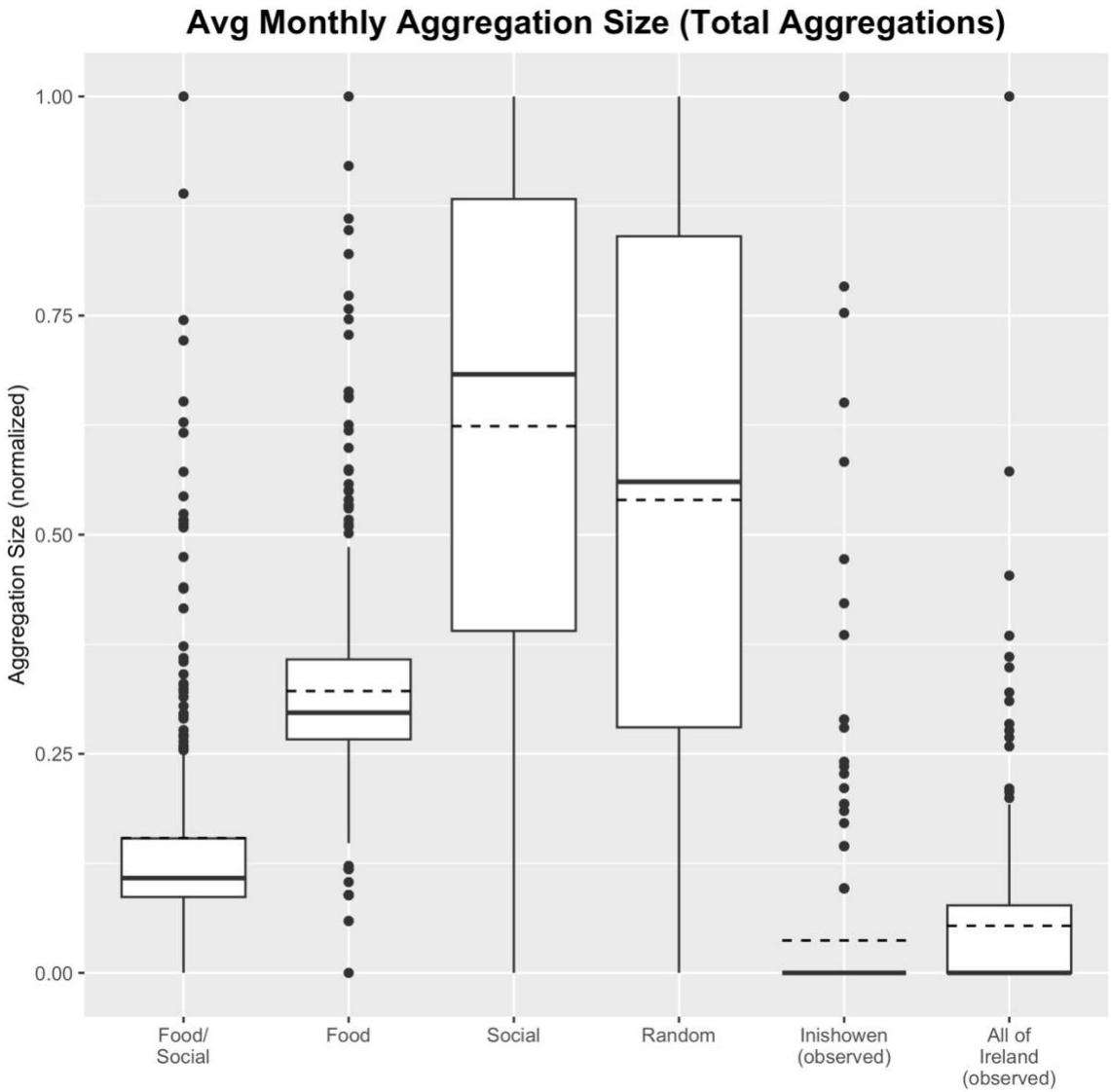

Figure 6: Boxplot of Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

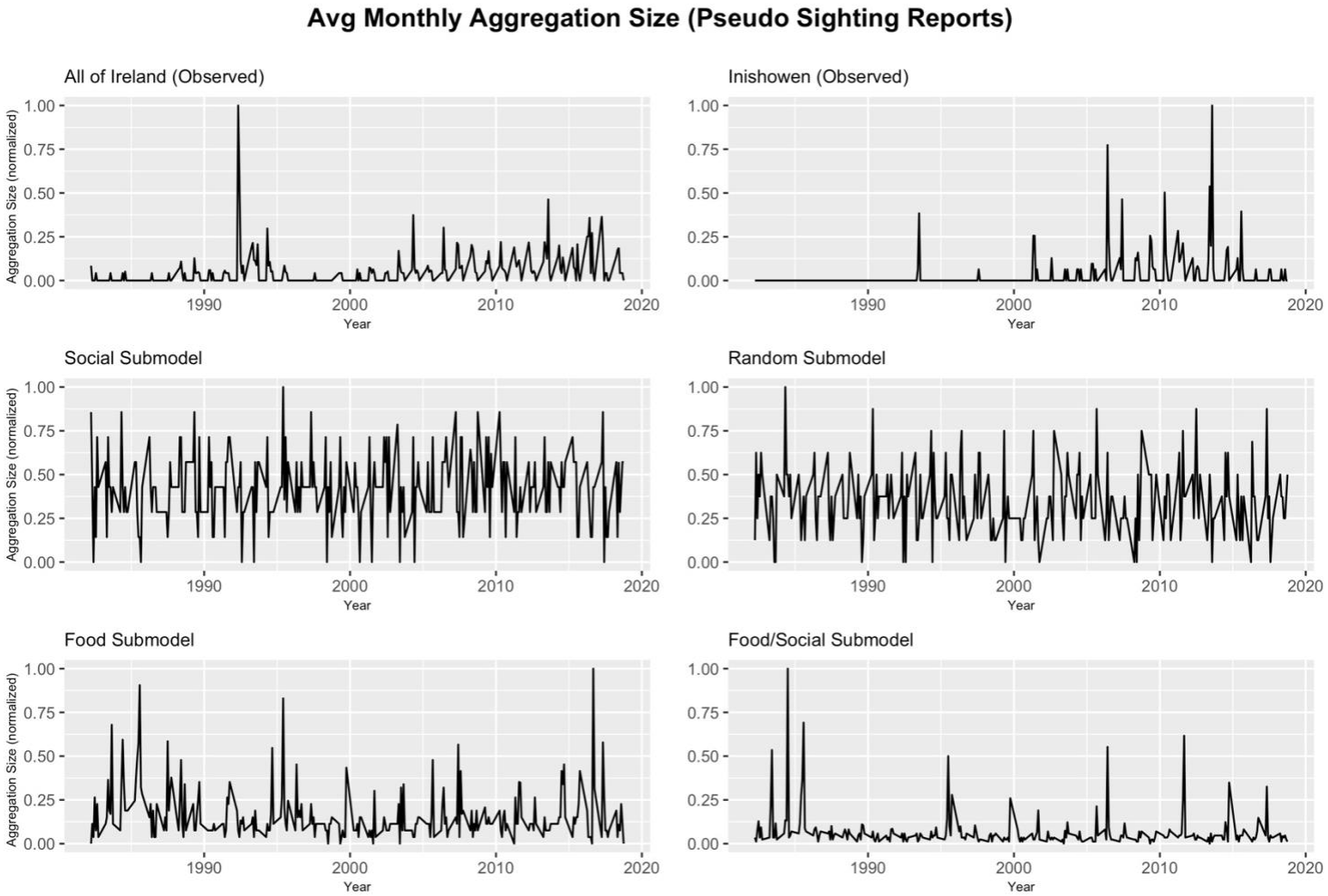

Figure 7: Time series Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports include single sharks and groups of 2+ sharks). Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

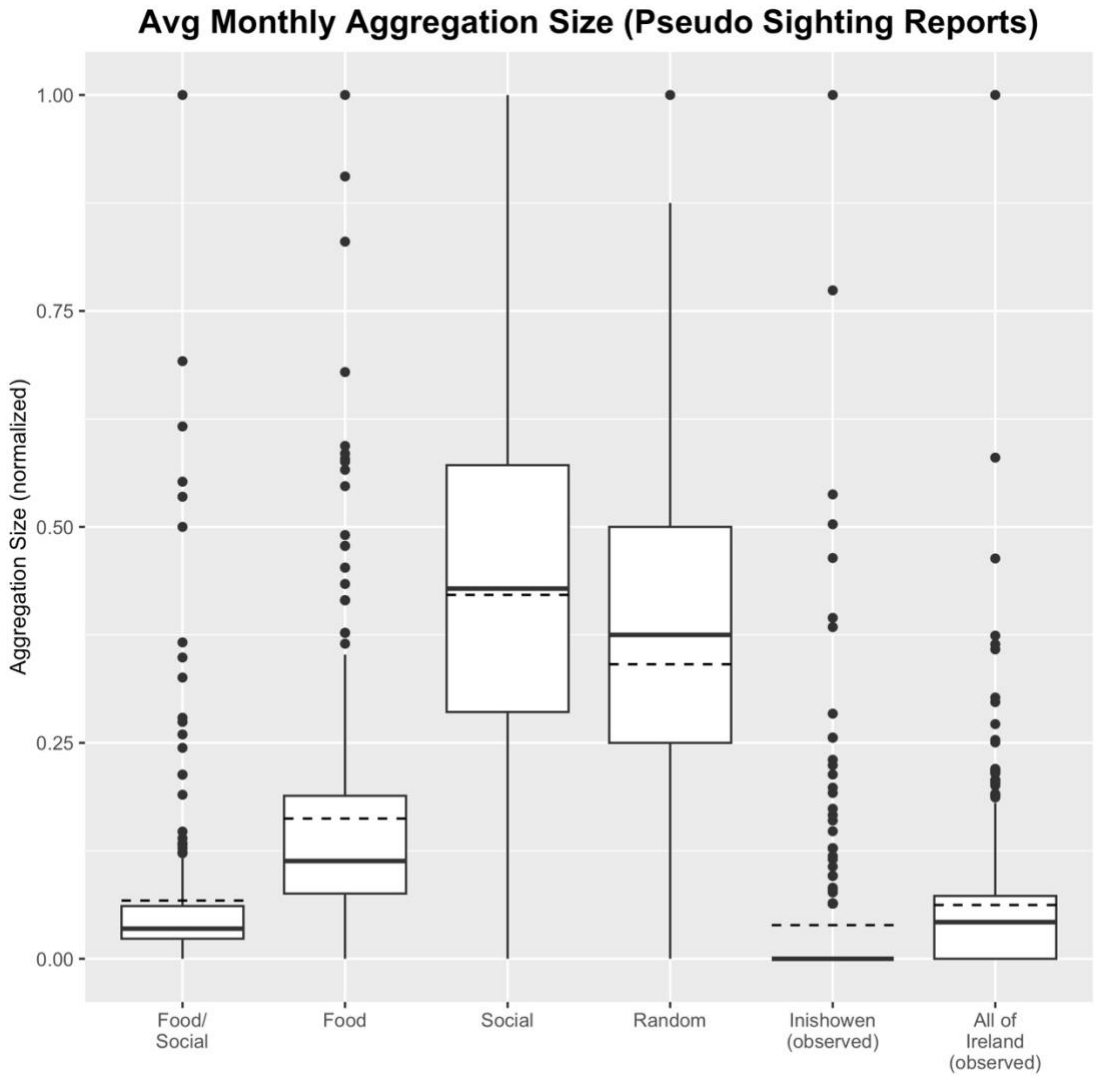

Figure 8: Boxplot of Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports include single sharks and groups of 2+ sharks). Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

CALANUS PERCENT TESTS

The following are results for the following settings:

Cal	Otherzp	Threshold ZP	Sense Distance	Swim Speed	Friend Min	No Eat	Return
17	10	1.00E+11	10	9	5	14	20

Results were calculated by averaging the monthly output of each submodel from 10 trials.

Every day, the model reports Total Aggregations, or *all* aggregations of sharks of two or more. The model also samples 10 random patches each day, and reports how many sharks are in each patch (Pseudo Sighting Reports). This includes single sharks and aggregations of two or more. Pseudo Sighting Reports are meant to represent the sightings reports that make up the IBSG/IWDG sightings database.

The average number of aggregations (2+ sharks) was 2,923 for the Social submodel, 80,282 for the Food submodel, 52,849 for the food/social submdoel, and 5,353 for the Random submodel.

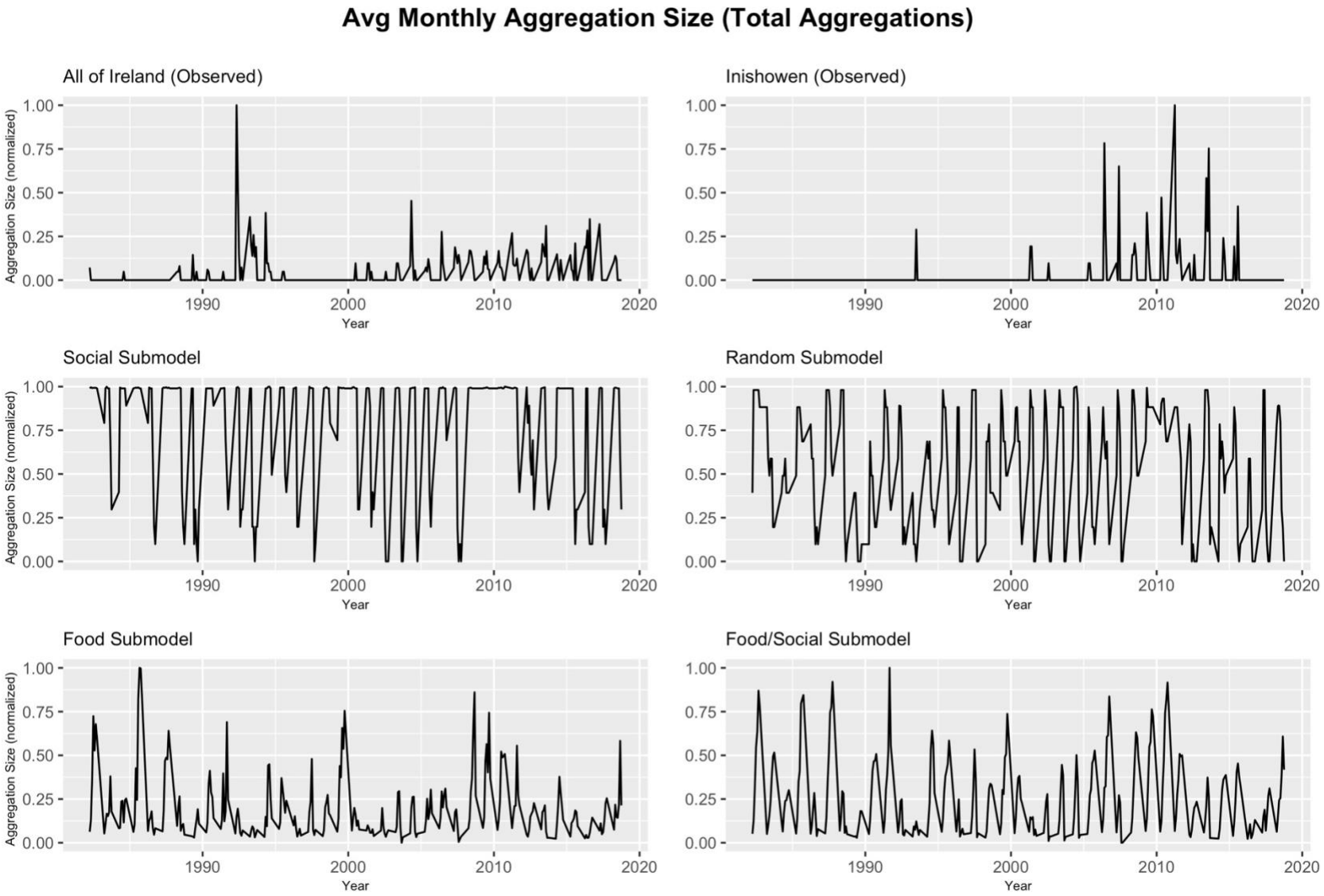

Figure 9: Time series Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports inc

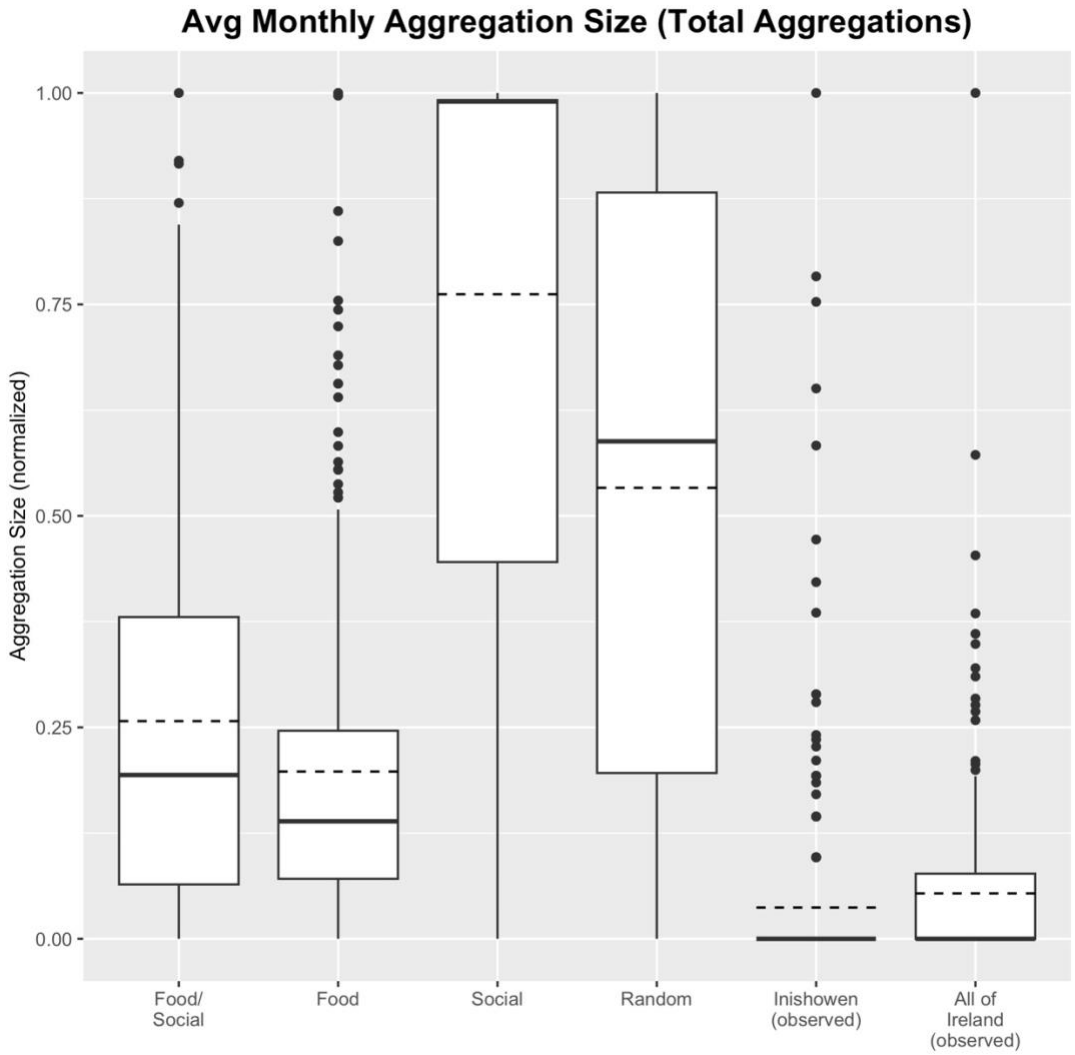

Figure 10: Boxplot of Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization. The dashed line represents the mean, the solid line represents the median.

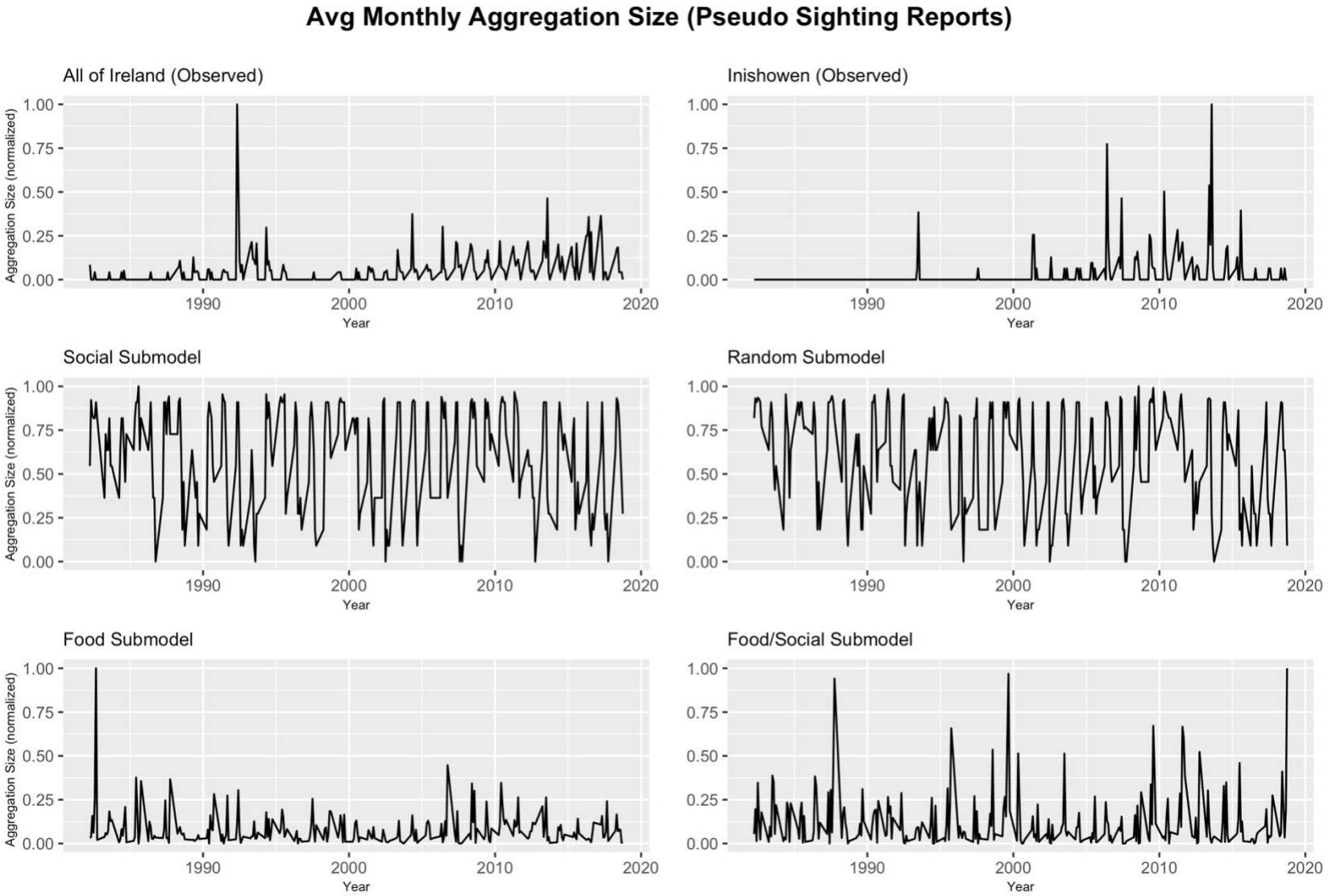

Figure 11: Times series data from Total Aggregations (groups of 2+ sharks) compared to IBSG/IWDG data. Average monthly aggregation size were normalized using min-max normalization.

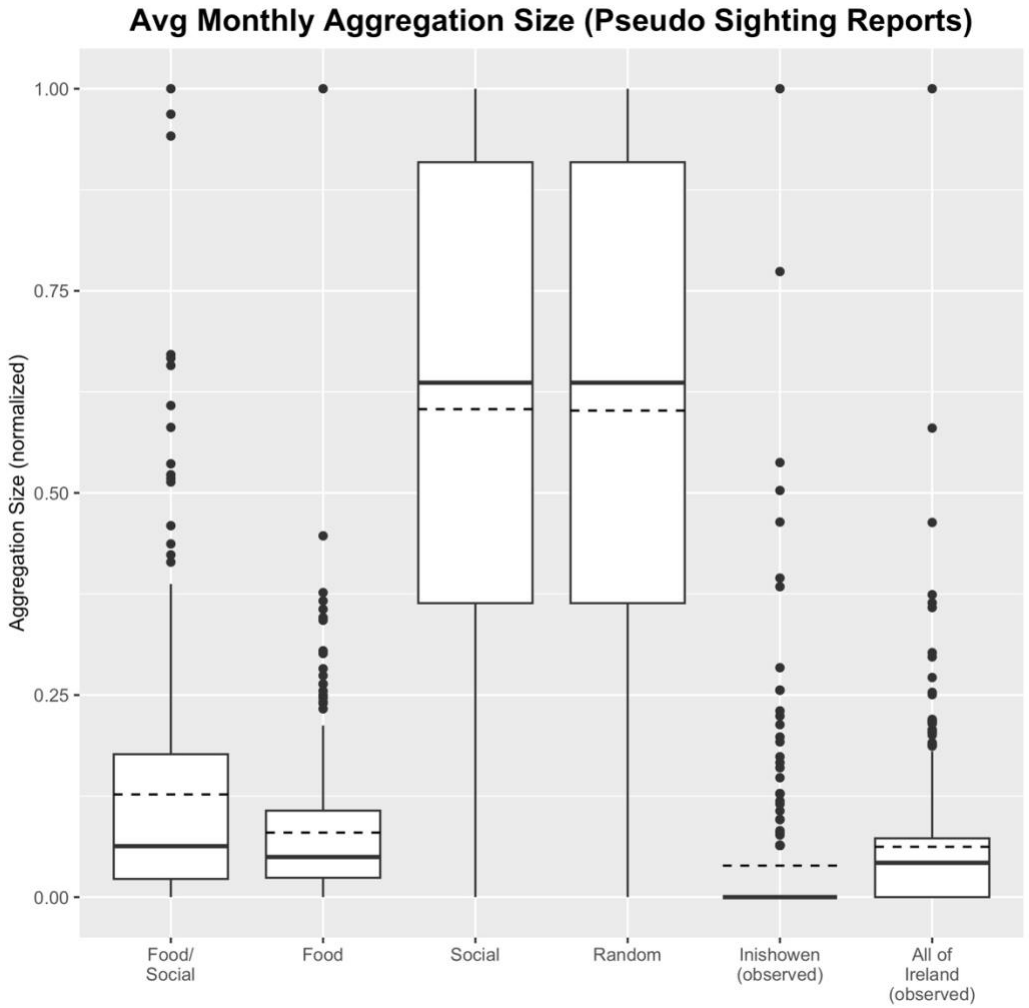

Figure 12: Boxplot of Pseudo Sighting Reports compared to IBSG/IWDG data. Pseudo Sighting Reports are documented in the model via daily sampling of 10 random 1 km x 1 km patches and reporting how many sharks are in each patch (Pseudo Sighting Reports incl