

Examining the relationship between manatee (*Trichechus manatus*) anatomy and environment and manatee death by watercraft collision.

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Abstract:

The mortality of West Indian Manatees (*Trichechus manatus*) has been a concern since 1972 when manatees were listed as endangered. As a result, the Florida Fish and Wildlife Conservation Commission and teams of partnering biologists began to collect data revolving the mortality of manatees throughout Florida in 1974 ("Fish and Wildlife"). Deaths of manatees by watercraft collision has accounted for over 20% of the deaths of manatees from 1974 to 2015. Examining relationships between the anatomy of manatees, their size and sex, and the environment surrounding the manatee, such as season or region, can help to bring call to factors worth looking into further surrounding the unfortunate frequency in human related deaths for the West Indian manatee. The data taken from the Florida Fish and Wildlife Conservation Commission is used in this analysis. The explanatory variables focused on in this study are the size of deceased manatees, the sex of the manatee, the region that the manatees are found in, and the season when the manatee was found. In order to explore a potential relationship a Generalized Linear Modeling approach was used to determine any relationship between the explanatory variables and the occurrence of Watercraft collision deaths in manatees. A Nonmetric Multidimensional Scaling(NMDS) analysis was used to help visualize potential differences between groupings of manatees that died from collision and those that didn't. The results of the Generalized Linear Modeling analyses showed that there were not any independent significant relationships of size, sex, region, and season with the occurrence of watercraft collision death in the West Indian Manatee. The NMDS analyses resulted in visualizations that suggested that there is not much evidence of a difference between manatees that die from collision and those that do not.

Introduction:

The West Indian Manatee (*Trichechus manatus*) was listed as endangered in 1972 ("Information"). The population of manatees had become dangerously low as a result of poaching, human development, and pollution ("Information"). Since 1974, the Florida Fish and Wildlife Conservation and teams of biologist have been collecting mortality data related to the West Indian Manatee ("Fish and Wildlife"). The program is often referred to as the Carcass Salvage program ("Fish and Wildlife"). Every manatee that is reported as sickly or dead is retrieved by the nearest participating team. If a manatee is found deceased, it is brought to a lab and its cause of death is assessed. Data regarding the location of the manatee, the size of the manatee, its determined sex, and probable cause of death is stored. The probable cause of death is broken down into 8 categories: Human Related: Flood Gate/Canal Lock(referring to manatees that are trapped in flood gates and canal locks.), Human Related: Watercraft Collision (manatees that are killed by watercrafts such as boats), Human Related: Other, Natural: Cold Stress (death caused by cold temperatures), Natural: Other, Perinatal(<= 150 cm) (referring to manatees that

died in infancy), Undetermined: Other, Undetermined: Too Decomposed, Verified: Not Recovered (manatees that are confirmed dead but are not recovered).

From 1974 to 2015 there have been 10,057 recorded manatee deaths. Of these 10,057 recorded deaths, 26 percent of them have been human related incidents. Of the human related incidents 83 percent of the deaths were caused by watercraft collision. As of most recent years, manatee deaths caused by blunt impact (deaths absent of cutting) have been more frequent than deaths caused by propellers meaning that boaters are more frequently making direct impact with manatees rather than manatees getting too close to a boaters' propellers("Information"). The objective of this study was to explore potential relationships between the anatomical (Size and Sex) traits and environmental (Location and Season) factors of deceased manatees and deaths caused by watercraft collisions. Effectively the hypothesis being tested in this analyses is that the occurrence of collisions in manatees differ with size, sex, region or season where the variables are independent of one another or have interactions.

Materials & Methods:

The Manatee Rescue and Mortality Response team is very thorough. Manatees that are reported injured or dead are recovered or verified deceased("Odell"). Trained biologist throughout Florida assess the necropsy of deceased manatees, record the size, determine the sex, record the date retrieved and document location information surrounding the manatees regardless of the state they are in when retrieved ("Fish and Wildlife"). The resulting data of this collection, sex, size, location information, and dates are used in this analysis.

There were three location classes reflecting the location of death within the data: the waterway, county, and city that the manatees were found in. This analysis focusses on determining how the environment surrounding deceased manatees relate deaths by watercraft collision however, due to restrictions in the data a uniform classification for location was created. The limitation in using the waterway class fell in the frequency of deaths in the waterways. There were 838 unique waterways that manatees were found in throughout Florida. Of those 838 waterways 506 out of 838 of them had less than or equal to two manatees that were retrieved in their waters and 655 out of 838 of the waterways had less than or equal to five manatees that were retrieved in their waterways¹. Given that the original dataset contained 9 classifications for cause of death and 20 percent of the data results in collisions it was determined that there were not enough data points per waterway to learn much from these waterways. Given that the lack of records occurred in more than 75 percent of the waterways using waterways as a metric was omitted. Similar results were found in city where 326 out of 559, over 58 percent, cities had a less than or equal to five manatees retrieved within the city limits. City as a result was also omitted. In order to gather location information, the location classes were reduced to a single classification, "Region", which indicates whether the manatee was found in Northwest, Northeast, Southwest, or Southeast Florida. The regions are generated based on the location of the county in Florida that a given deceased manatee was retrieved in.

¹ Refer to Appendix C for Frequency Distributions of Deceased Manatees by Waterway.

The dataset includes some information regarding the anatomy of the manatees. The size, given in centimeters, refers to the total body length of the manatee from its head to its tail's end. The data contained some missing data entries for the size of the manatees. Records with missing size information were omitted reducing the size of the dataset. Size was included in the analysis to examine potential relationships between size and deaths by watercraft collision. The manatees sex is also provided. The sex is broken down into three categories: male, female and undetermined. Manatees of an undetermined sex were removed from the analysis as it was determined harder to highlight differences in death by watercraft collision to sex if the sex is not known. The combination of these omissions reduced the dataset to 9,507 total data points from 10,057.

The date that every manatee was retrieved was recorded. It was desired to extrapolate some meaning from this. The dates were taken and mapped into seasons: winter, spring, summer, and fall and included in the analysis.

Generalized Linear Modeling

The data contains three categorical explanatory variables: sex, region, and season as well as a single continuous variable size(cm). The response that was studied is binomial capturing whether or not a manatee was killed from watercraft collision (T/F). Generalized linear modeling was used to analyze possible relationship of independent variables, that is, anatomical (sex and size), and environmental (season and region), and their interactions among one another with death by watercraft collision. The maximal model including all of the anatomical and environmental factors and their interactions was reduced using two approaches: Step AIC and Dredging.

Approach 1: Step AIC

Using the Step functionality in R the Step AIC function was used to reduce the maximal model. Step continually adds and removes elements of the model until the Akaike Information Criteria(AIC) is reduced. AIC is a measurement for the fittingness of a model to the data. The model was reduced to include size, region, sex and season with 6 interactions: Size and sex; region and sex; size and season; region and season; sex and season; size, sex and season.

Model 1: Maximal Model

Model 2: Region + Season + Sex + Size + Sex:Size + Region:Season + Region:Sex + Season:Sex + Size:Season + Sizecm:Sex:Season

Note: ":" Denotes interaction.

	Resid. Df	Resid. Dev	Df	Deviance	P-Value
1	9443	8778.29			
2	9476	8816.72	-33	-38.43	0.2369

Analysis of Deviance Table for Model 1 and Model 2.

There is sufficient evidence that there is not a significant difference between Model 1, the AIC Step reduced model, and Model 2, the maximal model. Therefore, model 1, the simpler model was chosen for the analysis.

Approach 2: Dredging

The Step AIC method takes a greedy approach to minimizing the AIC by continually adding and removing elements from the model until the AIC is reduced. This creates a reduced model but not necessarily the best possible model. There is an R library package called MuMIn that contains a function called Dredge which takes the maximal model and then breaks it apart into all possible combinations of models with interactions and independence. It then ranks the models based on the AIC of each of the models reporting them in order from lowest to highest AIC. This second approach served as validation for the model. The result of the dredge technique produced a model that was two steps simpler than the model reached in the Step AIC function containing interactions that were all present in both Dredge and Step AIC. The final minimal model from the Dredge function was size, region, sex and season with 4 interactions: region and sex, region and season, season and sex, and sex with size. Effectively removing the interaction of size and season and sex size and season.

Selection:

Given that Dredge and Step AIC resulted in very similar models with Dredge being two parameters simpler the model produced by Dredge was used to derive the relationship between the response, death by watercraft collision, and the explanatory variables.

Model 1: Maximal Model

Model 3: Region + Season + Sex + Size + Region:Season + Region:Sex + Season:Sex + Sex:Size

Note: ":" Denotes interaction.

	Resid. Df	Resid. Dev	Df	Deviance	P-Value
1	9443	8778.29			
3	9482	8828.62	-39	-50.33	0.1056

Analysis of Deviance Table for Model 1 and Model 3.

There is sufficient evidence that there is not a significant difference between Model 3, the dredge reduced model, and Model 2, the Maximal model. Therefore, Model 3, the simpler model was chosen for the analysis.

Model 1(Maximal):

Model 2(Step AIC): Region + Season + Sex + Size + Sex:Size + Region:Season + Region:Sex + Season:Sex + Size:Season + Sizecm:Sex:Season

Model 3(Dredge): Region + Season + Sex + Size + Region:Season + Region:Sex + Season:Sex + Sex:Size

Model 4(Intermediary Step 1): Region + Season + Sex + Size + Sex:Size + Region:Season + Region:Sex + Season:Sex + Sizecm:Sex:Season

Model 5(Intermediary Step 2): Region + Season + Sex + Size + Sex:Size + Region:Season + Region:Sex + Season:Sex + Size:Season

Note: “:” Denotes interaction.

	Resid. Df	Resid. Dev	Df	Deviance	P-Value
1	9443	8778.29			
2	9476	8816.72	-33	-38.43	0.2369
4	9476	8816.72	-0	-0.00	
5	9479	8824.05	-3	-7.33	0.0622
3	9482	8828.62	-3	-4.57	0.2059

Analysis of Deviance Table for Model 1 (Maximal), Model 2 (Step AIC), Model 3(Dredge), Model 4 (Model one step simpler than Step AIC Model), Model 5 (Alternate Model one Step simpler than Step AIC model).

There is sufficient evidence that there is no significant difference between the simplest model, model 3(Dredge) and more complex models. The Analysis of Deviance table shown above shows a breakdown from the Maximal model to Model 2 (Step AIC). Models 4 and 5 are formed from one of the two terms present in Step AIC, Size:Season and Size:Sex:Season respectively. (“:” Denotes interaction).

Nonmetric Multidimensional Scaling

In order to visualize the differences in the manatees that died from collision versus those that did not a Nonmetric Multidimensional Scaling (NMDS) of the data was performed. Two populations were identified. The population of manatees that died by watercraft collision and those that did not. Given that there were three categorical explanatory variables that were being examined they were converted to numerical factors from 1 to n, where n is the number of unique classifications per categorical explanatory variable. The Vegan package in R was used to generate an ordination of the categorical and continuous explanatory variables. The results of the ordination were plotted and color coordinated by Collision(T/F). It was expected that if the manatees that died from collision are different than the manatees that do not there would be some clustering in the NMDS that distinguish the Collision population from the Non-Collision population.

Given the large dataset, 9507 points, a NMDS could not be generated. In order to generate an approximation of the collision and non-collision populations 500 data points of manatees that died from collision and 500 data points of manatees that did not were randomly sampled and used in the multidimensional scaling. A few iterations of this random sampling based ordination

were carried through to get the best spread of visualizing these populations to help determine if they are distinct.

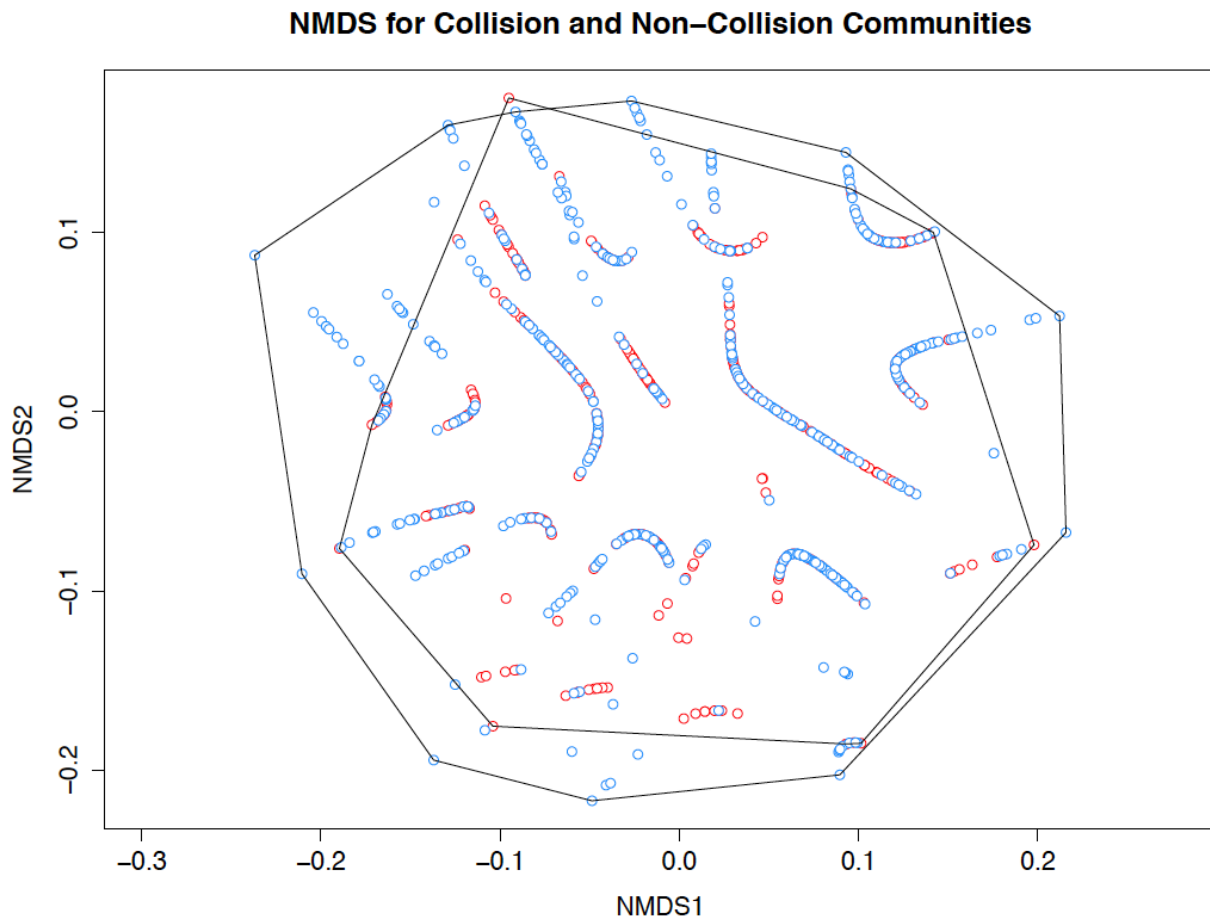


Figure 1: Nonmetric Multidimensional Scaling. Red: Collision Population. Blue: Non Collision Population.

To view more iterations of the NMDS generated through random sampling view Appendix B.

Results:

The study used the data collected by the Florida Fish and Wildlife Commission from 1974-2015. The dataset contained 10,057 entries which were reduced to 9,507 after pruning the data for missing size and sex information. The study aimed to shed light on factors that could be causing the large percentage of manatee death by water collision. Generalized Linear Modeling and NMDS analyses were conducted.

The results of the GLM modeling suggest that none of the explanatory variables are significant on their own. The selected model had interactions with region, season, sex and size with at least one of the other explanatory variables which meant that the independent variables could not be used to determine the overall relationship between an explanatory variable and the response variable. There were some significant interactions. For example, A manatee found in the Southeast Region has a log likelihood of 1.16 +/- 0.32 (1 S.E) with respect to the

intercept(Region Northeast). There was also a significant relationship shown for the Winter Season of -1.24 ± 0.31 however, it cannot be interpreted on its own. A table detailing the full estimated log likelihoods of the selected model are detailed in Appendix A. A table showing the confidence intervals for the parameter estimates can be found in Appendix A.

The random-sampling based Nonmetric Multidimensional Scaling(NMDS) produced several plots that all held the same general characteristics. In all given iterations of the NMDS, formed by sampling 500 random collision population manatees and 500 non collision population, there was little clustering between the different populations. For the most part they all spread throughout the distribution of the NMDS space. There was a distinct difference in the outer radius of the two populations. The non-collision population always confined the collision community (see Figure 1) showing that the collision community exist somewhere in the center. See Appendix B for the iterations of the the random-sampling based NMDS.

Discussion:

The result of the Generalized Linear Modeling showed some significant results. The model was simplified using the dredge functionality of the package MuMIn in R. Size on its own appeared to show a significant effect on the log likelihood of collision in comparison to the intercept. The log likelihood of collision increases by $0.011 \pm (0.0006)$ per unit of measurement in size(cm) however, size was shown to interact with sex. The model showed some significant interactions for the Southeast region and Winter, Southwest region and males(Sex) and Size and males(sex). These interactions, although significant, tell us very little about whether or not the anatomical features (Sex, Size) and environmental factors (region, season) have much of a relationship between the occurrence of collisions.

The results of the Nonmetric Multidimensional Scaling(NMDS) were very mixed. It was expected that if there was a difference between the population of manatees that died from watercraft collision and the population that did not that there would be some clear clustering to distinguish the two. Instead the iterations showed evidence that there may be very little difference between the two populations. The results of the NDMS may be skewed by the way that they are formed. 500 points from each population, collision and non-collision, were selected. So it does not contain all possible points however, the random sampling gives an adequate approximation of the true collision and non-collision population for the scaling. This does not necessarily discount the significant model that was formed for mapping out the effects that some of the explanatory variables and their interactions had on the log likelihood of manatee death by watercraft collision however, the results of the NDMS did not supply much evidence of a difference.

Based on the results of the Generalized Linear Modeling and the NDMS the anatomy and environment of the West Indian Manatees do not appear to be related to whether or not a given manatee dies from watercraft collision or not.

Acknowledgments:

Thanks to the Florida Fish and Wildlife Conservation Commission for being very helpful and providing the full manatee mortality dataset spanning the years of 1974 to 2015. Also thanks to my peers for offering me assistance at difficult points in the statistical analysis and design.

Special thanks to Stuart Wagenius and Jessamine Finch for their mentorship and guidance through this analysis.

Throughout the analysis several tools were used. The complete analysis was done using R. Additional packages were also used: Xtable, MuMIn, and Vegan.

Extra thanks to the creator of the MuMIn package for providing helper code to convert dredge tables to a latex format.

Literature Cited

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Appendices

Appendix A: Minimal Model Parameter Estimates with Standard Errors.

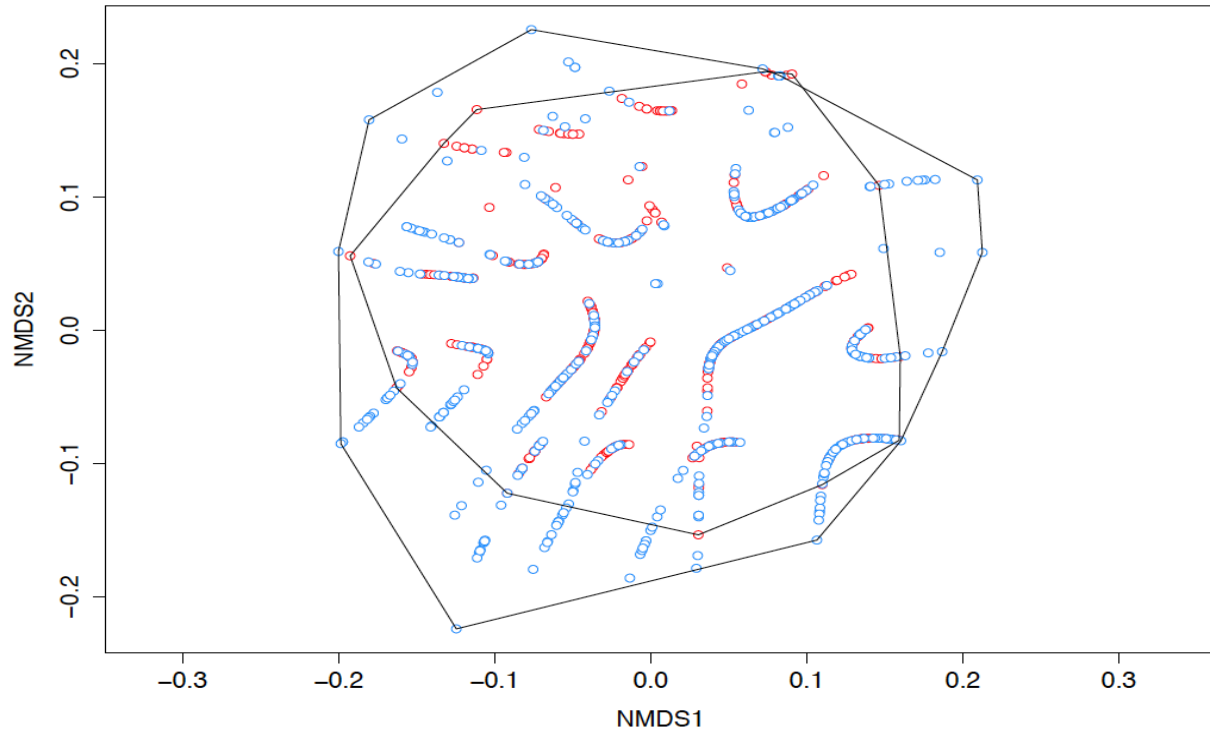
	Estimate	Std. Error	z value	P-value
(Intercept)	-3.7633	0.2948	-12.77	<0.0001
RegionNorthWestCentral	-0.6879	0.7168	-0.96	0.3372
RegionSouthCentralEast	-0.3335	0.2661	-1.25	0.2101
RegionSouthCentralWest	0.1536	0.2606	0.59	0.5557
SeasonSpring	0.5886	0.2801	2.10	0.0356
SeasonSummer	0.0073	0.2839	0.03	0.9794
SeasonWinter	-1.2404	0.3115	-3.98	0.0001
SexM	-0.3371	0.3135	-1.08	0.2822
Sizecm	0.0105	0.0006	18.59	<0.0001
RegionNorthWestCentral:SeasonSpring	-0.0329	0.6982	-0.05	0.9624
RegionSouthCentralEast:SeasonSpring	-0.1753	0.2942	-0.60	0.5512
RegionSouthCentralWest:SeasonSpring	-0.4743	0.2884	-1.64	0.1001
RegionNorthWestCentral:SeasonSummer	-0.1360	0.8412	-0.16	0.8716
RegionSouthCentralEast:SeasonSummer	0.1721	0.2986	0.58	0.5642
RegionSouthCentralWest:SeasonSummer	0.3807	0.2933	1.30	0.1944
RegionNorthWestCentral:SeasonWinter	-0.4375	0.8366	-0.52	0.6010
RegionSouthCentralEast:SeasonWinter	1.1621	0.3202	3.63	0.0003
RegionSouthCentralWest:SeasonWinter	0.5344	0.3191	1.67	0.0940
RegionNorthWestCentral:SexM	0.1382	0.5711	0.24	0.8087
RegionSouthCentralEast:SexM	-0.2125	0.1931	-1.10	0.2712
RegionSouthCentralWest:SexM	-0.5189	0.1918	-2.71	0.0068
SeasonSpring:SexM	-0.2647	0.1610	-1.64	0.1001
SeasonSummer:SexM	0.2021	0.1686	1.20	0.2307
SeasonWinter:SexM	-0.2117	0.1616	-1.31	0.1901
SexM:Sizecm	0.0034	0.0009	3.92	0.0001

Appendix A-2: Minimal Model Confidence Intervals.

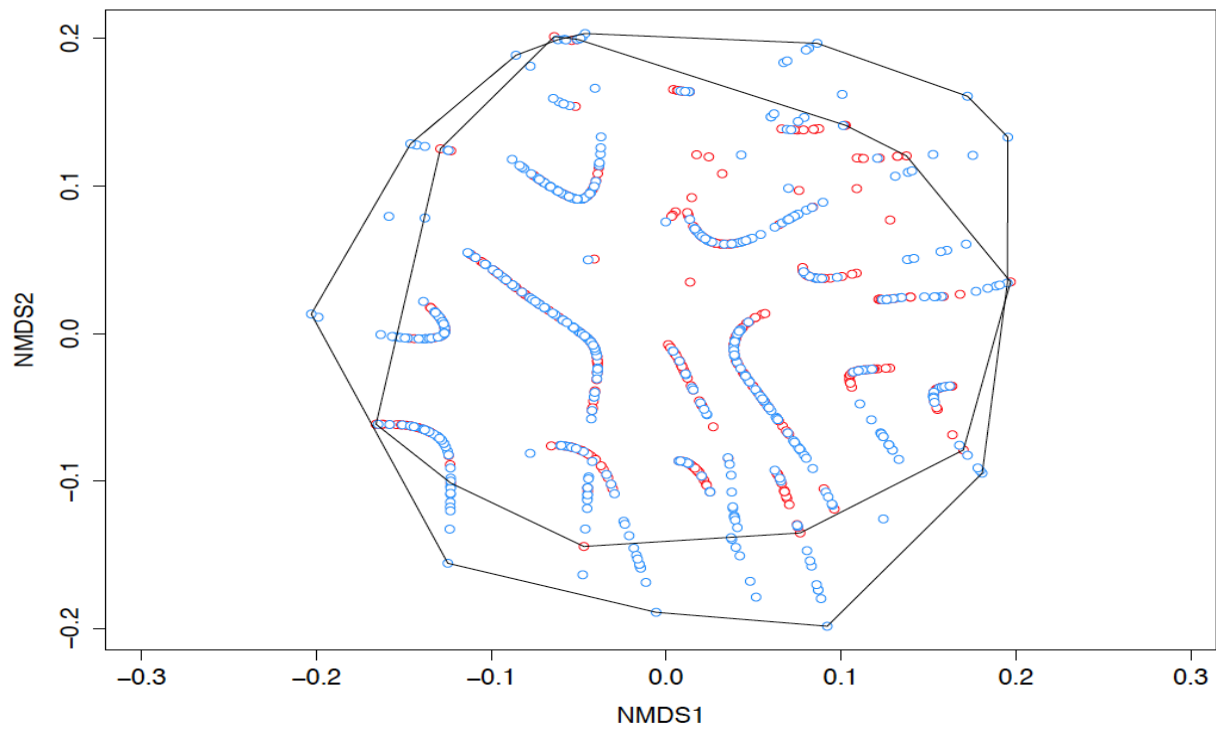
	2.5 %	97.5 %
(Intercept)	-4.35	-3.19
RegionNorthWestCentral	-2.17	0.66
RegionSouthCentralEast	-0.85	0.20
RegionSouthCentralWest	-0.35	0.67
SeasonSpring	0.04	1.14
SeasonSummer	-0.55	0.57
SeasonWinter	-1.86	-0.63
SexM	-0.95	0.28
Sizecm	0.01	0.01
RegionNorthWestCentral:SeasonSpring	-1.39	1.37
RegionSouthCentralEast:SeasonSpring	-0.76	0.40
RegionSouthCentralWest:SeasonSpring	-1.04	0.09
RegionNorthWestCentral:SeasonSummer	-1.83	1.51
RegionSouthCentralEast:SeasonSummer	-0.42	0.76
RegionSouthCentralWest:SeasonSummer	-0.20	0.95
RegionNorthWestCentral:SeasonWinter	-2.20	1.16
RegionSouthCentralEast:SeasonWinter	0.54	1.79
RegionSouthCentralWest:SeasonWinter	-0.09	1.17
RegionNorthWestCentral:SexM	-0.96	1.29
RegionSouthCentralEast:SexM	-0.59	0.17
RegionSouthCentralWest:SexM	-0.90	-0.14
SeasonSpring:SexM	-0.58	0.05
SeasonSummer:SexM	-0.13	0.53
SeasonWinter:SexM	-0.53	0.10
SexM:Sizecm	0.00	0.01

Appendix B: Sample Iterations of Random Sampled Nonmetric Multidimensional Scaling.

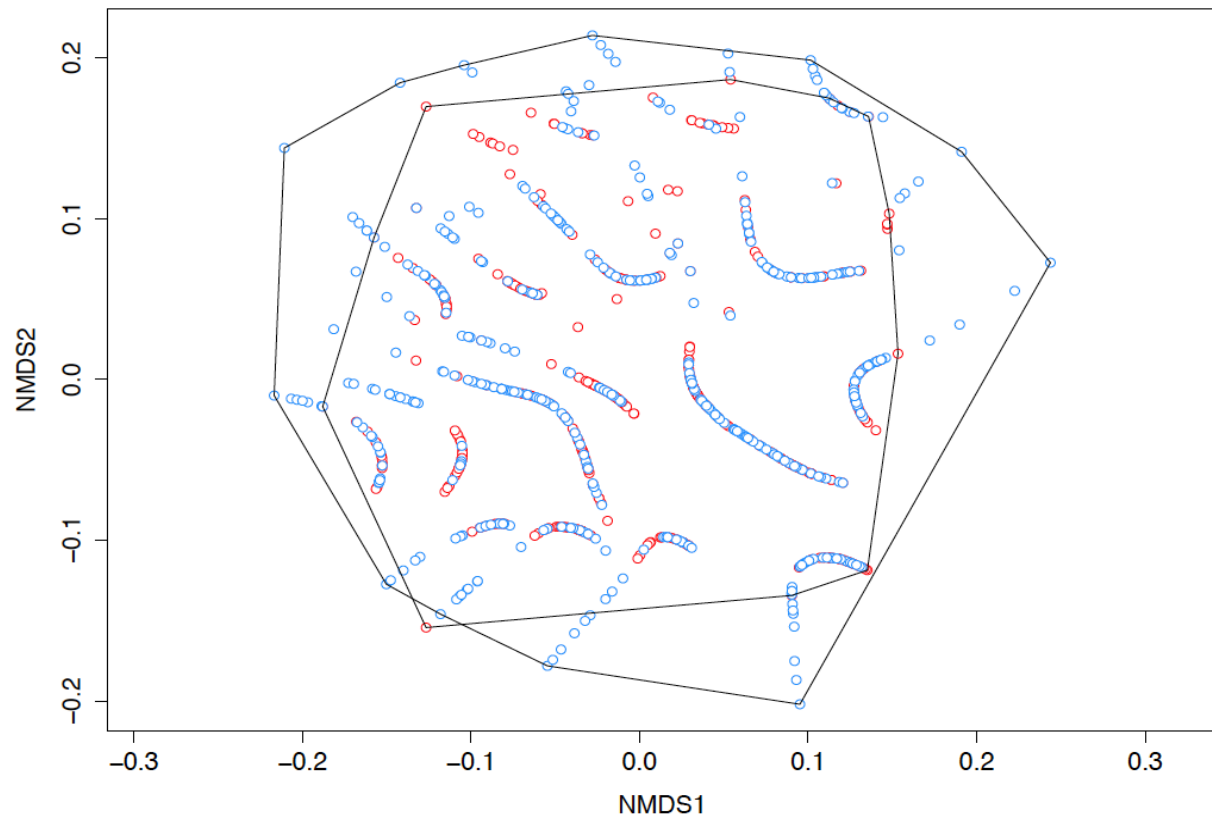
NMDS for Collision and Non-Collision Communities



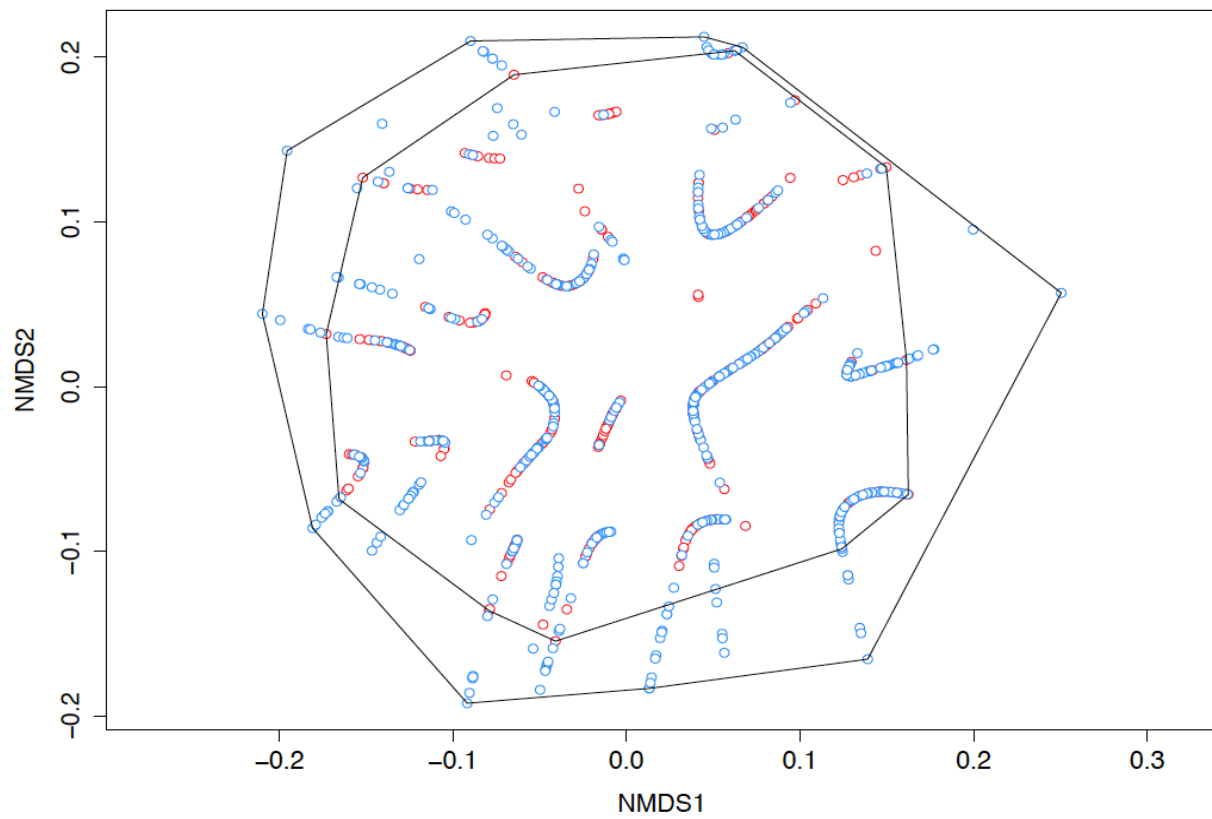
NMDS for Collision and Non-Collision Communities



NMDS for Collision and Non-Collision Communities



NMDS for Collision and Non-Collision Communities



Appendix C: Frequency Distributions of Waterways

Waterway	Counts	Waterway	Counts
1 Orange River	1	41 Bayboro Harbor	1
2 10 Mile Canal	2	42 Bayou Grande	2
3 10-A Canal	2	43 Bayou Texar	1
4 77th Avenue Canal	1	44 Beachwood Canal	1
5 951 Canal	1	45 Bear Pt. Cove	1
6 Addison Bay	6	46 Belcher Canal	1
7 Ainger Creek	4	47 Bells River	2
8 Alafia River	39	48 Berkeley Canal	4
9 Allen's Creek	2	49 Bessey Creek	5
10 Allens Creek	4	50 Bessie Creek	1
11 Alligator Bay	14	51 Bessy Creek	1
12 Alligator Bayou	1	52 Big Bay	1
13 Alligator Creek	15	53 Big Bayou	3
14 Amelia River	13	54 Big Carlos Pass	8
		Big Cypress Preserve	
15 Anclote Anchorage	1	55 NP	1
16 Anclote River	25	56 Big Hickory Pass	2
17 Anna Maria Sound	13	57 Big Lagoon	1
18 Anna Maria Sound (ICW)	1	58 Big Lostmans Bay	7
19 Apalachee Bay	1	59 Big Marco Pass	4
20 Apalachicola Bay	5	60 Big Marco Pass ICW	1
21 Apollo Beach	1	61 Big Marco River	4
22 Archie Creek	1	62 Big Mud Creek	1
23 Arlington River	3	63 Big Pass	1
24 Atlantic Ocean	127	64 Big Pottsburg Creek	1
25 Aucilla River	1	65 Big Sarasota Pass	1
26 Avery Bayou	1	66 Big Slough	5
27 Avocado Creek	1	67 Billy Creek	1
28 Back Bay	1	68 Billy's Creek	2
29 Bagley Cove	2	69 Bimini Bay	2
Bakers Haulover Inlet-			
30 ICW	1	70 Bird Creek	1
31 Banana Creek	9	71 Biscayne Bay	93
32 Banana River	665	72 Biscayne Bay ICW	2
Banana River/Barge			
33 Canal	1	73 Biscayne Canal	10
34 Barfield Bay	6	74 Biscayne Creek	1

35	Barge Canal	27	75	Bivens Creek	1
36	Barnes Sound	1	76	Black Bay	1
37	Barron River	16	77	Black Creek	17
38	Barron River Canal	4	78	Black Creek (C-1 canal)	1
				Black Creek (C-1	
39	Bartine Creek	1	79	Canal)	1
40	Battle Creek	1	80	Black Creek Canal	1

Waterway		Counts	Waterway		Counts
81	Black Point Channel	1	121	C-102 Canal	1
82	Black Water River	1	122	C-107 Canal	1
83	Blackburn Bay	12	123	C-12 Canal	3
84	Blackwater Bay	1	124	C-13 Canal	1
85	Blackwater River	10	125	C-18 Canal	4
86	Blackwater Sound	3	126	C-2 Snapper Creek	1
87	Blind Pass	2	127	C-23 Canal	1
88	Blue Hill Creek	3	128	C-24 Canal	1
89	Blue Lagoon	3	129	C-54 Canal	1
90	Blue Lagoon Lake	3	130	C-6 Canal	2
91	Blue Springs	2	131	C-7 Canal	2
92	Blue Waters	2	132	Cabana Colony Canal	2
93	Boca Ceiga Bay	5	133	Cabbagehead Bayou	1
94	Boca Ciega Bay	37	134	Caloosahatchee	3
95	Boca Ciega Bay ICW	3	135	Caloosahatchee Canal	30
96	Boca Grande Pass	4	136	Caloosahatchee River	695
97	Boca Raton ICW	1	137	Caloosahatchee River	1
98	Boggy Bayou	2	138	Caloosahatchee River	1
99	Bonita Waterway	1	139	Calosahatchee River	1
100	Booker Creek	1	140	Camachee Cove ICW	1
101	Bowlees Creek	5	141	Canal L-A	1
102	Bowles Creek	1	142	Canaveral Barge Canal	12
103	Boynton Beach ICW	1	143	Canaveral Locks	1
104	Boynton Inlet	2	144	Cannon Bay	1
105	Boynton-Delray ICW	2	145	Card Sound	1
				Card Sound Road	
106	Boynton/Delray ICW	10	146	Canal	1
107	Braden River	20	147	Carlin Park Pond	1

108	Broad River	12	148	Caxamabas Pass	1
109	Broad River Bay	4	149	Caxambas Bay	2
110	Broward River	2	150	Caxambas Pass	13
111	Bull Bay	4	151	CB-11 canal	5
112	Bulls Creek	2	152	Cedar River	4
113	Bulow Creek	1	153	Ceitus Lake	1
114	Buttonwood Bay	1	154	Chadwick Bayou	1
115	Buttonwood Canal	4	155	Charlotte Harbor	123
116	Buttonwood Harbor	3	156	Chassahowitzka River	4
117	Buttonwood Sound	4	157	Chatham River	1
118	C-10 canal	1	158	Chevelier Bay	18
119	C-10 Canal	5	159	Choctawhatchee Bay	6
120	C-10 Spur	1	160	Chokoloskee Bay	37

	Waterway	Counts		Waterway	Counts
161	Chokoloskee Pass	3	201	Cypress Creek	5
162	Clam Bay	2	202	Cypress Creek Canal	6
163	Clam Bayou	1	203	Dads Bay	1
164	Clam Pass	1	204	Dania Canal	2
165	Clark Creek	1	205	Dania Cutoff Canal	27
166	Clearwater Harbor	12	206	Dania Sound	1
167	Cleve Hinton Creek	1	207	Daughtery Creek	1
168	Clewiston Canal	1	208	Daughtry Bayou	1
169	Cockroach Bay	1	209	Dead Lake	3
170	Cocohatchee River	2	210	Dead River	1
171	Coffeepot Bayou	4	211	Deadmans Bay	1
172	Collier Bay	13	212	Deadmans Channel	1
173	Community Harbor	1	213	Deep Creek	5
174	Coon Key Pass	2	214	Deep Lagoon	1
175	Coopers Bayou	1	215	Deer Creek	1
176	Coot Bay	1	216	Delray Beach ICW	1
177	Coral Creek	4	217	Dickerson Bay	1
178	Coral Gables Canal	2	218	Dinken Bayou	2
179	Coral Gables Waterway	3	219	Dismal Key Pass	1
180	Cormorant Pass	1	220	Dixie Bay	7
181	Cotton Key Basin	3	221	Doctor's Lake	1
182	Cow Creek	1	222	Doctors Inlet	1

183	Cow Creek (canal)	1	223	Doctors Lake	14
184	Cowpens Anchorage	4	224	Doctors Pass	1
185	Cowpens Cut	2	225	Dollar Bay	9
186	Craig Creek	1	226	Dona Bay	2
187	Crane Creek	42	227	Double Bayou	1
188	Crescent Lake	2	228	Double Branch Creek	3
189	Crooked Creek	2	229	Dressels Canal	1
190	Crooked River	1	230	Dryman Bay	2
191	Cross Bay	1	231	Dumfoundling Bay	1
192	Cross Bayou	2	232	Dunn Creek	3
193	Cross Bayou Canal	5	233	Dunns Creek	1
	Cross Florida Barge				
194	Canal	32	234	Eagle Key Pass	1
195	Crystal Bay	23	235	Earman River	6
196	Crystal River	63	236	East Bay	8
197	Crystal River	1	237	East River	1
198	Culbreath Bayou	1	238	Eau Gallie Canal	1
199	Cumberland Sound	2	239	Eau Gallie River	46
				Eau Gallie River	
200	Cutler Bay	1	240	(Elbow Creek)	1

	Waterway	Counts		Waterway	Counts
241	El Rio Canal	3	281	Goodbys Creek	8
242	Elbow Creek	1	282	Goodland Bay	5
243	Estego Bay	1	283	Goose Creek Bay	1
244	Estero Bay	93	284	Gordon Pass	2
245	Estero River	5	285	Gordon River	16
246	Factory Bay	4	286	Gottfried Creek	5
247	Faka Union Basin	1	287	Goulds Canal	1
248	Faka Union Bay	5	288	Government Cut	2
249	Faka Union Canal	161	289	Governor's Creek	3
250	Fakahatchee Bay	3	290	Grand Canal	74
251	Fakahatchee Pass	1	291	Grande Bayou	1
252	Fakahatchee River	2	292	Great Pocket	12
253	Fakaunion Canal	1	293	Green House Creek	1
254	Ferguson Bay	1	294	Greenfield Creek	1
255	Ferguson River	1	295	Greenway Channel	1

256	Fish Hawk Creek	1	296	Guana River	1
257	Fish Trap Bay	4	297	Gulf County Canal	2
258	Fishermans Channel	1	298	Gulf of Mexico	120
	FL Power discharge				
259	canal	1	299	Gullivan Bay	25
260	Flagler Beach ICW	2	300	Haldeman Creek	3
261	Florida Barge Canal	2	301	Halfway Creek	13
262	Florida Bay	33	302	Halifax Creek	1
	Florida Cross State				
263	Canal	1	303	Halifax Harbour	1
	Florida Turnpike				
264	Drainage Ditch	1	304	Halifax River	115
265	Forked Creek	18	305	Halifax River ICW	22
266	Fort George River	1	306	Hall Bay	3
267	Fort Pierce Inlet	1	307	Halls River	5
268	Foster Bay	1	308	Hancock Creek	5
269	Fox Cut	1	309	Harney River	5
270	Fox Cut ICW	7	310	Harris Bayou	1
271	Frenchmans Creek	2	311	Hatchet Creek	1
272	Freshwater Bayou	1	312	Haulover Canal	5
273	Frog Creek	1	313	Hawk Channel	1
274	Ft. Pierce Inlet	4	314	Hells Bay	5
275	Garfield Cut	2	315	Henderson Creek	21
276	Garfield Cut (ICW)	1	316	Hendry Creek	11
277	Garrison Channel	1	317	Henry Creek Canal	2
278	Gasparilla Sound	34	318	Herman Bay	1
279	Glover Bight	2	319	Hillsboro Canal	8
				Hillsboro Drainage	
280	Golden Beach ICW	1	320	Canal	2

	Waterway	Counts		Waterway	Counts
321	Hillsboro Inlet	2	361	Inner Doctors Bay	1
322	Hillsboro Inlet ICW	6	362	Intracoastal Waterway	70
323	Hillsboro River	4	363	Iona Cove	1
324	Hillsboro River (ICW)	4	364	Jackson River	1
				Jacksonville Beach	
325	Hillsborough Bay	43	365	ICW	1
326	Hillsborough River	21	366	Jenkins Creek	3

327	Hobe Sound	13	367	Jewfish Creek	1
328	Hobe Sound ICW	2	368	Jim Long Lake	1
329	Hogtown Bayou	1	369	Joe Bay	3
330	Holdeman River	2	370	Joe River	7
331	Homestead Canal	1	371	Joe River Bay	1
332	Homosassa River	52	372	Joe's Creek	1
333	Homosassa Springs	1	373	Johns Island Creek	1
334	Honeymoon Lake	1	374	Johns Pass	1
335	Honolulu Canal	1	375	Johns Pass ICW	1
336	Horse Creek	1	376	Johnson Bay	23
337	Hospital Creek	1	377	Jolly River	2
338	House Hammock Bay	1	378	Jug Creek	7
339	Hudson Bay	1	379	Julington Creek	16
340	Hudson Bayou	2	380	Juno Beach ICW	1
341	Hudson River	1	381	Jupiter Harbor	1
342	Hunter Creek	3	382	Jupiter Inlet	2
343	Hurricane Bay	6	383	Jupiter Inlet ICW	1
344	Hurricane Pass	3	384	Jupiter Narrows	1
345	Huston Bay	6	385	Jupiter Sound	12
346	Huston River	3	386	Karen Canal	1
347	ICW	8	387	Kesson Bayou	1
348	Imperial River	51	388	Key Vaca Cut	1
349	Indain River	1	389	Kings Bay	76
350	Indian Creek	2	390	Kiss Lake	1
351	Indian Key Channel	1	391	Kissimmee River	7
352	Indian Key Pass	5	392	Klosterman Creek	1
353	Indian Prairie Canal	2	393	Kreamer's Bayou	1
354	Indian River	1163	394	Krueger Creek	1
355	Indian Rlver	1	395	L-10 Canal	1
356	Indian River	1	396	L-5 Canal	1
357	Indian River ICW	1	397	L-8 canal	1
358	Indian River Lagoon	19	398	L-8 Tieback canal	1
359	Indian Rocks ICW	1	399	Lake Beresford	4
360	Indina River	1	400	Lake Boca Raton	1

	Waterway	Counts		Waterway	Counts
401	Lake Dexter	4	441	Little Homosassa River	1

402	Lake George	5	442	Little Madiera Bay	1
403	Lake Hicpochee	4	443	Little Manatee River	29
404	Lake Mabel	6	444	Little Marco River	1
405	Lake Monroe	10	445	Little Mud Creek	1
406	Lake Okeechobee	1	446	Little Pottsburg Creek	2
407	Lake Okeechobee	59	447	Little River	33
	Lake Okeechobee Rim				
408	Canal	2	448	Little River Canal	1
				Little River Canal (C7	
409	Lake Placid	2	449	Canal)	1
410	Lake Ponte Vedra	1	450	Little Roberts Bay	1
411	Lake Rodgers ICW	5	451	Little Sarasota Bay	24
412	Lake Santa Barbara	1	452	Little Shark River	1
413	Lake Surprise	3	453	Little Tomoka River	2
414	Lake Sylvia	1	454	Loch Doon Loch	1
415	Lake Tarpon Canal	1	455	Long Bayou	5
	Lake Tarpon Outfall				
416	Canal	2	456	Long Creek	1
417	Lake Woodruff	4	457	Long Sound	2
418	Lake Worth	73	458	Lopez River	7
419	Lake Worth (ICW)	3	459	Lostman's River	2
420	Lake Worth Creek	16	460	Lostmans River	3
421	Lake Worth Creek (ICW)	4	461	Loxahatchee River	22
422	Lake Worth Creek ICW	7	462	Lyons Bay	5
423	Lake Worth ICW	5	463	Mahi Waterway	1
424	Lake Worth Inlet	1	464	Manatee Bay	4
425	Lake Worth Lagoon	5	465	Manatee Creek	4
426	Lake Wyman	4	466	Manatee Pocket	10
427	Lane Bay	8	467	Manatee River	50
428	Lane River	2	468	Manatee Springs	1
429	Largo Sound	1	469	Mandalay Channel	2
430	Last Huston Bay	2	470	Mantanzas Pass	1
431	Lemon Bay	117	471	Mapp Creek	1
432	Lemon Bay (ICW)	2	472	Marco Pass	2
433	Lemon Bay ICW	1	473	Marco River	12
434	Lemon Creek	1	474	Maria Sanchez Lake	1
435	Lettuce Lake ICW	1	475	Marina Bay (ICW)	1
436	Little Alligator Creek	1	476	Marsh Branch	1
437	Little Bokeelia Bay	3	477	Mason Creek	3
438	Little East Creek (ICW)	1	478	Matanzas Inlet ICW	1
439	Little Hickery Bay	1	479	Matanzas Pass	11

440	Little Hickory Bay	8	480	Matanzas River	30
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	Waterway	Counts		Waterway	Counts
481	Matanzas River (ICW)	2	521	Murray Creek	1
482	Matanzas River ICW	9	522	Myakka Cutoff	1
483	Matecumbe Harbor	1	523	Myakka River	53
484	Matlacha Pass	183	524	Myakkahatchee Creek N Fork Loxahatchee	2
485	Maule Lake	1	525	River	1
486	Maximo Channel	3	526	N. Fork St. Lucie River	3
487	Mayakkahatchee River	1	527	N. Fork, New River	1
488	Mcgirts Creek	1	528	N. Fork, St. Lucie River	1
489	McIlvane Bay	3	529	Naples Bay	23
490	McKay Bay	3	530	Naples ICW	1
491	McKay Creek	2	531	Nassau River	4
492	Merrick Canal	1	532	Nassau Sound	5
493	Miami Canal	6	533	New Found Harbor	5
494	Miami River	39	534	New River	49
495	Middle River	11	535	New River Canal	22
496	Miguel Bay	2	536	Newfound Harbor	21
497	Military Canal	2	537	Nomans River	1
498	Mill Cove	2	538	Noonan Creek	1
499	Mill Creek	1	539	Norris Dead River	4
500	Misners Branch Creek	1	540	North Bay North Fork	2
501	Mobbly Bay	1	541	Loxahatchee River	1
502	Mobbly Bayou	1	542	North Fork New River North Fork St. Lucie	1
503	Moccasin Creek	1	543	River	1
504	Monroe Lake	2	544	North Lake	2
505	Montezuma Canal	1	545	North Lake (ICW)	1
506	Moore Creek	1	546	North Line Canal North Mosquito	1
507	Moore Haven Canal	1	547	Lagoon	1
508	Moorings Bay	2	548	North New River Canal North Prong Sebastian	2
509	Mosquito Lagoon	110	549	River	1
510	Mosquito Lagoon ICW	1	550	North River	20

511	Moultrie Creek	3	551	North Yacht Basin NW Fork Loxahatchee	1
512	Mowry Canal	4	552	River	1
513	Mud Bay	3	553	Ochlockonee Bay	2
514	Mud Cove	1	554	Ochlockonee River	1
515	Mud Flats Creek	1	555	Ocklawaha River	1
516	Mud River	8	556	Okeechobee Canal Okeechobee Rim	1
517	Mullet Creek	5	557	Canal Okeechobee	10
518	Mullet Key Bayou	5	558	Waterway	23
519	Mullet Lake	2	559	Oklawaha River	5
520	Mullock Creek	21	560	Old Clearwater Bay	1

	Waterway	Counts		Waterway	Counts
561	Old Tampa Bay	59	601	Ponce de Leon Inlet	2
562	Oleta River	6	602	Ponce Inlet	1
563	Orange River	201	603	Ponce Inlet (ICW)	1
564	Ordona Canal	1	604	Porpoise Creek ICW	1
565	Ortega River	24	605	Port Canaveral Port Canaveral Barge	42
566	Ostego Bay	1	606	Canal	3
567	Oyster Bay	4	607	Port Canaveral Inlet	5
568	Oyster Creek	1	608	Port Canaveral Lock	6
569	Pablo Creek	11	609	Port Everglades	33
570	Pablo Creek (ICW)	4	610	Port Everglades (ICW)	1
571	Pablo Creek ICW	5	611	Port Everglades Basin	2
572	Palm Bay	2	612	Port Everglades Canal	1
573	Palm Coast Canal	8	613	Port Everglades ICW Port Everglades	3
574	Palm River	1	614	Turning Basin	3
575	Palm Valley ICW	2	615	Potters Creek	1
576	Palma Sola Bay	17	616	Pottsburg Creek	3
577	Pansy Bayou	3	617	Powell Creek	1
578	Pass-A-Grille Channel	1	618	Prices Creek	1
579	Peace River	87	619	Primo Bay	1
580	Peacocks Pocket	1	620	Princeton Canal	2
581	Peck Lake	3	621	Punta Blanca Creek	1

582	Peck Lake ICW	1	622	Quarry Creek	1
583	Pecks Lake	1	623	Queens Cove	1
584	Pelican Bay	11	624	Rabbit Key Pass	1
585	Pelicer Creek	1	625	Raccoon Creek	1
586	Pellam Waterway	1	626	Redfish Pass	3
587	Perico Bayou	2	627	Ribault River	2
588	Periwinkle Bay	1	628	Rice Creek	2
589	Peters Creek	2	629	Rice Creek	1
590	Peterson Bayou	1	630	Rim Canal	6
591	Phillipi Creek	1	631	Riviera Bay	8
592	Phillippi Creek	11	632	Roberts Bay	39
593	Pine Island Sound	160	633	Roberts River	7
594	Pirates Cove	1	634	Robinson Creek	2
595	Pithlachascotee River	12	635	Robinson's Creek	1
596	Placida Harbor	31	636	Rock Creek	5
597	Placido Bayou	5	637	Rocky Bay	2
598	Pompano Canal	4	638	Rocky Creek	23
599	Ponce de Leon Cut	1	639	Rodgers Park	1
600	Ponce de Leon Cut ICW	1	640	Rodgers River	1

	Waterway	Counts		Waterway	Counts
641	Rodgers River Bay	10	681	Shark River	4
642	Rodman Dam	4	682	Shell Creek	17
643	Rookery Bay	14	683	Shell Key Bay	1
644	Rookery Bay Channel	1	684	Sherman Creek	2
645	Rookery Bay ICW	1	685	Shipyard Creek	1
646	Roosevelt Channel	3	686	Shivers Bay	2
647	Rose Bay	2	687	Silver Glen Spring	1
648	Rose Creek	1	688	Silver Lake	1
649	Route 41 Canal	1	689	Silver Smith Creek	1
	Royal Palm Hammock				
650	Creek	1	690	Silversmith Creek	1
651	Rum Bay	1	691	Sisters Creek	2
652	S. Fork New River	1	692	Six Mile Creek	2
653	Safety Harbor	10	693	Sky Lake	1
654	Salt Creek	12	694	Smith Creek	6
655	Salt River	3	695	Smith Creek ICW	7

656	Salt Run	2	696	Smokehouse Bay	12
657	Salt Springs Run	1	697	Smokehouse Creek	7
658	San Carlos Bay	106	698	Snake Creek	22
659	San Carlos Creek	3	699	Snake Creek Canal	6
660	San Pablo Creek (ICW)	1	700	Snapper Creek	8
661	San Pablo River ICW	2	701	Snapper Creek Canal	2
662	San Sebastian River	3	702	South Creek	1
663	Sanchez Creek	1	703	South Fork New River	7
				South Fork St. Lucie	
664	Sanctuary Sound	41	704	Canal	1
				South Fork St. Lucie	
665	Sand Hill Creek	1	705	River	2
666	Sandfly Pass	1	706	South Grand Canal	1
667	Santa Rosa Sound	1	707	South Jupiter Narrows	2
				South Jupiter Narrows	
668	Sarasota Bay	65	708	ICW	2
669	Sarasota Pass	1	709	South Lake	1
670	Sawpit Creek	1	710	South Lake ICW	2
671	Sebastian Creek	2	711	South Sound Creek	1
672	Sebastian Inlet	4	712	Sparkman Channel	1
673	Sebastian River	95	713	Spreader Canal	1
674	Seven Palm Lake	1	714	Spring Bayou	3
675	Sexton Cove	1	715	Spring Creek	2
676	SFWMD C-111 Canal	1	716	Spring Garden Lake	1
677	SFWMD L-31 East Canal	1	717	Spring Lake	4
678	Shackett Creek	1	718	Spring Lake Garden	1
679	Shakett Creek	5	719	Spring Warrior Creek	1
680	Shark Bight Channel	1	720	Spruce Creek	12

	Waterway	Counts		Waterway	Counts
721	SR 951 Canal	1	761	Tarkiln Bay	2
722	St. Andrews Bay	1	762	Tarpon Basin	7
723	St. Augustine Inlet	1	763	Tarpon Basin Channel	1
724	St. George Sound	5	764	Tarpon Bay	33
725	St. Johns	1	765	Tarpon Bay tributary	1
726	St. Johns River	533	766	Tarpon Bayou	1
727	St. Johns River	1	767	Tarpon River	4
728	St. Joseph Bay	3	768	Tavernier Creek	6

729	St. Joseph Sound	3	769	Taylor Creek	19
730	St. Lucie Canal	37	770	Taylor River	1
731	St. Lucie Inlet	3	771	Ten Mile Canal	40
732	St. Lucie Inlet (ICW)	1	772	Ten Mile Canal	1
733	St. Lucie Locks	1	773	Ten Thousand Islands	3
734	St. Lucie River	76	774	Terra Ceia Bay	15
735	St. Marks River	7	775	Texar Bayou	1
736	St. Martin's River	2	776	The Narrows	3
737	St. Martins River	4	777	The Nightmare	1
738	St. Mary's Entrance	1	778	Thompson's Creek	1
739	St. Marys River	1	779	Three Sisters Spring	2
740	St. Sebastian River	3	780	TIA Canal	2
741	Steinhatchee River	3	781	Tippecanoe Bay	1
742	Stirrup Key Bight	1	782	Tocoi Creek	1
743	Storter Bay	1	783	Tolomato River	6
744	Stranahan River	9	784	Tolomato River ICW	3
745	Stranahan River ICW	8	785	Tom's Creek	2
746	Strickland Bay	1	786	Tomoka Basin	3
747	Strickland Creek	11	787	Tomoka Basin ICW	1
748	Stump Pass	3	788	Tomoka River	93
749	Sunday Bay	5	789	Trouble Creek	2
750	Sunset Cove	5	790	Trout River	20
751	Suwannee Canal	1	791	Tucker Cove	1
752	Suwannee Inlet	1	792	Turkey Creek	44
753	Suwannee River	32	793	Turkey Point Canal	1
754	Sweetwater Bay	1	794	Turnbull Bay	1
755	Sweetwater Creek	1	795	Turnbull Creek	3
756	Sykes Creek	152	796	Turner Creek	1
757	Tamiami Canal	36	797	Turner River	10
758	Tamiami Trail Canal	1	798	Turners Creek	1
759	Tampa Bay	133	799	Turtle Bay	9
760	Tampa Bypass Canal	1	800	Two Island Bay	2

	Waterway	Counts		Waterway	Counts
801	Unknown Bay	2			
802	Vanderbilt Channel	1			
803	Vanderbilt Lagoon	2			

804	Venetian Bay	3
805	Venice ICW	1
806	Venice Inlet	1
807	Waccasassa Bay	4
808	Waccasassa River	3
809	Wagner Creek	1
810	Wakulla River	5
811	Wares Creek	2
812	Warm Mineral Spring	1
813	Warner Creek	1
814	Warner East Bayou	2
815	Warner West Bayou	1
816	Water Turkey Bay	2
817	Watson River	2
818	Weeki Wachee River	4
819	Welaka Springs	2
820	West Lake ICW	2
821	Whidden Creek	1
822	Whipray Basin	1
823	Whiskey Creek	16
824	Whitaker Bayou	2
825	Whitcomb Bayou	1
826	Whitewater Bay	44
827	Widdens Creek	1
828	Wiggins Pass	3
829	Wilderness Waterway	1
830	Willoughby Creek	5
831	Wills Branch Creek	1
832	Withlacoochee Bay	5
833	Withlacoochee River	49
834	Withlacoochee River	2
835	Wood River	2
836	Woods Creek	1
837	Wooten's Pond	1
838	Zeigler Dead River	1