RECONSTITUTING THE ESTUARINE COMMUNITY OF MAINLAND NEARSHORE SOUTH-CENTRAL BISCAYNE BAY

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Joseph Serafy, Diego Lirman, Sarah Bellmund, Thomas Jackson

Presentation for GEER 2017, April 17-19, Coral Springs, FL

This project is based on monitoring data from the open water area adjacent to the Biscayne Bay shoreline, where CERP-related changes in freshwater flow to the bay will be most strongly reflected in changes in salinity and epifauna affected by salinity.

CERP aims to restore a more natural inflow volume and distribution in space and time, potentially increasing the area, frequency and duration of mesohaline and low polyhaline salinity conditions.

IBBEAM
Integrated Biscayne Bay Ecological Monitoring and Assessment

Long-term Objective of Project to be described today:

Visualizing the target nearshore estuarine epifaunal community

Developing community performance measures and targets to help us get there and know when we've arrived.

MONITORING AREA

IBBEAM Epifaunal Monitoring

47 sites

2007 - 2016

DRY season

January-March

WET season

July-September

- A 1-m^2 throw-trap, cleared with a sweep net (4 sweeps), was used to sample **epifauna** in a 3-m^2 area at each site.
- Samples consisted of **small fish**, shrimp, crabs, and echinoderms.
- **Salinity** and other environmental variables were measured at each site.
- **Fish** were identified to species or higher taxa, weighed, and measured.

Approach

- **Fish community dynamics in relation to salinity is the main focus of this presentation.**
- **We assign fish species to halohabitat types based on the median salinity of the distribution of their members.**
- **Then we compare halohabitat groups for how they change over time and differ between 5-yr periods.**

This overview of fish species in relation to salinity covers the 10-yr period 2007-2016 and two 5-yr periods within it: 2007-2011 and 2012-2016.

Our hypotheses:

1. The nearshore epifauna fish community can be assigned to four halohabitat types that change differently in response to change in salinity.

2. Change in the fish community can be documented quantitatively in a 5-yr period.

Total Collecting Period 2007-2016

2007-2011 Collections

2012-2016 Collections

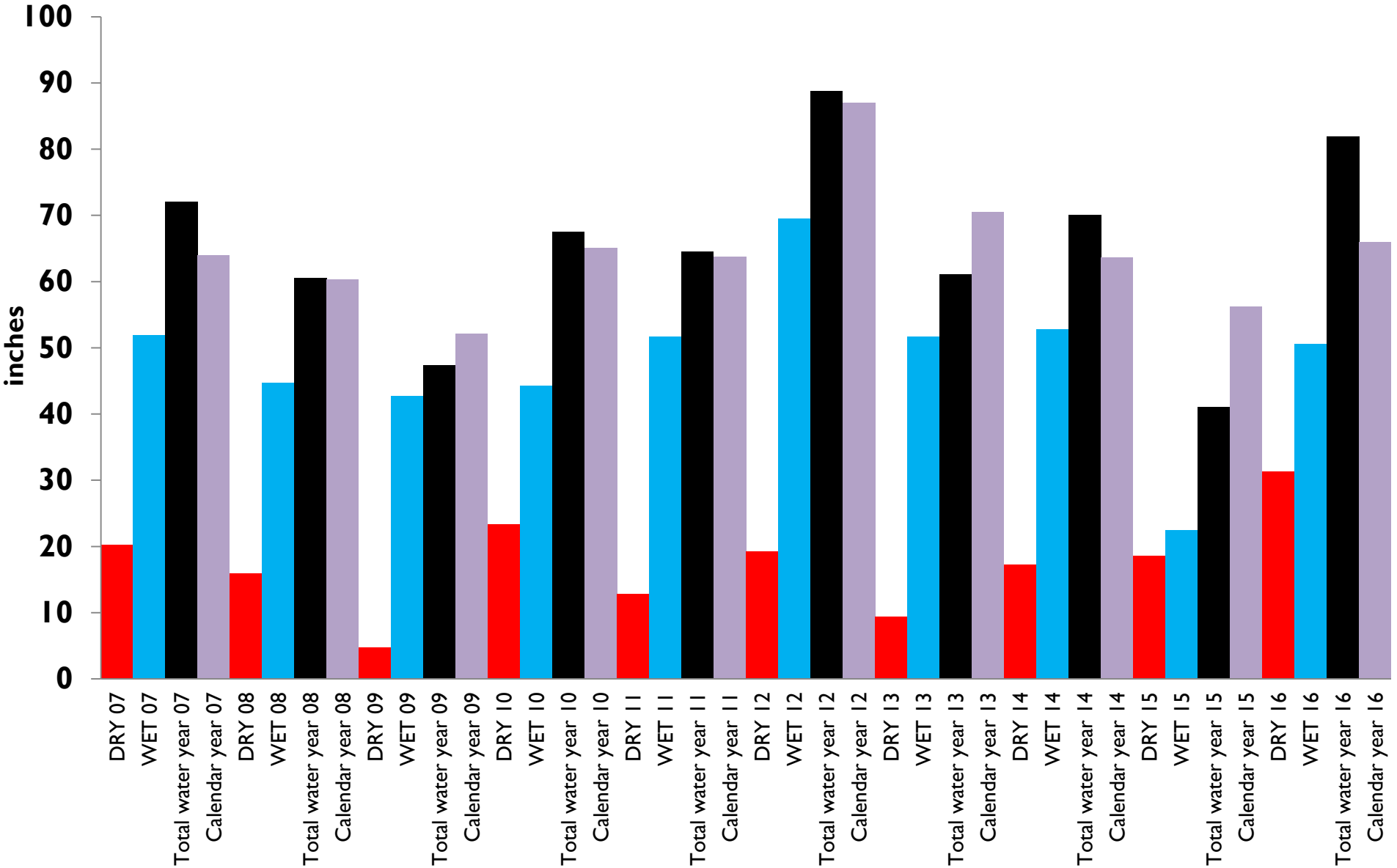
Box-plots were prepared to display the salinity of distribution of all individuals of each species collected over the selected period.

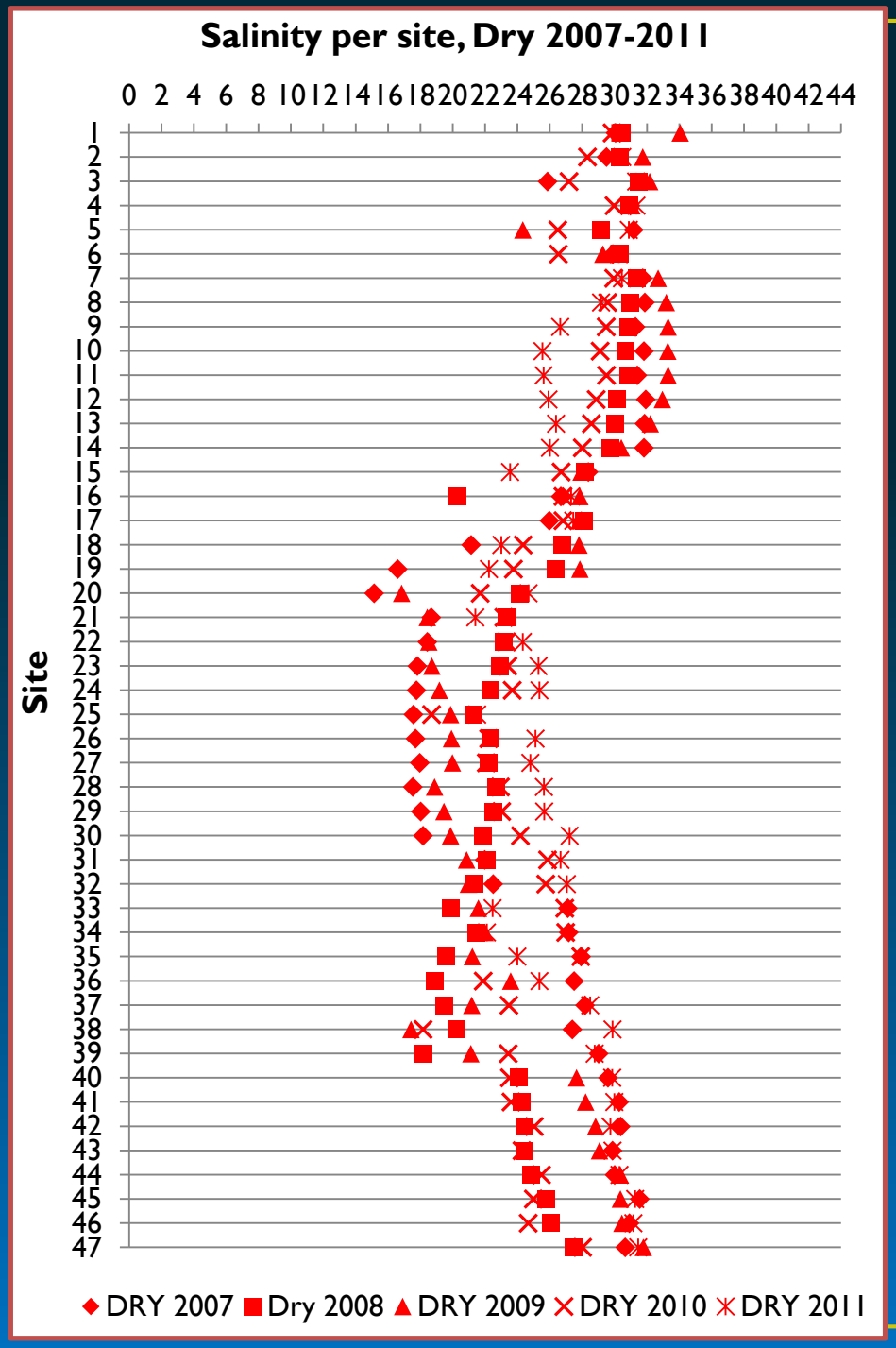
Box plot components

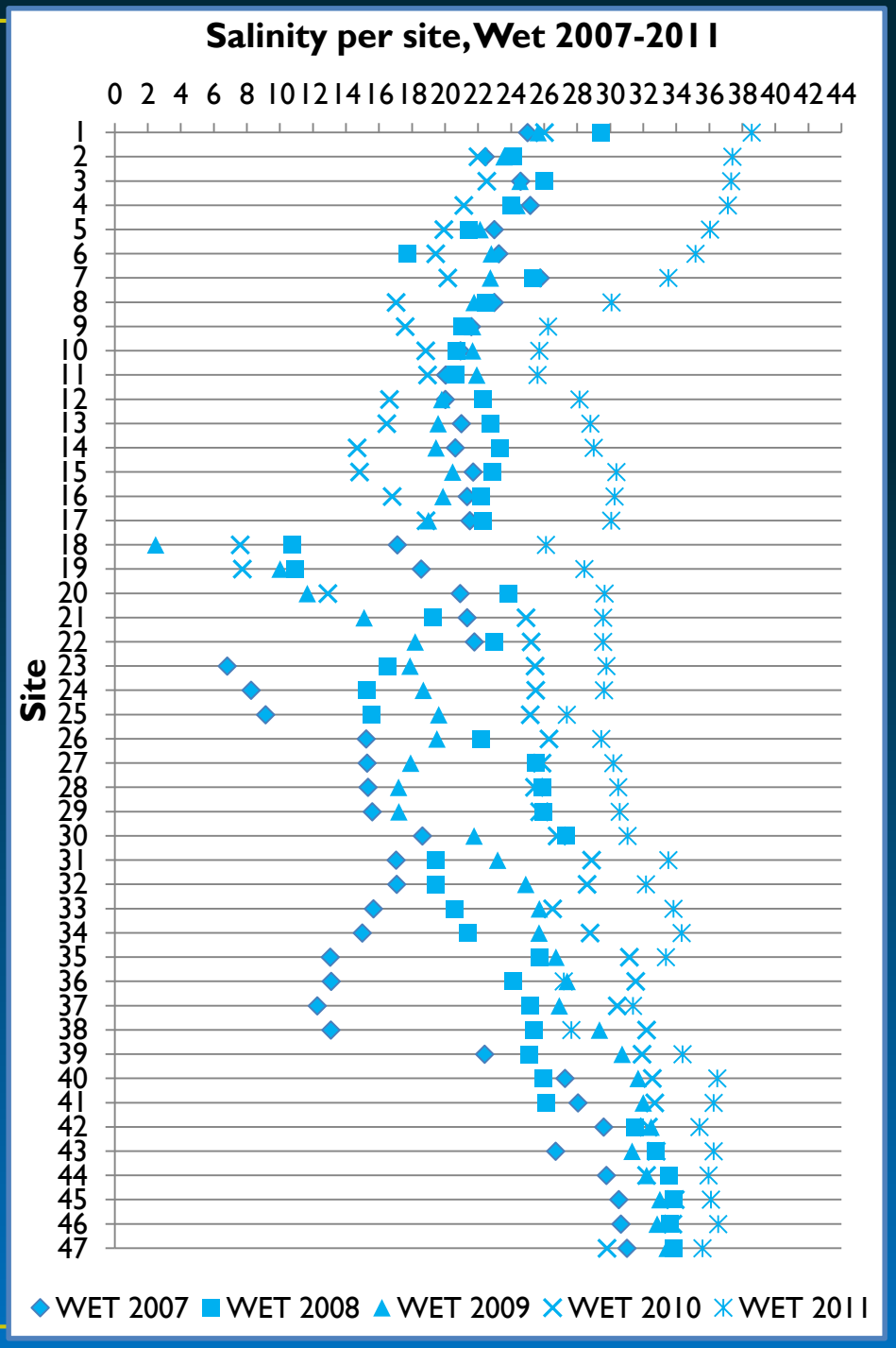
- Median
- 25 and 75 percentiles
- 5 and 95 percentiles
- Outliers

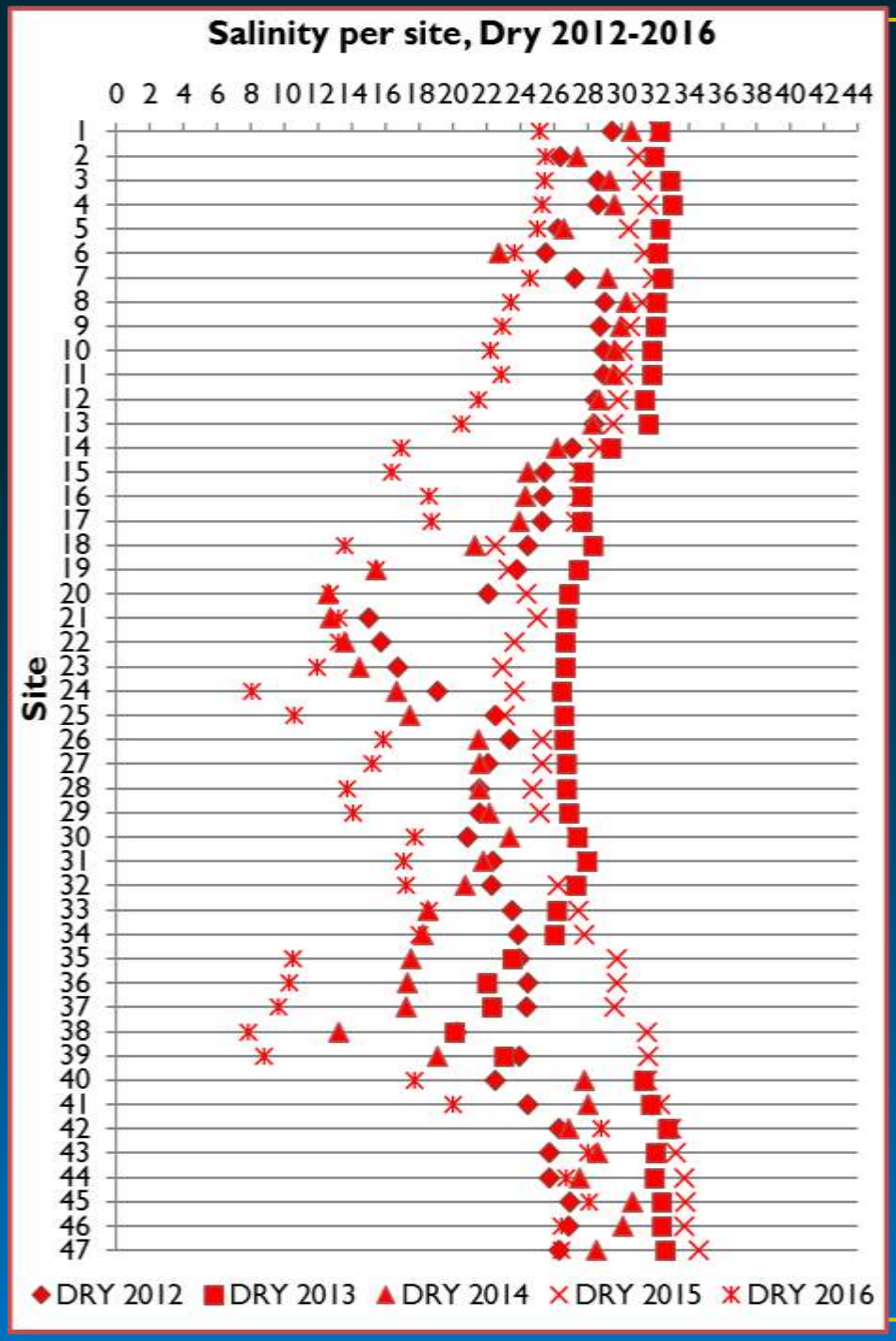
Species were classified to halohabitat based on median salinity of their distribution.

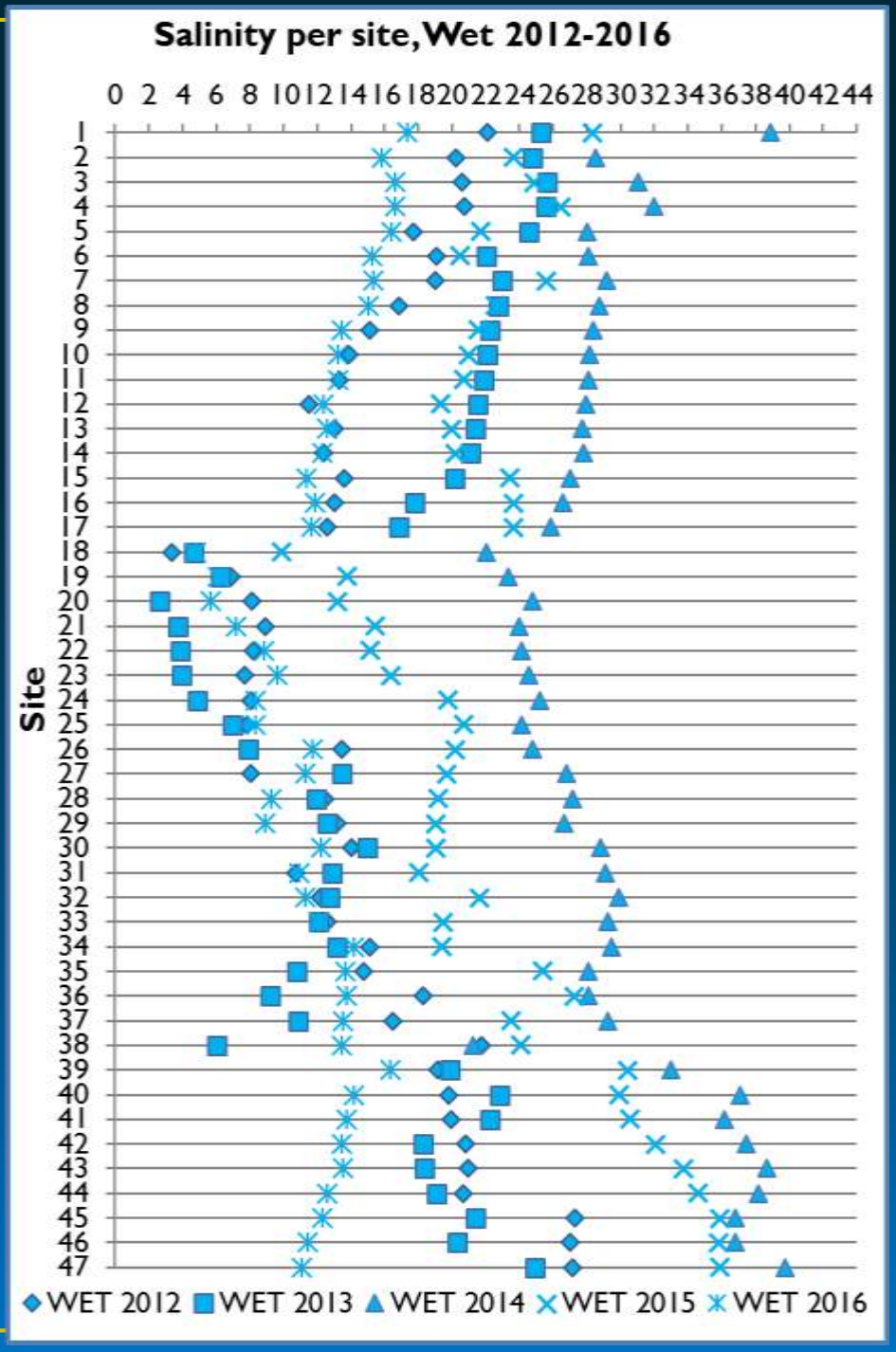
Precipitation 2007-2016



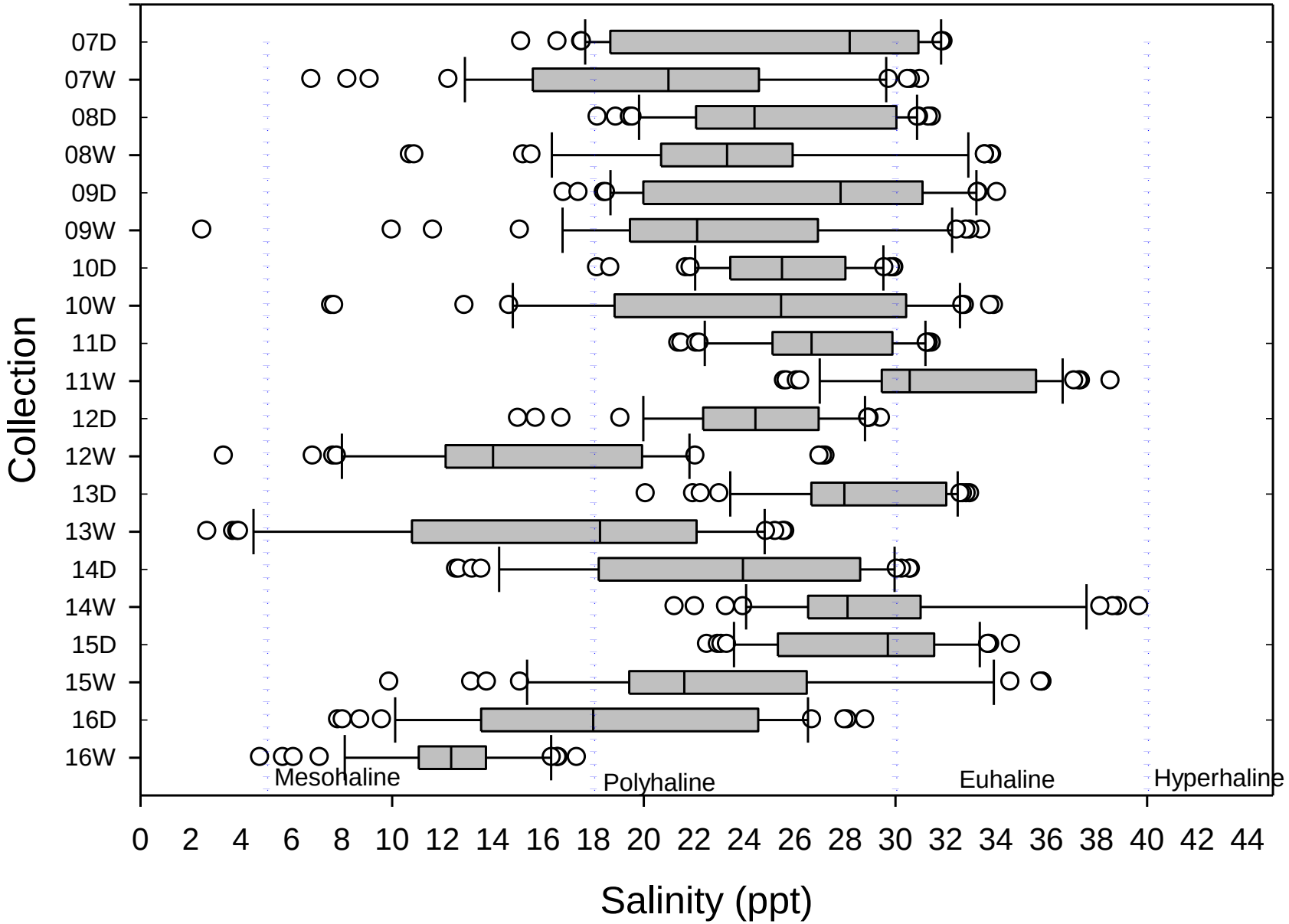

Salinity per site, Dry 2007-2011
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Site
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
DRY 2007
Dry 2008
DRY 2009
DRY 2010
DRY 2011

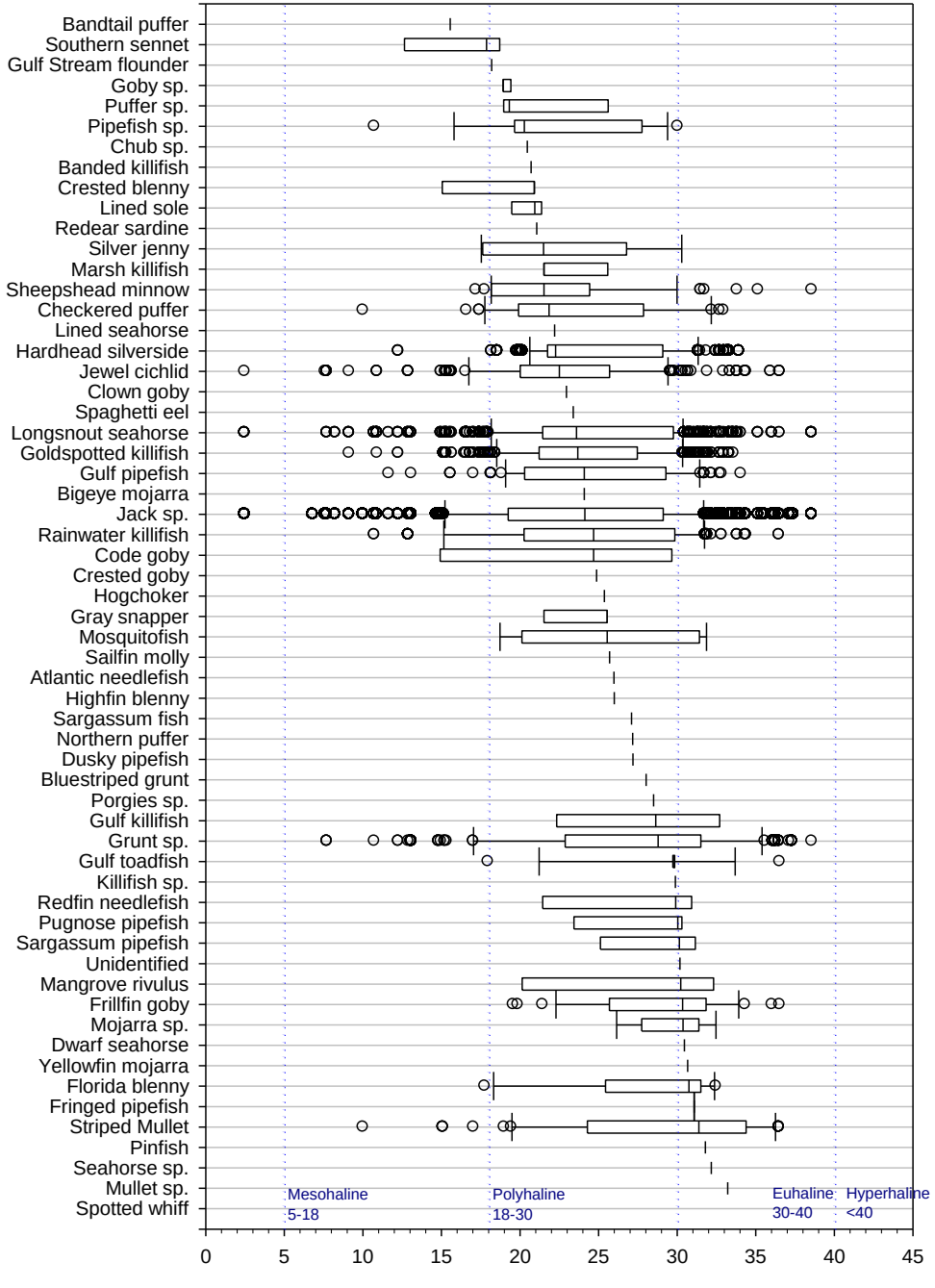

Salinity per site, Wet 2007-2011
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Site
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
WET 2007
WET 2008
WET 2009
WET 2010
WET 2011


Salinity per site, Dry 2012-2016
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Site
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
DRY 2012
DRY 2013
DRY 2014
DRY 2015
DRY 2016


Salinity per site, Wet 2012-2016
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Site
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
WET 2012
WET 2013
WET 2014
WET 2015
WET 2016

Salinity per site 2007-2016

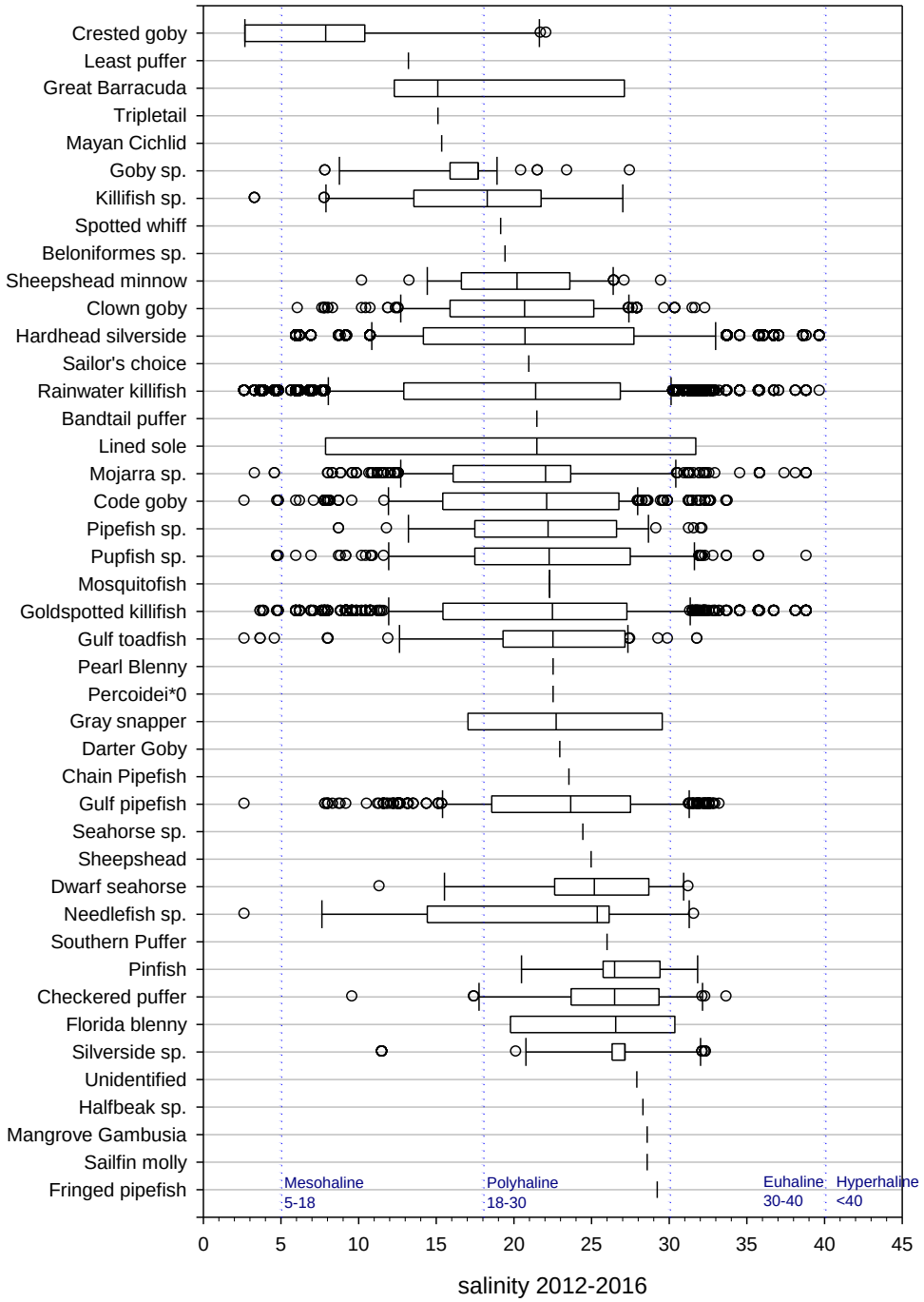




Collection 2007-2011

Distribution:
Median
25 and 75 percentiles
5 and 95 percentiles
Outliers

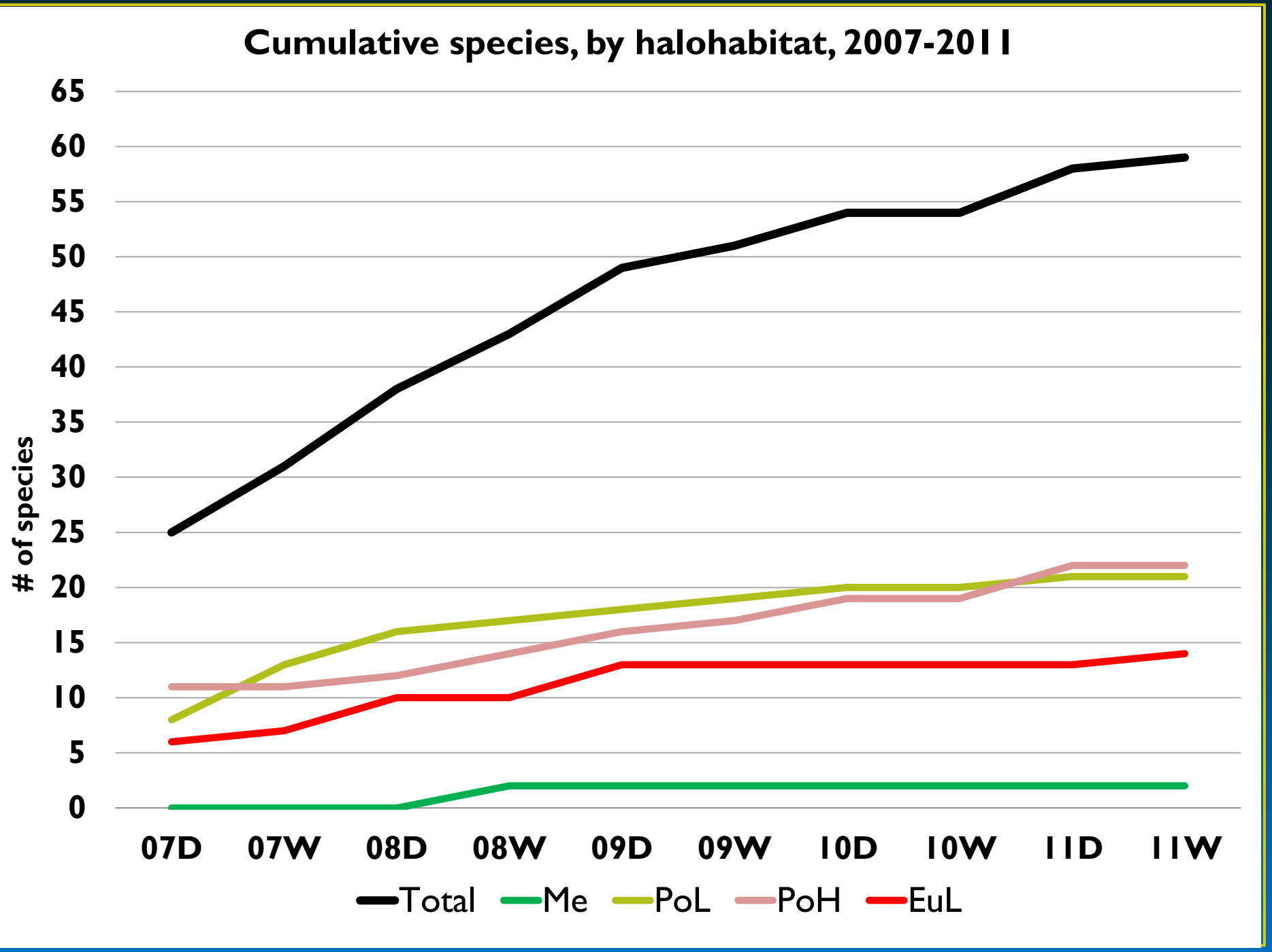
Halohabitats:
Mesohaline 5-18
Polyhaline Low18-24
Polyhaline High 24-30
Euhaline Low 30-35
Euhaline High 35-40
Hyperhaline >40

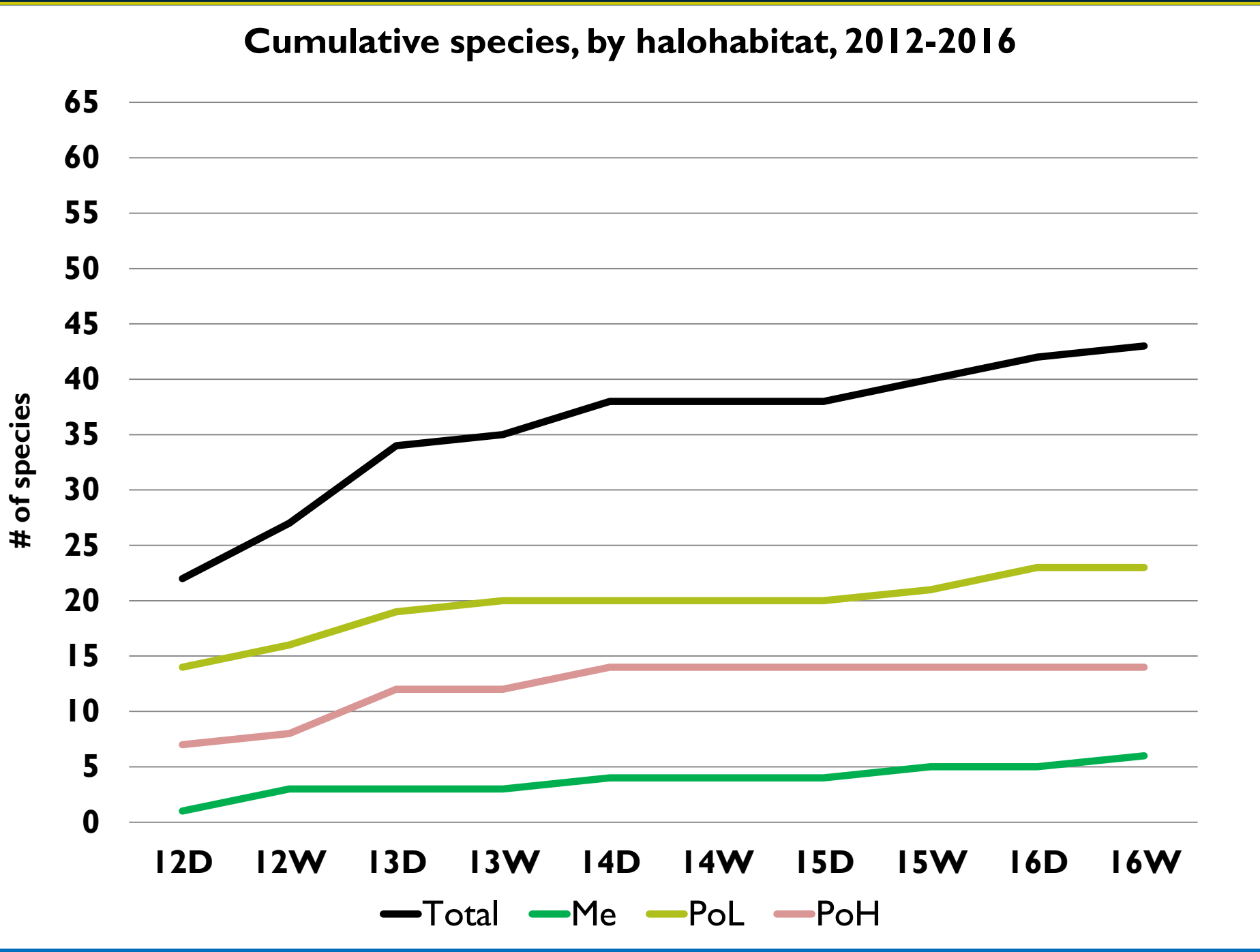


Collection 2012-2016

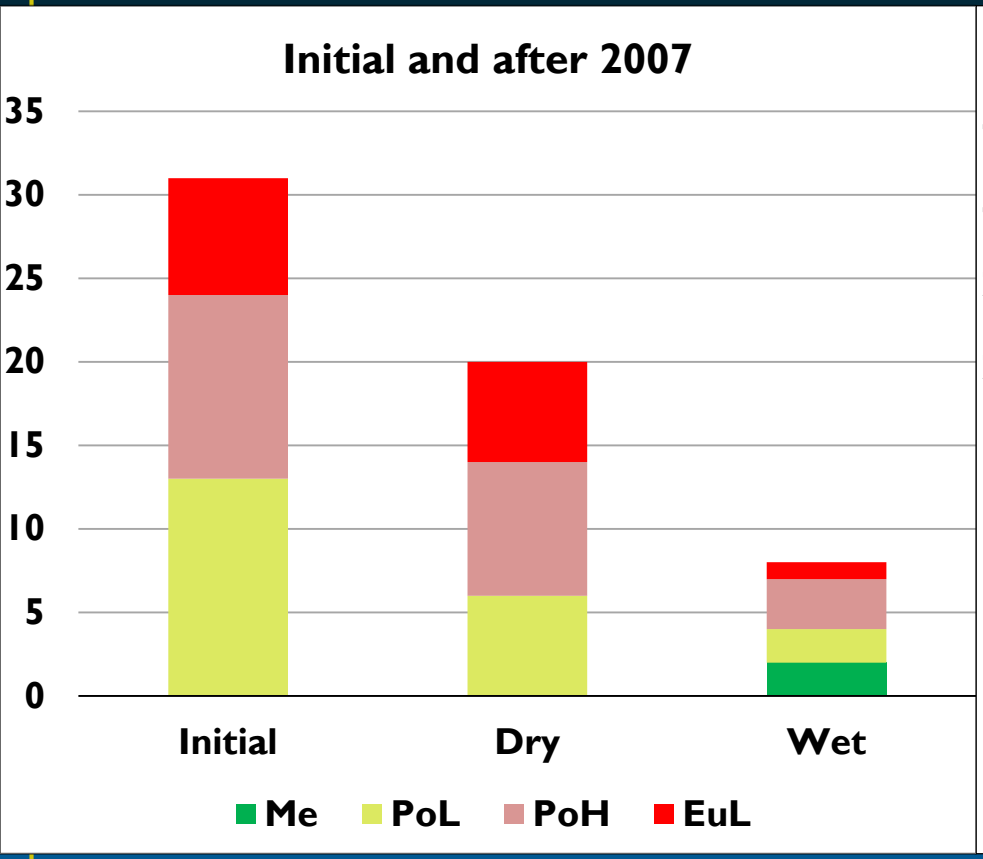
Distribution:
Median
25 and 75 percentiles
5 and 95 percentiles
Outliers

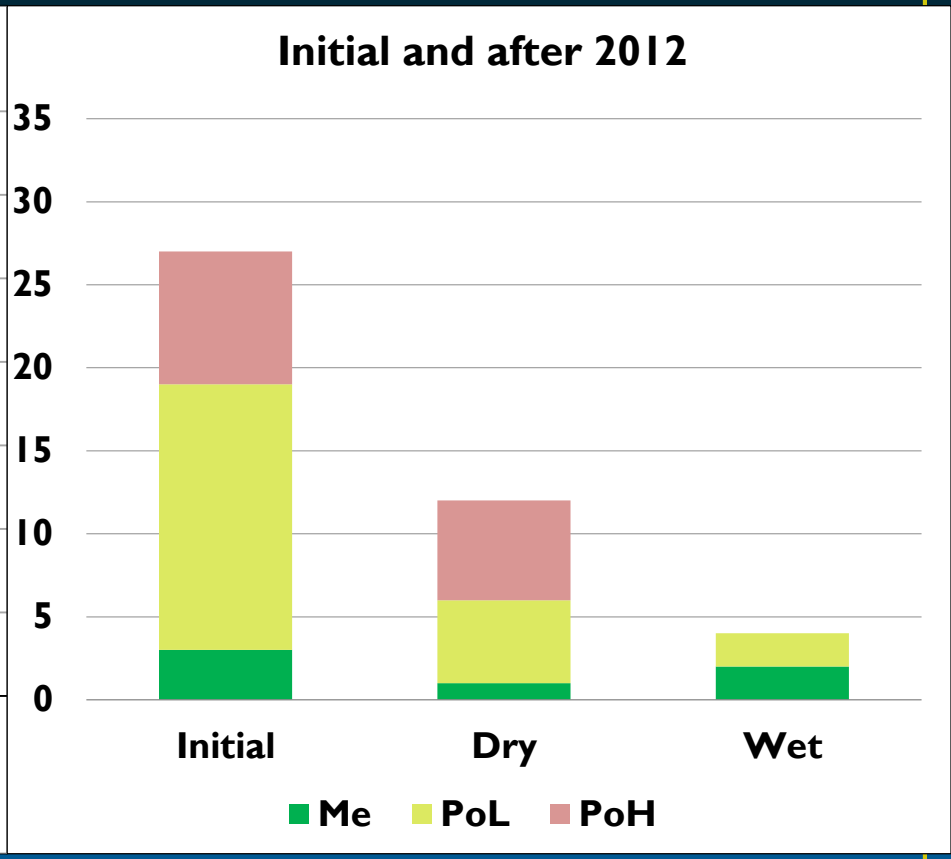
Halohabitats:
Mesohaline 5-18
Polyhaline Low18-24
Polyhaline High 24-30
Euhaline Low 30-35
Euhaline High 35-40
Hyperhaline >40


Cumulative species, by halohabitat, 2007-2011
# of species
65
60
55
50
45
40
35
30
25
20
15
10
5
0
07D
07W
08D
08W
09D
09W
10D
10W
11D
11W
Total
Me
PoL
PoH
EuL

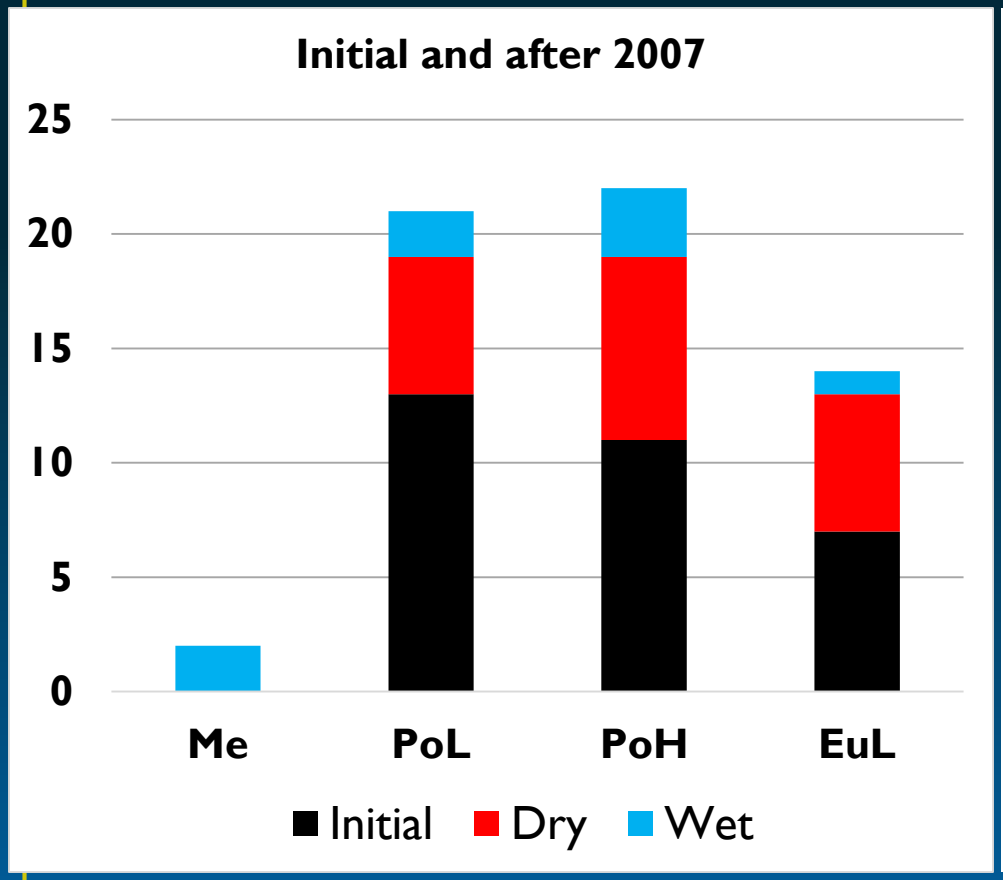

Cumulative species, by halohabitat, 2012-2016
# of species
65
60
55
50
45
40
35
30
25
20
15
10
5
0
12D
12W
13D
13W
14D
14W
15D
15W
16D
16W
Total
Me
PoL
PoH

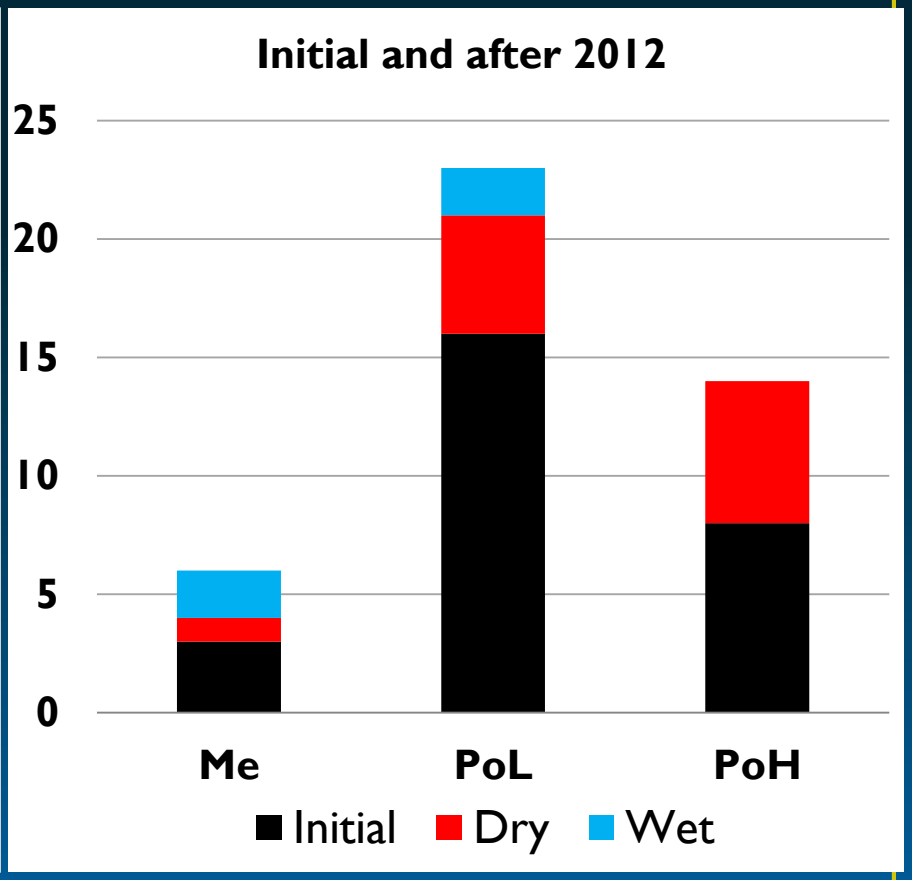
Species added after indicated initial year, by halohabitat type.



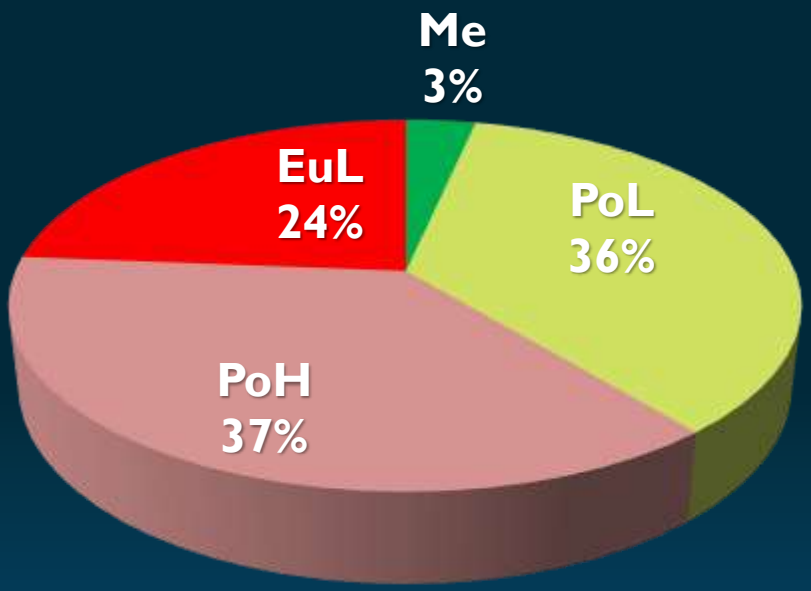


Species added after indicated initial year, by season

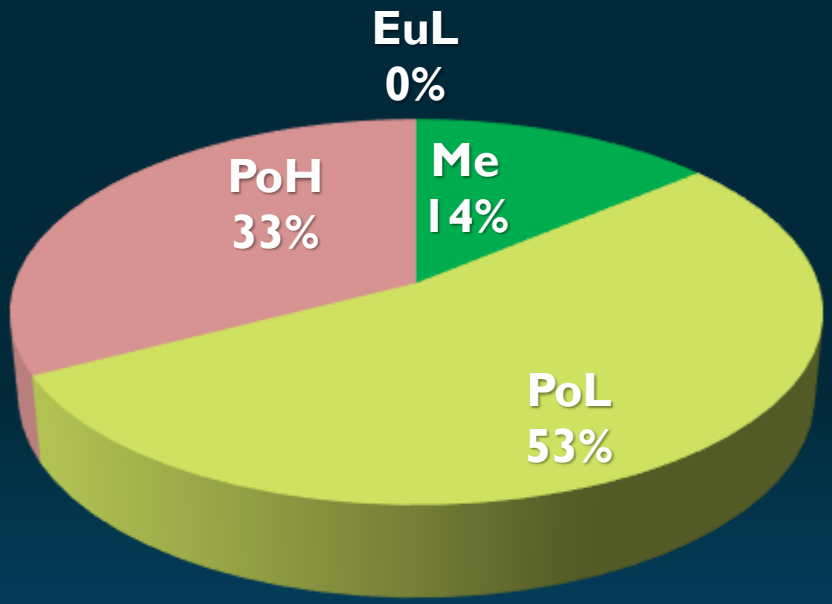




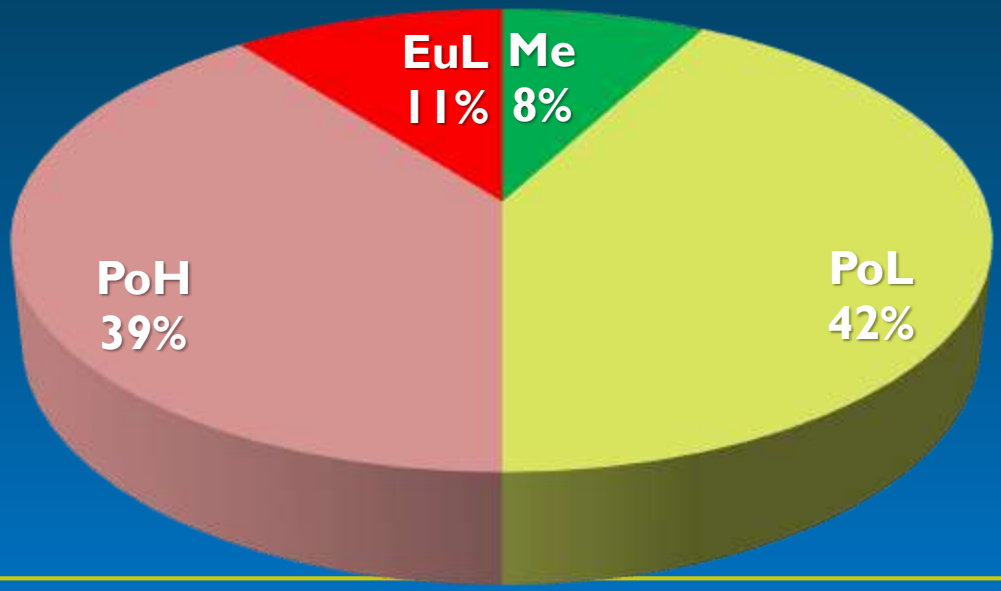
Percentage by halohabitat 2007-2011

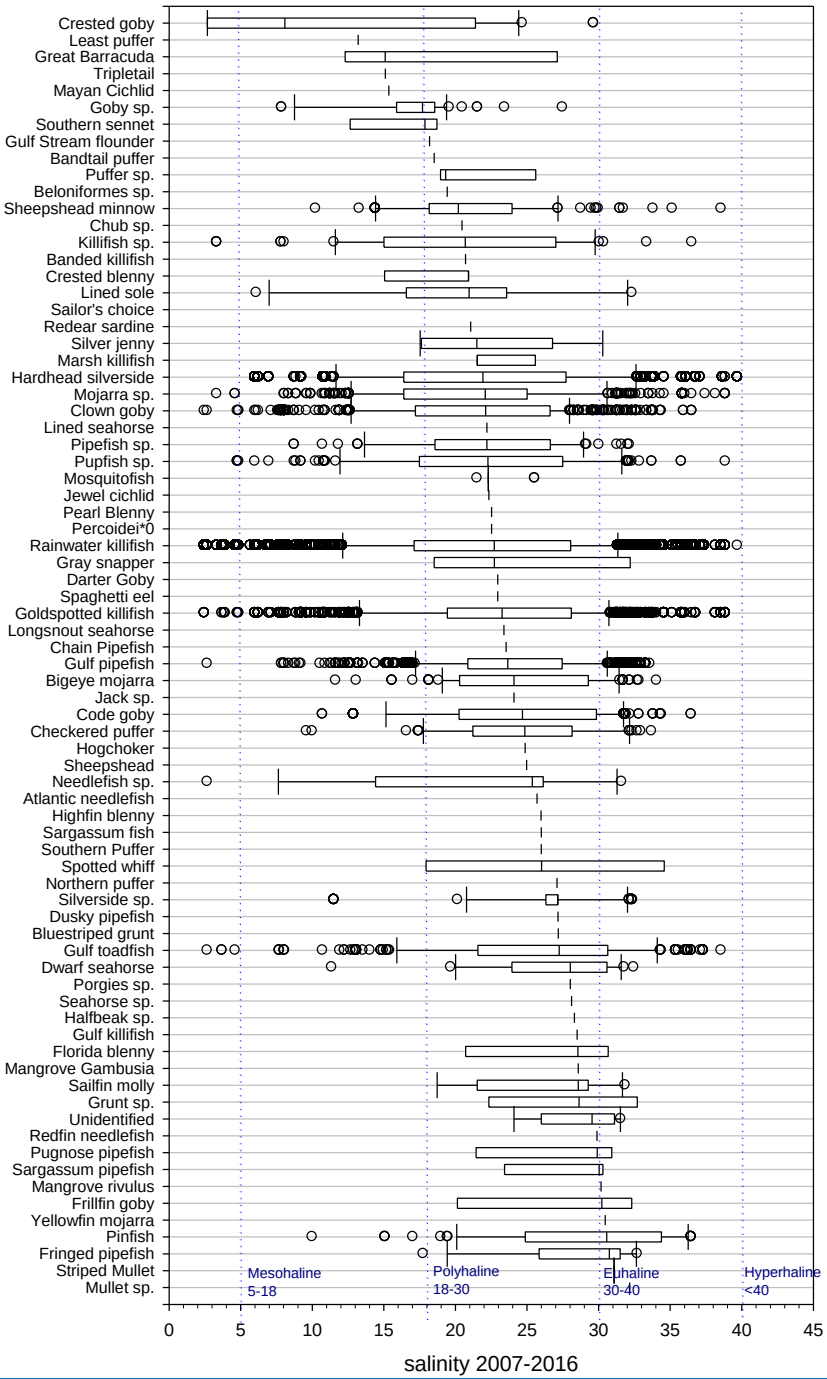


Percentage by halohabitat 2012-2016



Percentage by halohabitat, 2007-2016





Collection 2007-2016

- Median
- 25 and 75 percentiles
- 5 and 95 percentiles
- Outliers

Halohabitats

- Mesohaline 5-18
- Polyhaline Low18-24
- Polyhaline High 24-30
- Euhaline Low 30-35
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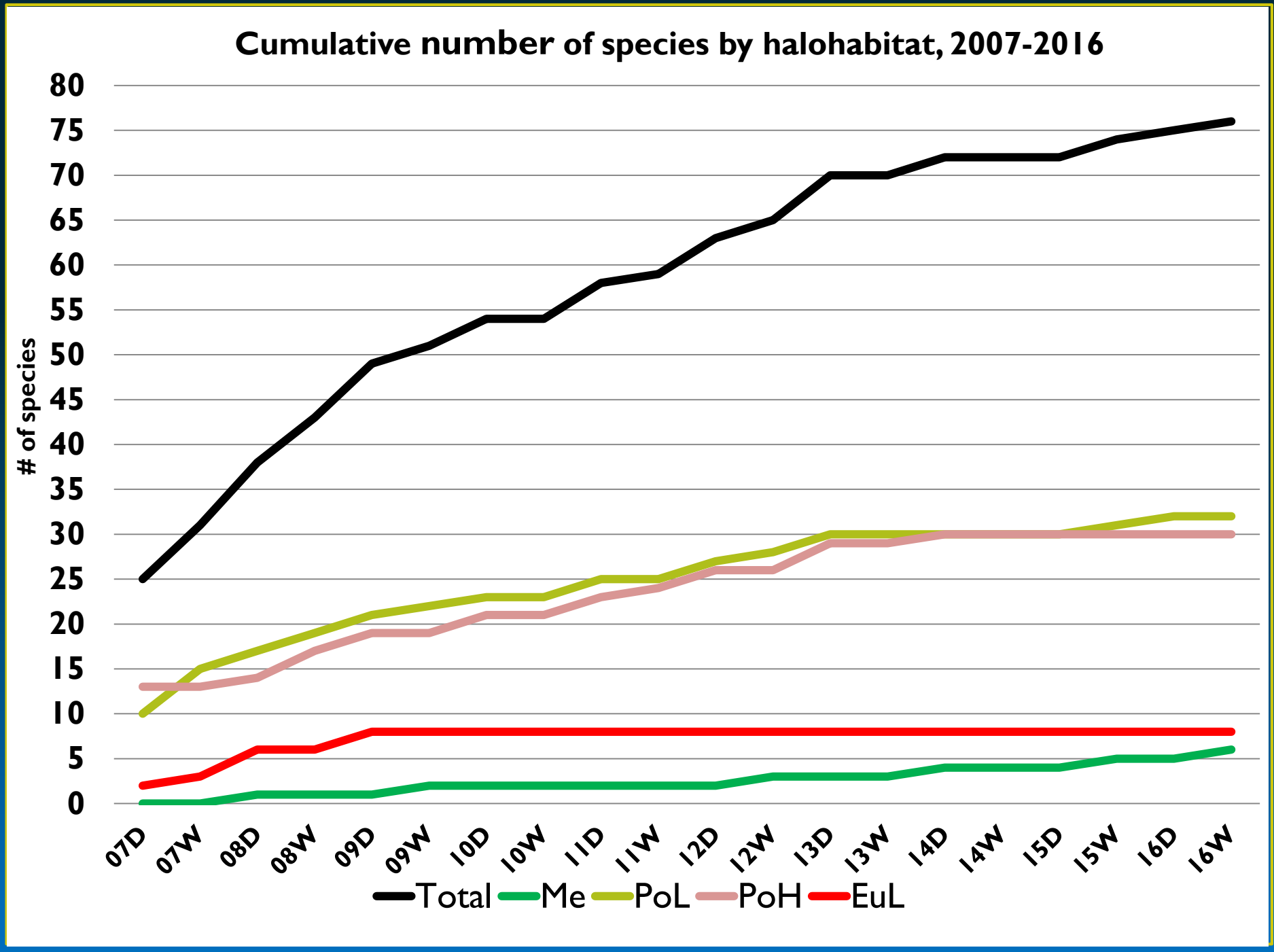
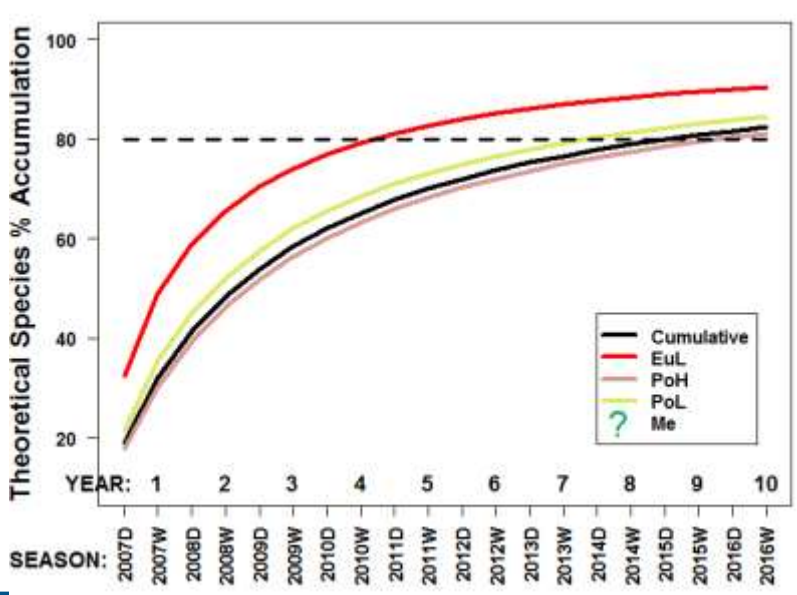

Cumulative number of species by halohabitat, 2007-2016
# of species
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
07D
07W
08D
08W
09D
09W
10D
10W
11D
11W
12D
12W
13D
13W
14D
14W
15D
15W
16D
16W
Total
Me
PoL
PoH
EuL

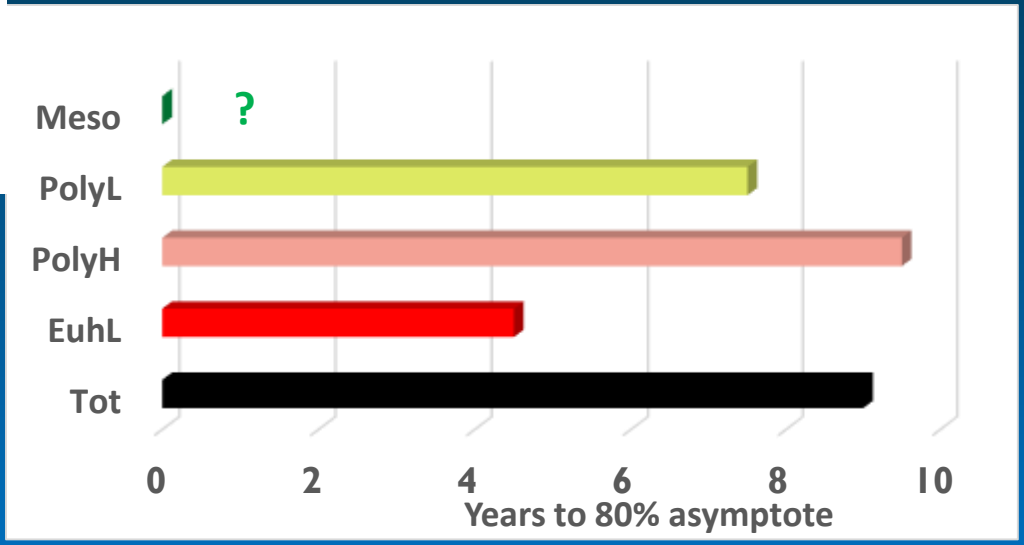
Test of Hypotheses:

Number of years to 80% of asymptote with nonlinear least squares equation for each halohabitat type based on 10 years of cumulative species presence data.



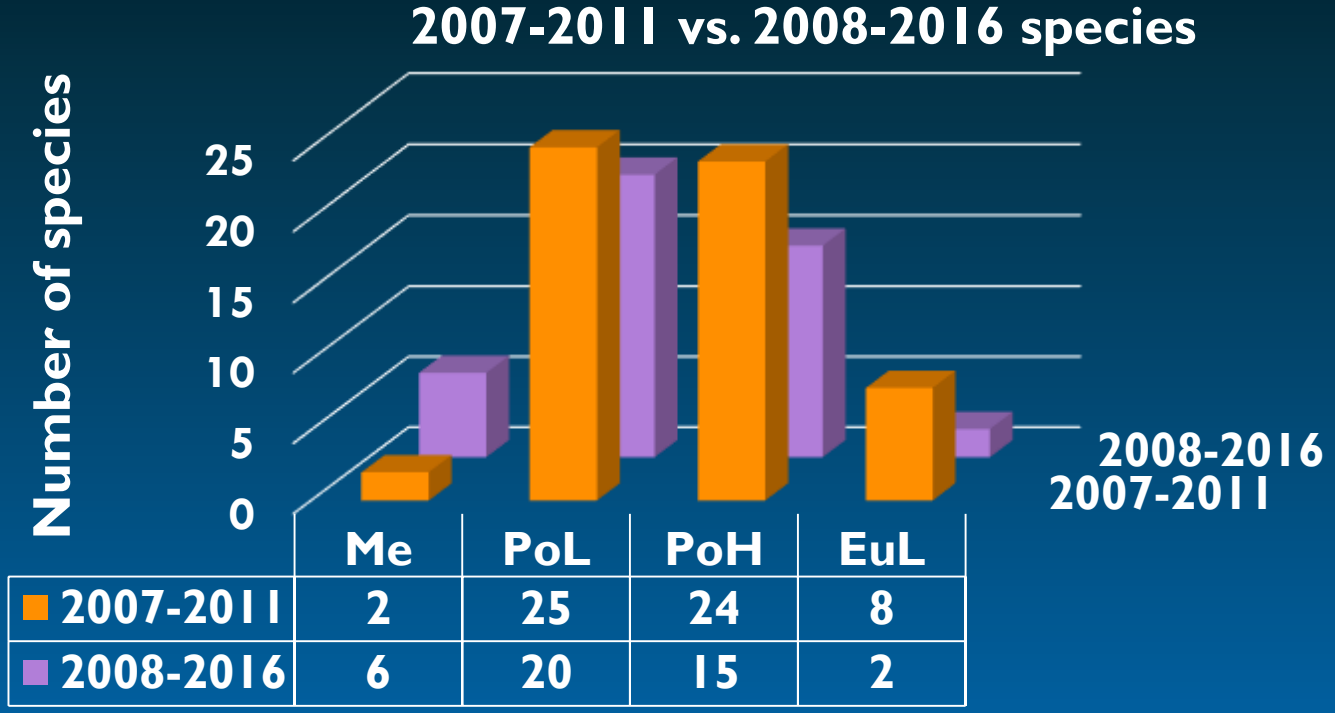
Results: Species richness reaches 80% of asymptote in less than 10 years for all halohabitat types except mesohaline, which may continue to increase beyond 10 years.

Analysis: Curves with asymptotes were fitted to trajectories of cumulative species added by collection (year-season).



Test of Hypotheses:

Result: No significant difference in distribution of species by halohabitat in 2012-2016 period compared to 2007-2015 period.



	Me	PoL	PoH	EuL
2007-2011	2	25	24	8
2008-2016	6	20	15	2

$n = 102; X^2 = 4.703; p > 0.1$

Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

Classification consistent throughout: 7				
Common Name	**Scientific Name**	**2007-2011**	**2007-2016**	**2012-2016**
Clown goby	*Microgobius gulosus*	353	556	203
Goldspotted killifish	*Floridichthys carpio*	1768	3590	1822
Gulf pipefish	*Syngnathus scovelli*	750	1352	602
Hardhead silverside	*Atherinomorus stipes*	1038	6358	5320
Lined sole	*Achirus lineatus*	7	14	7
Pipefish sp.	*Sygnathiidae*	16	71	55
Sheepshead minnow	*Cyprinodon variegatus*	69	133	64

Classification went from lower to higher salinity, contrary to halohabitat change: 2				
Bandtail puffer	*Sphoeroides spengleri*	1	2	1
Checkered puffer	*Sphoeroides testudineus*	49	79	30

Classification went from higher to lower salinity, following halohabitat change: 13				
Code goby	*Gobiosoma robustum*	313	856	543
Crested goby	*Lophogobius cyprinoides*	5	30	25
Dwarf seahorse	*Hippocampus zosterae*	9	23	14
Florida blenny	*Chasmodes saburrae*	1	7	6
Goby sp.	*Gobiidae*	4	62	58
Gray snapper	*Lutjanus griseus*	2	7	5
Killifish sp.	*Cyprinodontiformes*	18	70	52
Mojarra sp.	*Gerridae sp.*	37	595	558
Mosquitofish	*Gambusia affinis*	3	37	34
Rainwater killifish	*Lucania parva*	14949	26188	11239
Seahorse sp.	*Hippocampinae sp.*	1	2	1
Spotted whiff	*Citharichthys macrops*	2	4	2
Unidentified		8	10	2

Classification did not change from 1st 5yr to 10yr: 4				
Code goby	*Gobiosoma robustum*	313	856	543
Fringed pipefish	*Anarchopterus criniger*	10	12	2
Gulf toadfish	*Opsanus beta*	345	433	88
Pinfish	*Lagodon rhomboidalis*	75	84	9

Distribution by halohabitat type of fish species common to both 5-yr periods

n = 26

X^2 = 10.29

p = 0.0119

Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

Species present only in 2007-2011 period: 33

Common Name	Scientific Name	2007-2011	2007-2016	2012-2016
Atlantic needlefish	*Strongylura marina*	1	1	
Banded killifish	*Fundulus diaphanus*	2	2	
Bigeye mojarra	*Eucinostomus havana*	113	113	
Bluestriped grunt	*Haemulon sciurus*	2	2	
Chub sp.	*Cyprinidae*	1	1	
Crested blenny	*Hypleurochilus geminatus*	4	4	
Dusky pipefish	*Syngnathus floridae*	1	1	
Frillfin goby	*Bathygobius soporator*	4	4	
Grunt sp.	*Haemulidae*	8	8	
Gulf killifish	*Fundulus grandis*	1	1	
Gulf Stream flounder	*Citharichthys arctifrons*	1	1	
Highfin blenny	*Lupinoblennius nicholsi*	1	1	
Hogchoker	*Trinectes maculatus*	2	2	
Jack sp.	*Carangidae*	1	1	
Jewel cichlid	*Hemichromis bimaculatus*	1	1	
Lined seahorse	*Hippocampus erectus*	2	2	
Longsnout seahorse	*Hippocampus reidi*	2	2	
Mangrove rivulus	*Rivulus marmoratus*	1	1	
Marsh killifish	*Fundulus confluentus*	5	5	
Mullet sp.	*Mugilidae sp.*	1	1	
Northern puffer	*Sphoeroides maculatus*	2	2	
Porgies sp.	*Sparidae*	1	1	
Puffer sp.	*Tetraodontidae sp.*	4	4	
Pugnose pipefish	*Bryx dunckeri*	3	3	
Redear sardine	*Harengula humeralis*	1	1	
Redfin needlefish	*Strongylura notata*	1	1	
Sargassum fish	*Histrio histrio*	2	2	
Sargassum pipefish	*Syngnathus pelagicus*	4	4	
Silver jenny	*Eucinostomus gula*	9	9	
Southern sennet	*Sphyraena picudilla*	4	4	
Spaghetti eel	*Moringua edwardsi*	1	1	
Striped Mullet	*Mugil cephalus*	15	15	
Yellowfin mojarra	*Gerres cinereus*	2	2	

$n_1 = 33; n_2 = 17$

$X^2 = 8.02$

$p = 0.036$

Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

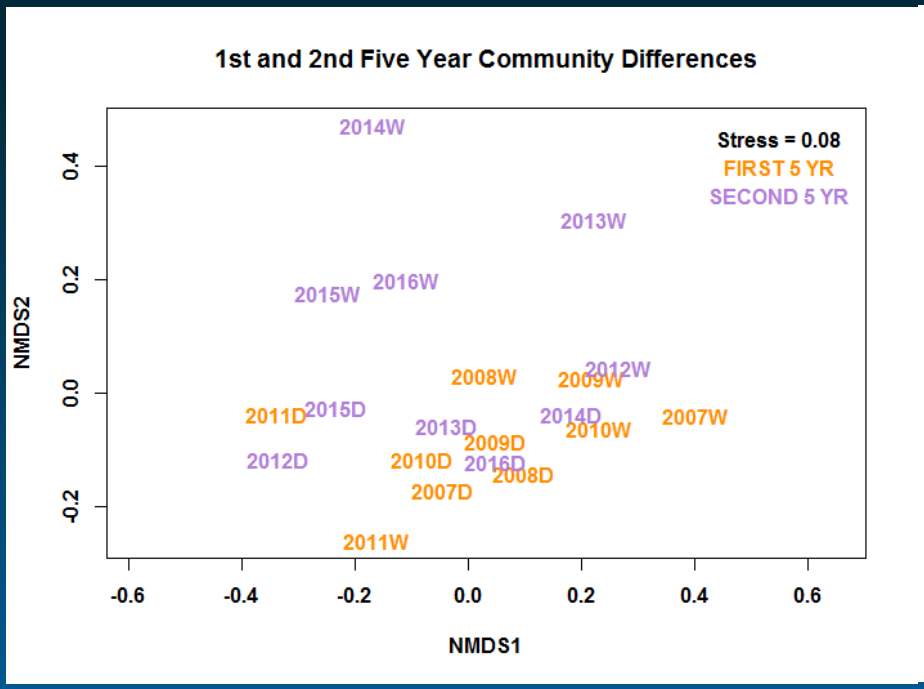
Species present only in 2012-2016 period: 17

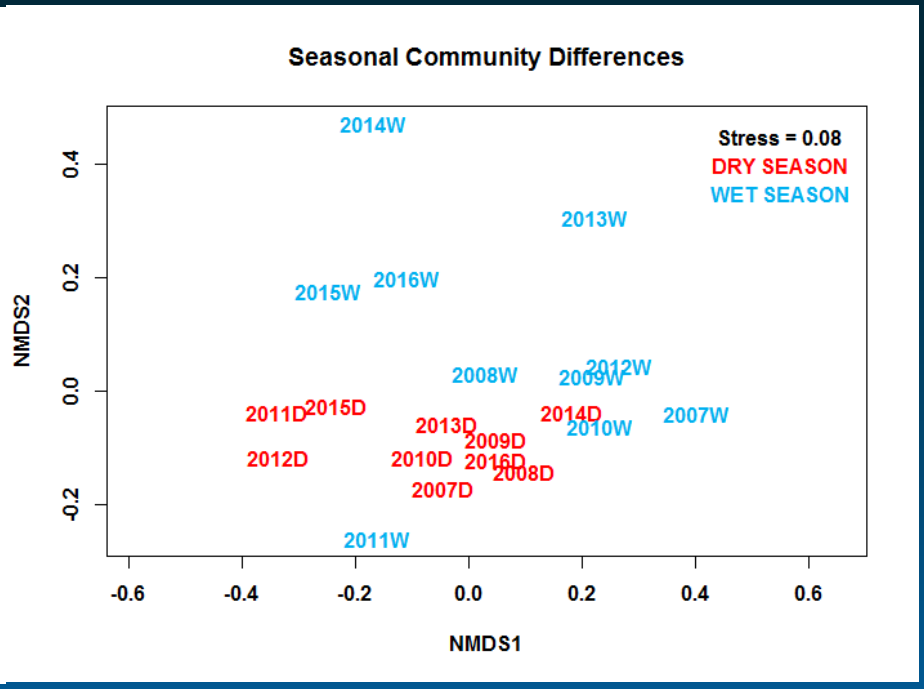
Common Name	Scientific Name	2007-2011	2007-2016	2012-2016
Beloniformes sp.	*Beloniformes sp.*		1	1
Chain Pipefish	*Syngnathus louisianae*		1	1
Darter Goby	*Ctenogobius boleosoma*		1	1
Great Barracuda	*Sphyraena barracuda*		3	3
Halfbeak sp.	*Hemiramphidae*		1	1
Least puffer	*Sphoeroides parvus*		1	1
Mangrove Gambusia	*Gambusia rhizophorae*		4	4
Mayan Cichlid	*Cichlasoma urophthalmus*		1	1
Needlefish sp.	*Needlefish sp.*		17	17
Pearl Blenny	*Entomacrodus nigricans*		1	1
Percoidei	*Percoidei*		1	1
Pupfish sp.	*Cyprinodontidae*		196	196
Sailor's choice	*Haemulon parra*		1	1
Sheepshead	*Archosargus probatocephalus*		2	2
Silverside sp.	*Atherinidae*		120	120
Southern Puffer	*Sphoeroides nephelus*		1	1
Tripletail	*Lobotes surinamensis*		1	1

Distribution by halohabitat type of fish species unique to 1st (left) and 2nd (right) 5-yr periods.

Test of Hypotheses:

NMDS plots and 2-way PERMANOVA results comparing 1) 1st and 2nd 5-yr period and 2) seasonal differences in fish community species abundances



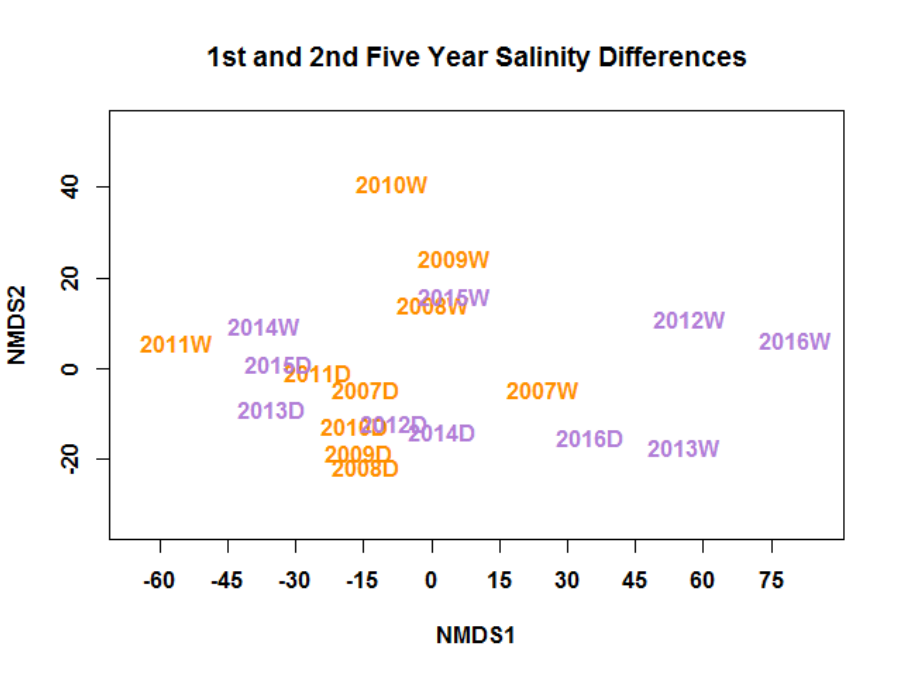


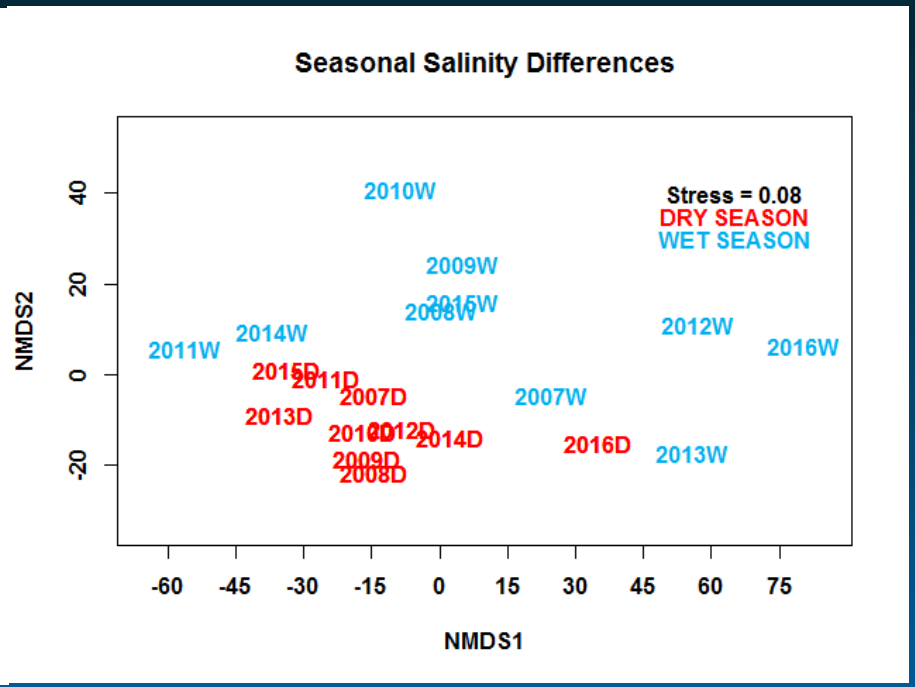
Result: Permanova suggests species abundance differs significantly between between 1st and 2nd 5-yr period and season.

PERMANOVA results: Season F = 4.91, p = 0.004;
5-yr Period F = 2.84, p = 0.045

Perspective:

NMDS plot and 2-way PERMANOVA results comparing salinity at sampling sites by 1) 1st and 2nd 5-yr period and 2) season.





Result: Permanova did not find significant differences in site salinities, separated by season, between 5-yr periods.

PERMANOVA results: Season F = 4.06, p = 0.039;

5-yr Period F = 1.51, p = 0.222

SUMMARY

- More than 5 years of data are required to confidently assign species to halohabitat type based on the species' median salinity; 10 years of data appear more reliable.
- Saturation curves fit to cumulative species curves explained more than 90% of their variance and reached 80% of their asymptote in less than 10 years.
- A contingency table test found no sig. diff. in distribution of species among halohabitat types in 2nd vs. 1st 5-yr periods.
- Halohabitat type distributions differed significantly (↓ salinity) in the 26 spp. common to both 5-yr periods.
- Halohabitat distributions differed between the 1st period unique spp. (n=33) and 2nd period unique spp. (n=17) (↓ salinity).
- A 2-way PERMANOVA test found a significant difference in species abundances between both 5-yr periods and seasons.
- A 2-way PERMANOVA test found a significant difference in site salinities between seasons but not between 5-yr periods.

NEXT STEPS

- Investigate species-specific contributions to community differences between 5-yr periods.
- Further investigate community structure relative to environmental gradients (i.e., expand NMDS analyses).
- Use other sources of information beyond present dataset to develop a comprehensive list of species that could potentially colonize a more consistent nearshore Biscayne Bay estuarine habitat.
- Investigate food web structure of nearshore Biscayne Bay and how this structure is affected by differing halohabitats and associated spp.


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

THANK YOU !

Thanks for your attention.

- The BBEAM Team

Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

Common Name	Scientific Name			2012-2016
Atlantic needlefish	*Strongylura marina*	1	1	
Banded killifish	*Fundulus diaphanus*	2	2	
Bandtail puffer	*Sphoeroides spengleri*	1	2	1
Beloniformes sp.	*Beloniformes sp.*		1	1
Bigeye mojarra	*Eucinostomus havana*	113	113	
Bluestriped grunt	*Haemulon sciurus*	2	2	
Chain Pipefish	*Syngnathus louisianae*		1	1
Checkered puffer	*Sphoeroides testudineus*	49	79	30
Chub sp.	*Cyprinidae*	1	1	
Clown goby	*Microgobius gulosus*	353	556	203
Code goby	*Gobiosoma robustum*	313	856	543
Crested blenny	*Hypleurochilus geminatus*	4	4	
Crested goby	*Lophogobius cyprinoides*	5	30	25
Darter Goby	*Ctenogobius boleosoma*		1	1
Dusky pipefish	*Syngnathus floridae*	1	1	
Dwarf seahorse	*Hippocampus zosterae*	9	23	14
Florida blenny	*Chasmodes saburrae*	1	7	6
Frillfin goby	*Bathygobius soporator*	4	4	
Fringed pipefish	*Anarchopterus criniger*	10	12	2
Goby sp.	*Gobiidae*	4	62	58
Goldspotted killifish	*Floridichthys carpio*	1768	3590	1822
Gray snapper	*Lutjanus griseus*	2	7	5
Great Barracuda	*Sphyraena barracuda*		3	3
Grunt sp.	*Haemulidae*	8	8	
Gulf killifish	*Fundulus grandis*		1	1

Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

Common Name	Scientific Name	2007-2011	2007-2016	2012-2016
Gulf pipefish	*Syngnathus scovelli*	750	1352	602
Gulf Stream flounder	*Citharichthys arctifrons*	1	1	
Gulf toadfish	*Opsanus beta*	345	433	88
Halfbeak sp.	*Hemiramphidae*		1	1
Hardhead silverside	*Atherinomorus stipes*	1038	6358	5320
Highfin blenny	*Lupinoblennius nicholsi*	1	1	
Hogchoker	*Trinectes maculatus*	2	2	
Jack sp.	*Carangidae*	1	1	
Jewel cichlid	*Hemichromis bimaculatus*	1	1	
Killifish sp.	*Cyprinodontiformes*	18	70	52
Least puffer	*Sphoeroides parvus*		1	1
Lined seahorse	*Hippocampus erectus*	2	2	
Lined sole	*Achirus lineatus*	7	14	7
Longsnout seahorse	*Hippocampus reidi*	2	2	
Mangrove Gambusia	*Gambusia rhizophorae*		4	4
Mangrove rivulus	*Rivulus marmoratus*	1	1	
Marsh killifish	*Fundulus confluentus*	5	5	
Mayan Cichlid	*Cichlasoma urophthalmus*		1	1
Mojarra sp.	*Gerridae sp.*	37	595	558
Mosquitofish	*Gambusia affinis*	3	37	34
Mullet sp.	*Mugilidae sp.*	1	1	
Needlefish sp.	*Needlefish sp.*		17	17
Northern puffer	*Sphoeroides maculatus*	2	2	
Pearl Blenny	*Entomacrodus nigricans*		1	1
Percoidei	*Percoidei*		1	1

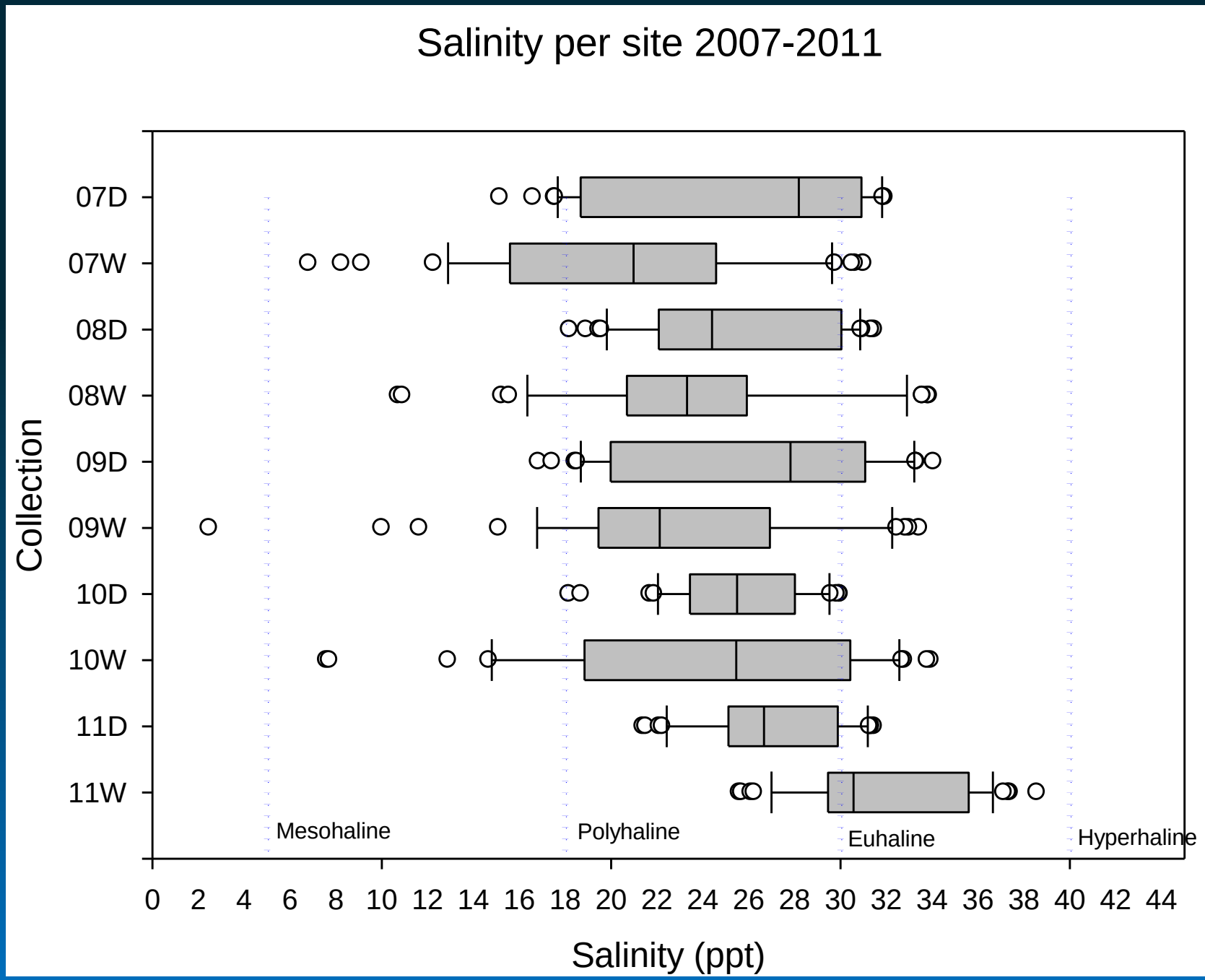
Halohabitat Color Key	Me	PoL	PoH	EuL	No fish

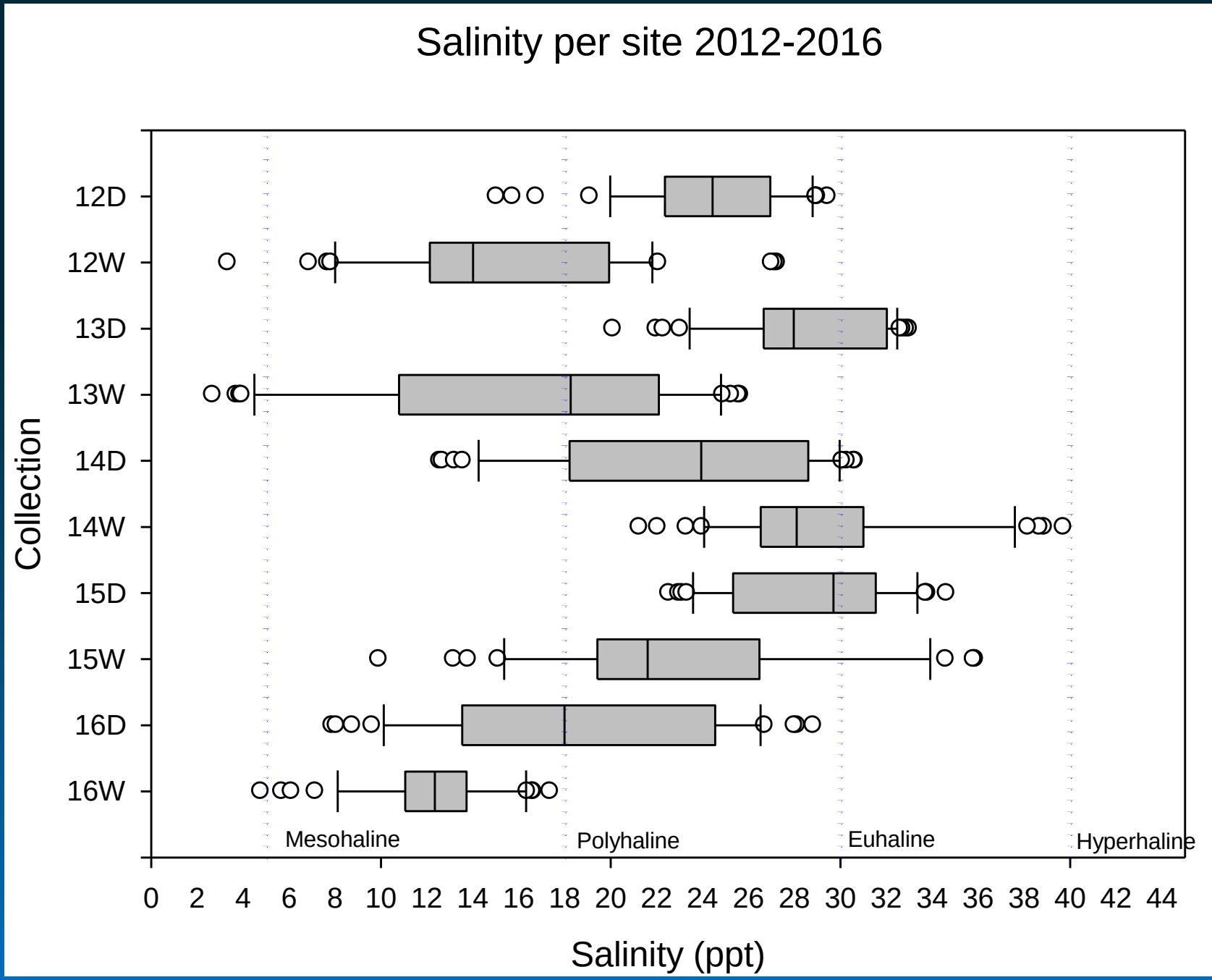
Common Name	Scientific Name	2007-2011	2007-2016	2012-2016
Pinfish	*Lagodon rhomboidalis*	75	84	9
Pipefish sp.	*Sygnathiidae*	16	71	55
Porgies sp.	*Sparidae*	1	1	
Puffer sp.	*Tetraodontidae sp.*	4	4	
Pugnose pipefish	*Bryx dunckeri*	3	3	
Pupfish sp.	*Cyprinodontidae*		196	196
Rainwater killifish	*Lucania parva*	14949	26188	11239
Redear sardine	*Harengula humeralis*	1	1	
Redfin needlefish	*Strongylura notata*	1	1	
Sailfin molly	*Poecilia latipinna*	9	14	5
Sailor's choice	*Haemulon parra*		1	1
Sargassum fish	*Histrio histrio*	2	2	
Sargassum pipefish	*Syngnathus pelagicus*	4	4	
Seahorse sp.	*Hippocampinae sp.*	1	2	1
Sheepshead	*Archosargus probatocephalus*		2	2
Sheepshead minnow	*Cyprinodon variegatus*	69	133	64
Silver jenny	*Eucinostomus gula*	9	9	
Silverside sp.	*Atherinidae*		120	120
Southern Puffer	*Sphoeroides nephelus*		1	1
Southern sennet	*Sphyraena picudilla*	4	4	
Spaghetti eel	*Moringua edwardsi*	1	1	
Spotted whiff	*Citharichthys macrops*	2	4	2
Striped Mullet	*Mugil cephalus*	15	15	
Tripletail	*Lobotes surinamensis*		1	1
Unidentified		8	10	2
Yellowfin mojarra	*Gerres cinereus*	2	2	

SLIDES REMOVED FOLLOW

FIELD PARAMETERS RECORDED

- Site
- Latitude and longitude
- Time
- Date
- Salinity
- Temperature
- Dissolved oxygen (DO)
- Conductivity
- pH
- Water depth
- Sediment depth
- SAV species-specific and community % cover (10-0.25 m^2 quadrats)


Salinity per site 2007-2011
Collection
07D
07W
08D
08W
09D
09W
10D
10W
11D
11W
Mesohaline
Polyhaline
Euhaline
Hyperhaline
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Salinity (ppt)


Salinity per site 2012-2016
Collection
12D
12W
13D
13W
14D
14W
15D
15W
16D
16W
Mesohaline
Polyhaline
Euhaline
Hyperhaline
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Salinity (ppt)

Halohabitat Categories, with upper and lower salinity bounds:

Halohabitat	Lower salinity boundary	Upper salinity boundary
		5.000
Mesohaline	5.001	18.000
Polyhaline Low	18.001	24.000
Polyhaline High	24.001	30.000
Euhaline Low	30.001	35.000
Euhaline High	35.001	40.000
Hyperhaline	40.001+	

Halohabitats

- Oligohaline 0-5
- Mesohaline 5-18
- Polyhaline 18-30
  - Poly Low 18-24
  - Poly High 25-30
- Euhaline 30-40
- Hyperhaline >40

HYPOTHESES

1. **The favorable salinity range for a fish species in a study area is reflected in the distribution of individuals with respect to salinity.**

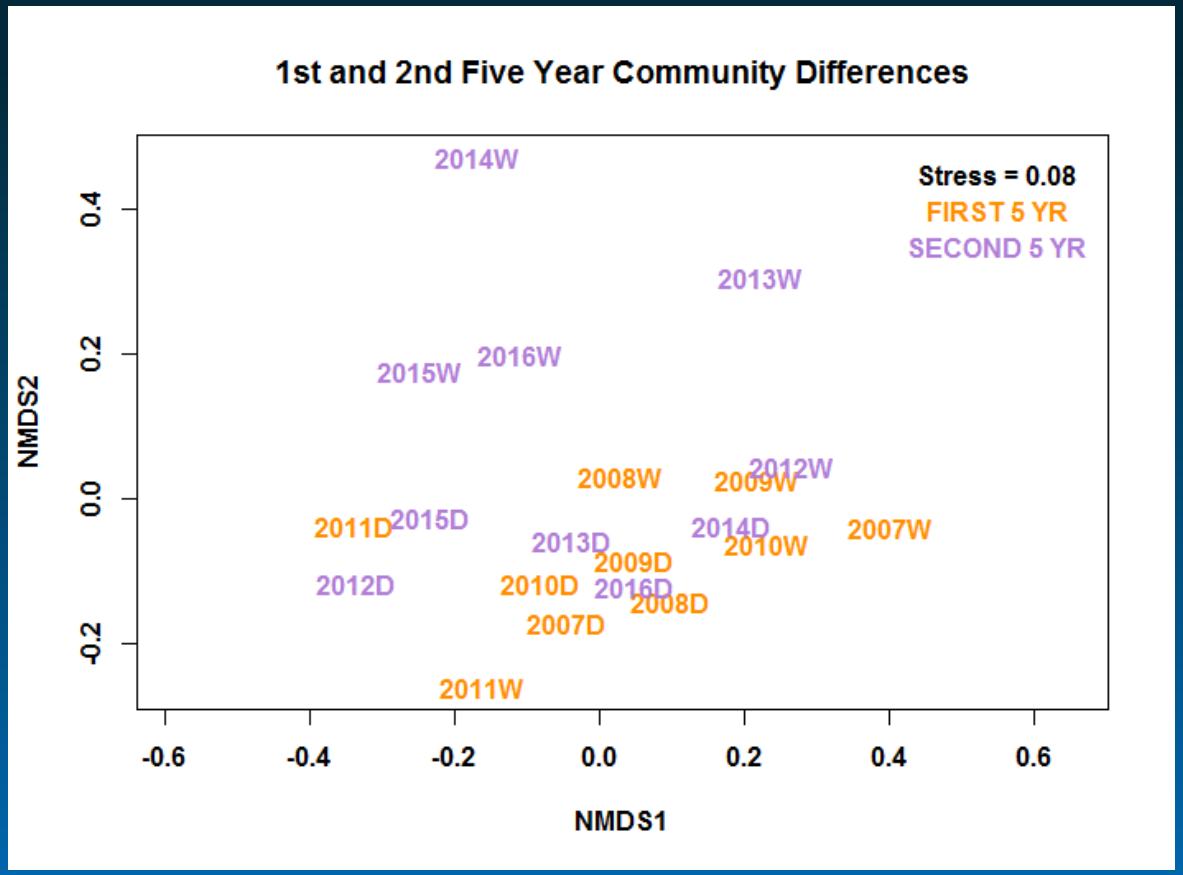
2. **The fish community changes over time in response to change in salinity.**

3. **Change in the fish community can be documented quantitatively in a 5-yr period.**

Hypotheses Tests with
Contingency Tables
Nonlinear least-squares regression

Test of Hypotheses 2 and 3:

NMDS plot and PERMANOVA results comparing first (2007-2011) and second (2012-2016) fish community species abundances

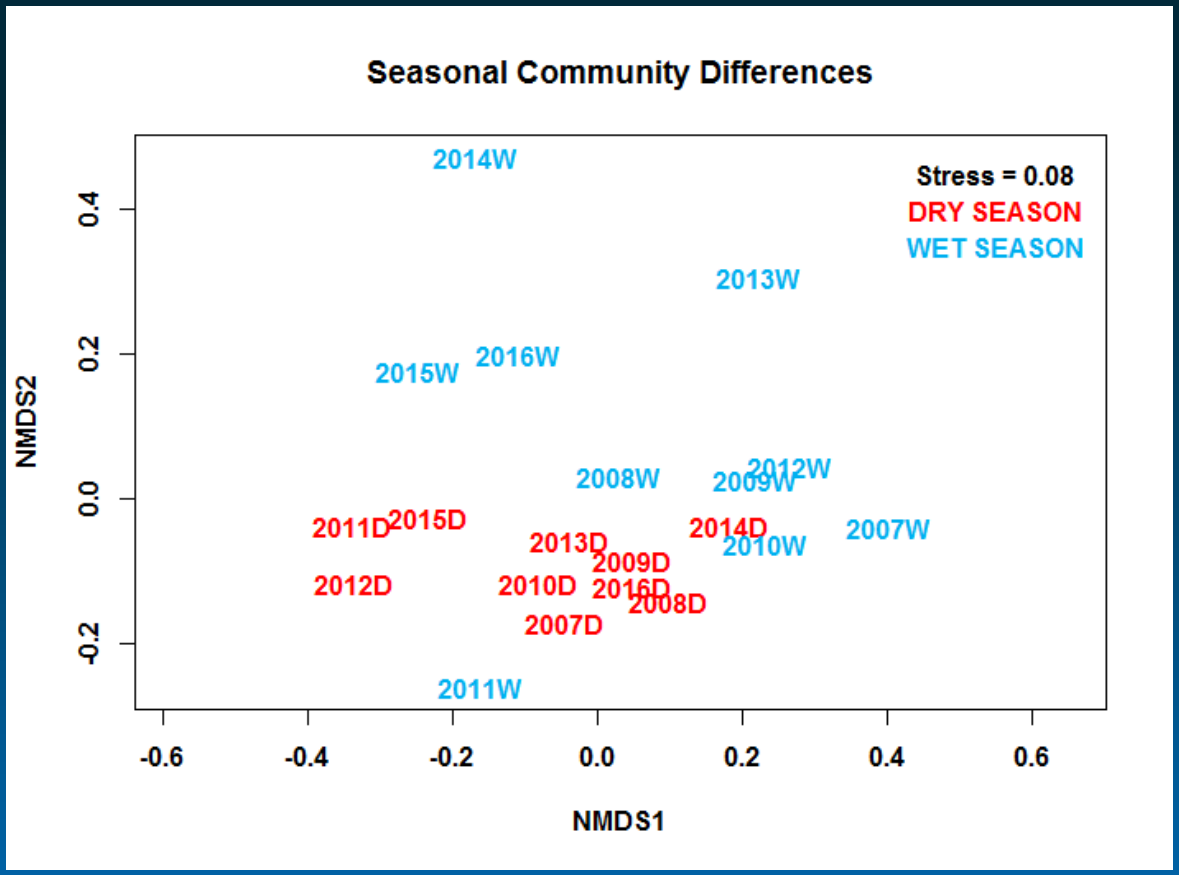


Result: At $p \leq 0.10$, Permanova suggests species abundance difference between the first (2007-2011) and second (2012-2016) 5 years.

PERMANOVA test result: p = 0.062

Perspective:

NMDS plot and PERMANOVA results of comparison of dry and wet season fish species abundances over 10-year period, 2007-2016



Result: Difference between dry season and wet season species abundance distributions are significant at $p \leq 0.05$.

PERMANOVA results: p = 0.004

This overview of fish species in relation to salinity covers the 10-yr period 2007-2016 and two 5-yr periods within it: 2007-2011 and 2012-2016.

Our hypotheses:

1. **The favorable salinity range for a fish species in a study area is reflected in the distribution of individuals with respect to salinity.**

2. **The nearshore fish community can be assigned to four halohabitat types that change differently in response to change in salinity.**

3. **Change in the fish community can be documented quantitatively in a 5-yr period.**