

Metadata from Clucas et al. 2019

All fish in spawning condition: ripe/running, occasionally ripening/ripe/running or spent

11-24 fish per sampling location

2 locations sampled in each of 2 years:

Northeast GB: 2006 & 2007

Stellwagen: 2006 & 2007

Questions about Genome Study

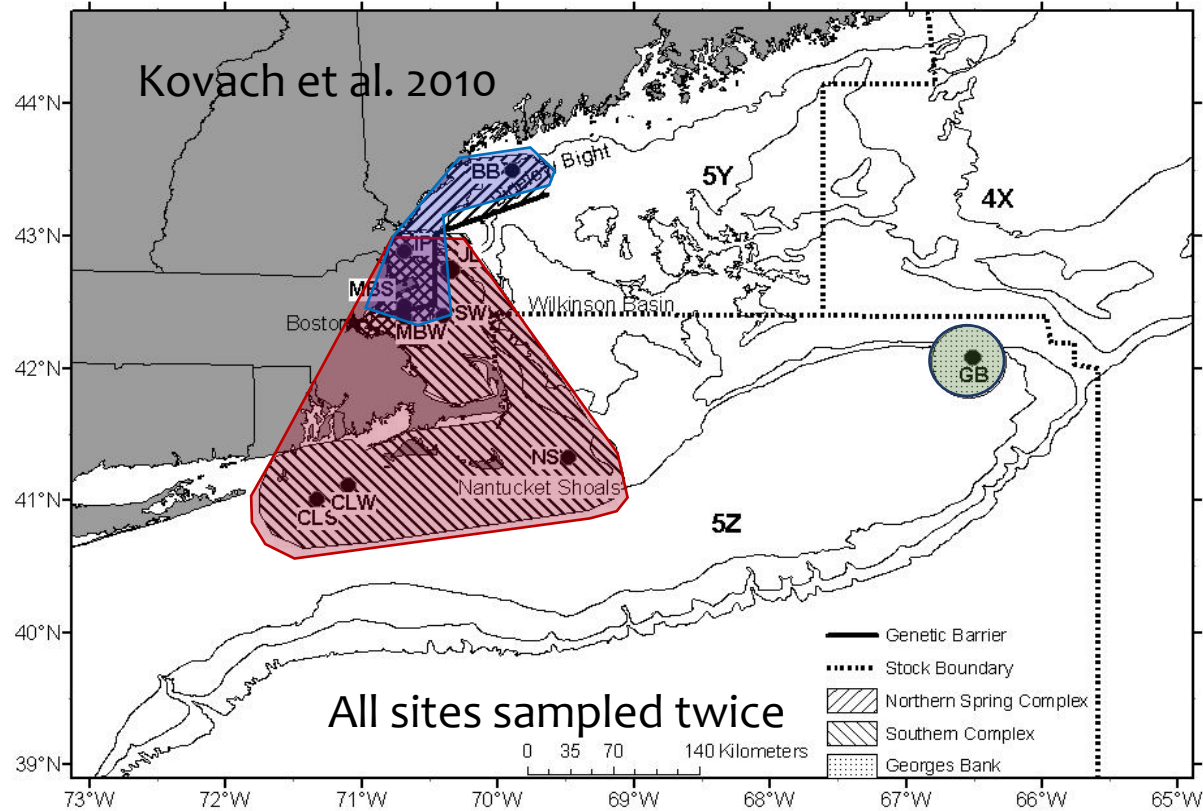
Temporal stability & statistical testing addressed in prior studies (2007-2018)
- assignment testing, p-values, allele frequency differentiation tests

Whole genome study built on this prior work with goals of leveraging whole genome information for new insights:

1. Explore fine scale patterns of structure → southern New England
2. Determine how adaptive variation drives structure → complexity
3. Identify candidate genes that drive structure → environmental gradients, migratory ecotypes, thermal tolerance & reproductive function (timing)

Statistical assignment testing not feasible with whole genome data ...
requires a carefully selected subset of markers → future research priority.

Temporal Stability



Temporal Stability over 5 years (2003 – 2008)

wGoM spring IP/MB (2003, 2006, 2008)

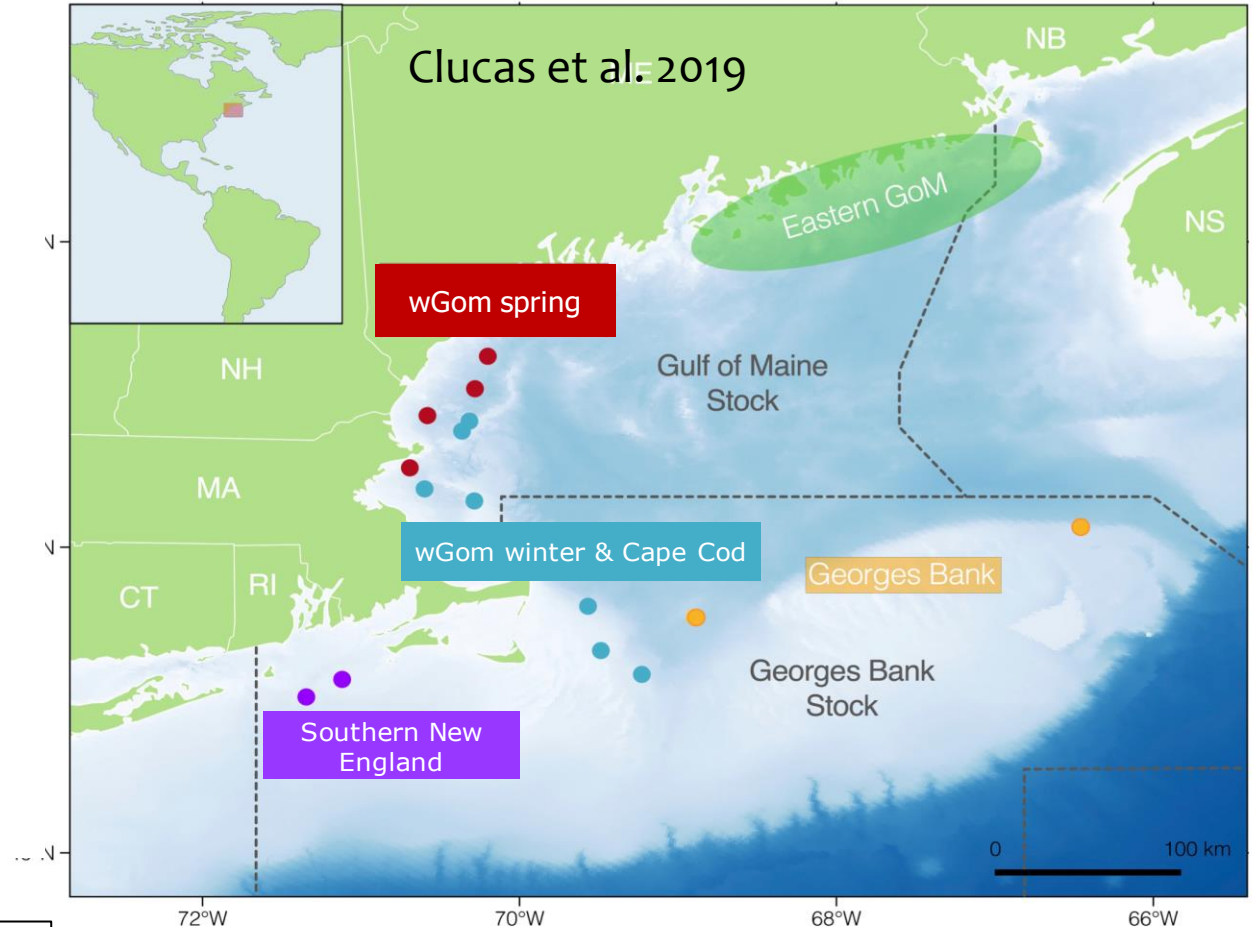
wGoM winter IP/MB (2003, 2006, 2007)

Stellwagen (2005, 2006, 2007)

Cape Cod (2003, 2006)

Georges Bank (2005, 2006, 2007)

3 groups –
statistically
significant p-
values for FST



Temporal stability not yet shown for SNE & wGB

Temporal Stability

Corroborated by same conclusions about population structure of winter spawning wGom, spring spawning wGoM & Georges Bank in multiple studies with different years sampled.

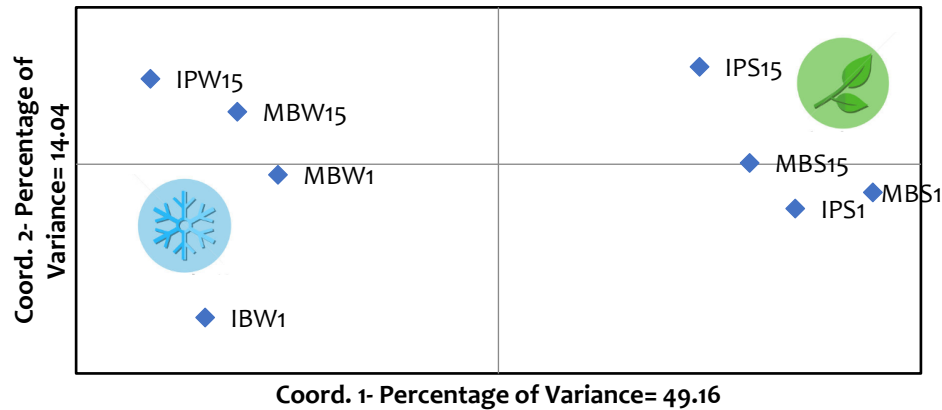
- Wirgin et al. 2007 - 2003
- Kovach et al. 2010 - 2006-2008
- Barney et al. 2017 - 2013-2014
- Clucas et al. 2019a (PLoS One) – same 2006/2007 GB + 2015 MB/IP bays
- Canadian Consortium (Puncher et al. in review) ~ 2017-2019, including Cape Cod area

Statistical Significance of Structure

Spring vs. Winter wGoM

Winter vs. spring $F_{ST} = 0.0185$
(CI: 0.0142–0.0233)

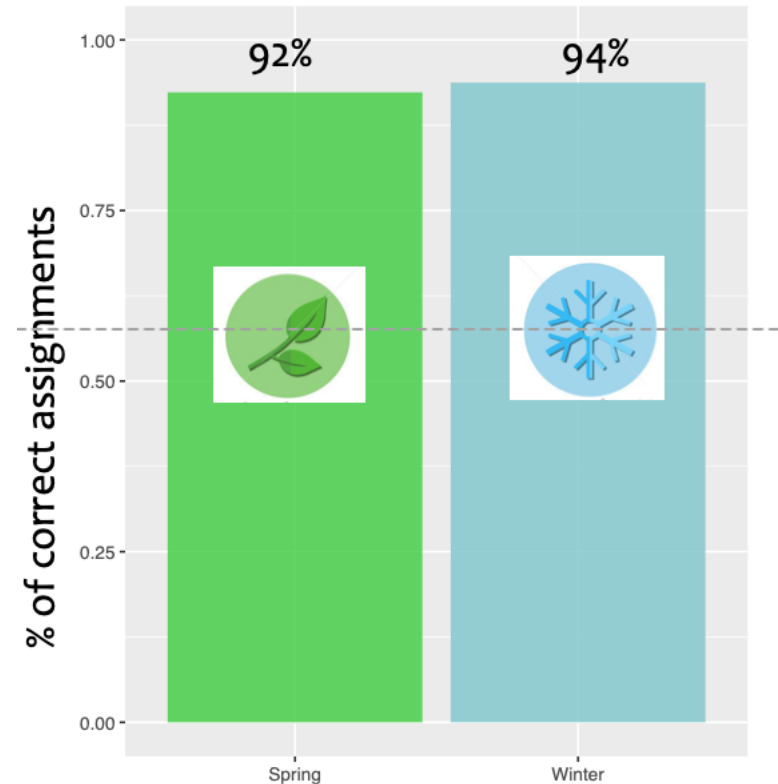
Temporal Stability of 2015 with 2003-2008



Microsatellites

3128 genome-wide SNPs

Assignment accuracy



75 -88% accuracy to each Bay

Kerr et al. 2018 – unpublished report to NOAA

Spring & Winter wGoM, Georges Bank, eGoM

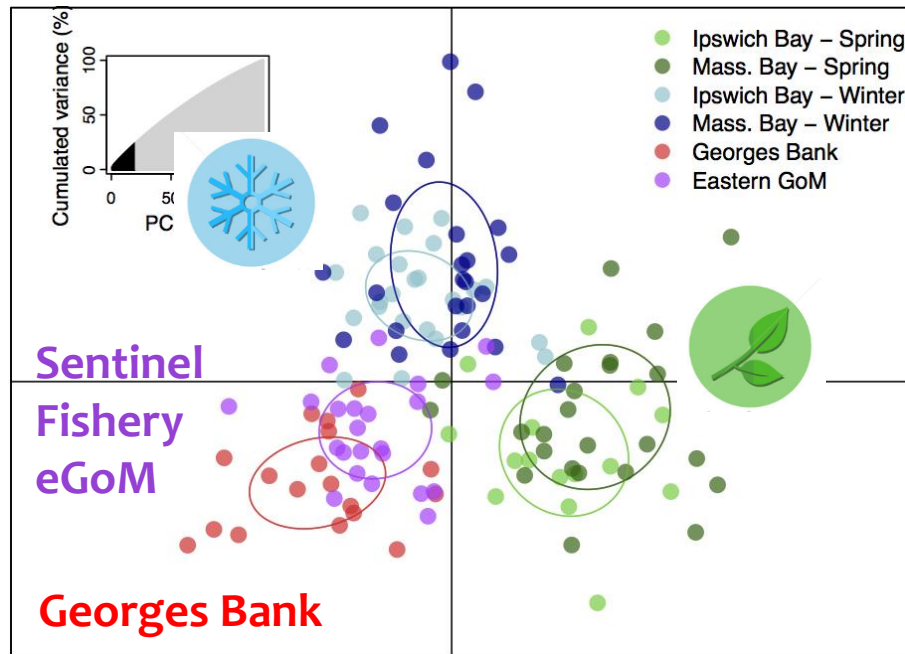
FST values – statistically significant

IP spring vs. IP winter: 0.0185 (0.0142- 0.0233)

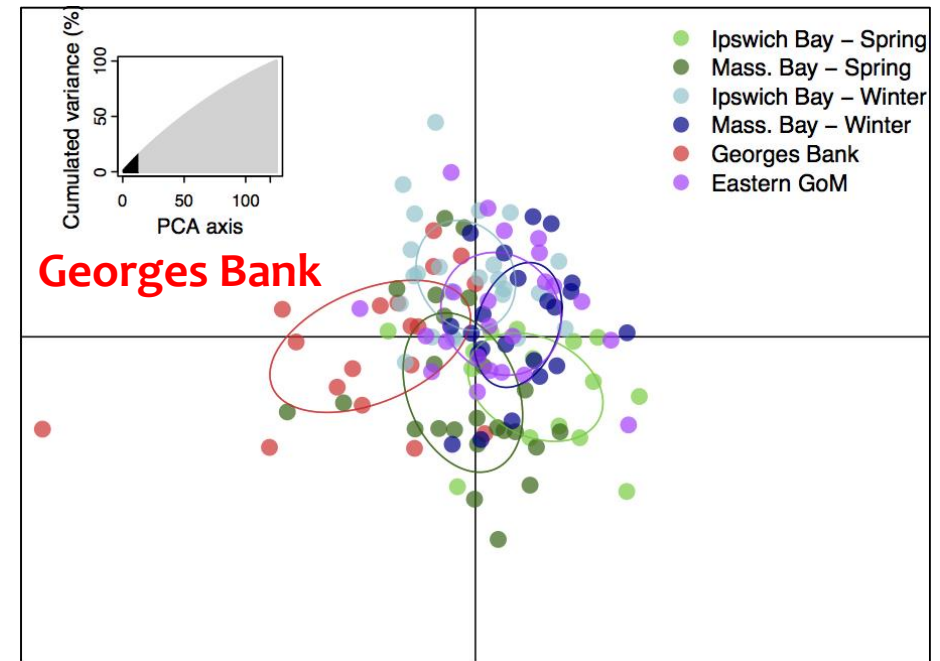
IP spring vs. MB spring: 0.0073 (0.0045-0.0108)

IP spring vs. GB: 0.0202 (0.0154 – 0.0255)

IP winter vs. GB: 0.0148 (0.0116-0.0119)



All 3128 SNP markers



2689 neutral SNP markers
(adaptive markers removed)

FST from whole genome data in Clucas et al. 2019

	St. Pierre Bank	Eastern Scotian Shelf	Bigelow Bight north	Cape Cod offshore	Cox Ledge (Apr)	Cox Ledge (Dec)	Georges Bank northeast peak	Georges Bank west	Great South Channel	Ipswich Bay spring	Ipswich Bay winter	Jeffrey's Ledge	Massachusetts Bay spring	Massachusetts Bay winter	Nantucket Shoals	eGoM inshore	eGoM offshore	Penobscot Bay	Stellwagen Bank	Bigelow Bight south
St. Pierre Bank	***	0.016	0.031	0.05	0.062	0.059	0.034	0.036	0.049	0.033	0.053	0.045	0.030	0.049	0.051	0.055	0.045	0.051	0.042	0.026
Eastern Scotian Shelf	0.016	***	0.018	0.032	0.039	0.038	0.019	0.02	0.031	0.021	0.035	0.027	0.019	0.031	0.031	0.032	0.027	0.031	0.026	0.018
Bigelow Bight north	0.031	0.018	***	0.018	0.022	0.02	0.011	0.013	0.016	0.013	0.019	0.016	0.014	0.019	0.016	0.019	0.015	0.017	0.013	0.014
Cape Cod offshore	0.05	0.032	0.018	***	0.013	0.014	0.013	0.016	0.013	0.018	0.015	0.014	0.023	0.015	0.012	0.014	0.014	0.013	0.012	0.022
Cox Ledge (Apr)	0.062	0.039	0.022	0.013	***	0.013	0.017	0.019	0.014	0.023	0.016	0.015	0.029	0.018	0.013	0.014	0.016	0.014	0.015	0.03
Cox Ledge (Dec)	0.059	0.038	0.02	0.014	0.013	***	0.016	0.018	0.015	0.022	0.015	0.015	0.027	0.017	0.014	0.014	0.015	0.014	0.014	0.028
Georges Bank northeast peak	0.034	0.019	0.011	0.013	0.017	0.016	***	0.009	0.013	0.013	0.017	0.013	0.014	0.015	0.013	0.013	0.011	0.013	0.01	0.015
Georges Bank west	0.036	0.02	0.013	0.016	0.019	0.018	0.009	***	0.015	0.017	0.019	0.014	0.017	0.017	0.015	0.014	0.013	0.015	0.012	0.019
Great South Channel	0.049	0.031	0.016	0.013	0.014	0.015	0.013	0.015	***	0.018	0.015	0.014	0.021	0.015	0.012	0.014	0.014	0.014	0.012	0.022
Ipswich Bay spring	0.033	0.021	0.013	0.018	0.023	0.022	0.013	0.017	0.018	***	0.02	0.018	0.013	0.018	0.019	0.021	0.017	0.018	0.014	0.013
Ipswich Bay winter	0.053	0.035	0.019	0.015	0.016	0.015	0.017	0.019	0.015	0.02	***	0.016	0.023	0.017	0.014	0.016	0.017	0.015	0.014	0.026
Jeffrey's Ledge	0.045	0.027	0.016	0.014	0.015	0.015	0.013	0.014	0.014	0.018	0.016	***	0.021	0.016	0.013	0.014	0.014	0.014	0.013	0.021
Massachusetts Bay spring	0.03	0.019	0.014	0.023	0.029	0.027	0.014	0.017	0.021	0.013	0.023	0.021	***	0.023	0.023	0.024	0.02	0.021	0.017	0.015
Massachusetts Bay winter	0.049	0.031	0.019	0.015	0.018	0.017	0.015	0.017	0.015	0.018	0.017	0.016	0.023	***	0.015	0.017	0.017	0.016	0.014	0.024
Nantucket Shoals	0.051	0.031	0.016	0.012	0.013	0.014	0.013	0.015	0.012	0.019	0.014	0.013	0.023	0.015	***	0.013	0.013	0.013	0.012	0.024

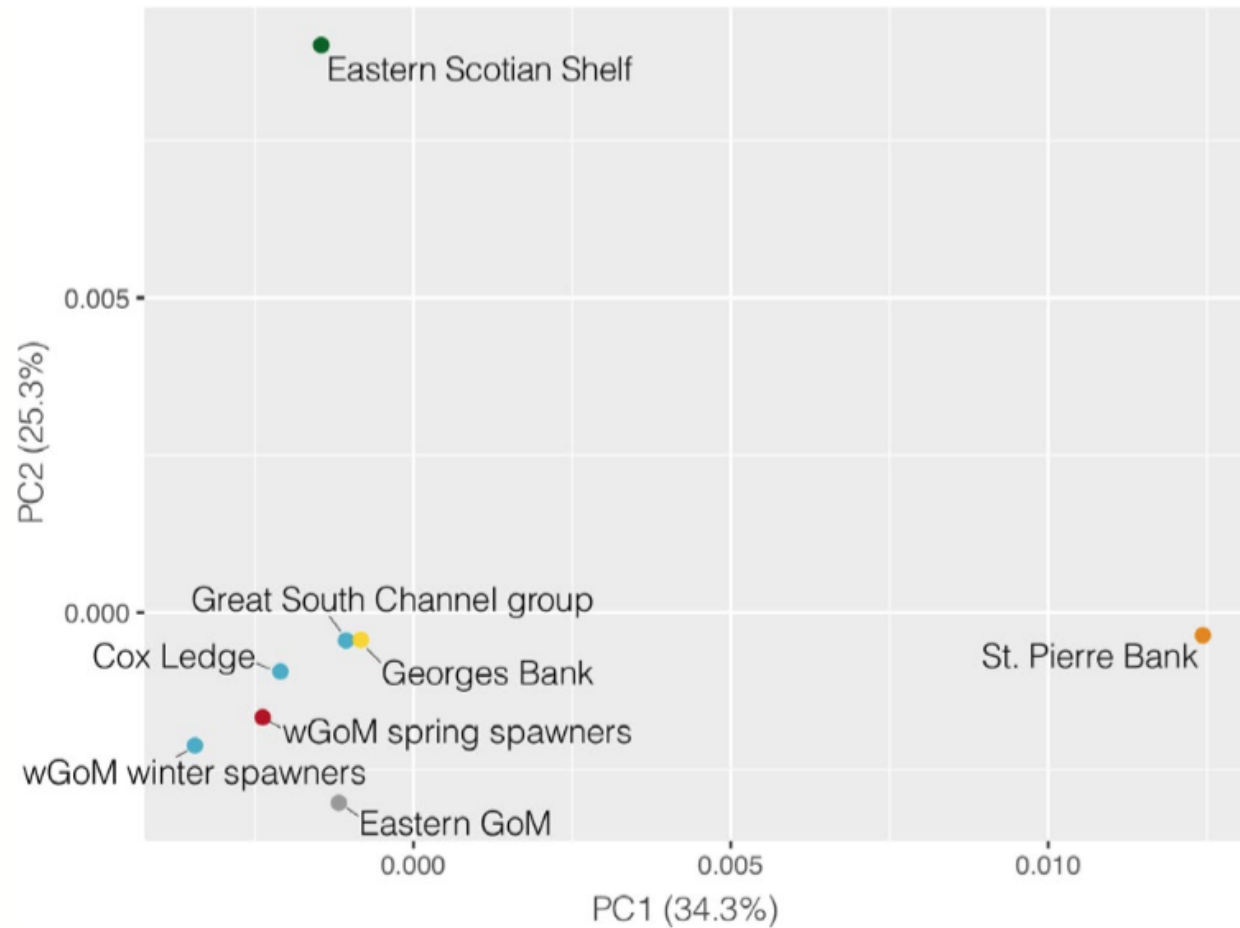
FST across groups from Clucas et al. 2019 dataset

	St. Pierre Bank (3PS)	Eastern Scotian Shelf (4vsW)	wGoM Spring	wGoM Winter	Great South Channel	Cox Ledge	Georges Bank	Eastern GoM
St. Pierre Bank (3PS)	***							
Eastern Scotian Shelf (4vsW)	0.0230	***						
wGoM Spring	0.0358	0.0221	***					
wGoM Winter	0.0547	0.0333	0.0159	***				
Great South Channel	0.054e	0.0323	0.0158	0.0084	***			
Cox Ledge	0.0674	0.0424	0.0223	0.0111	0.0078	***		
Georges Bank	0.0417	0.0215	0.0139	0.0131	0.0089	0.0141	***	
Eastern GoM	0.0553	0.0323	0.0161	0.0110	0.0071	0.0095	0.0082	***

FST from neutral data in Clucas et al. 2019

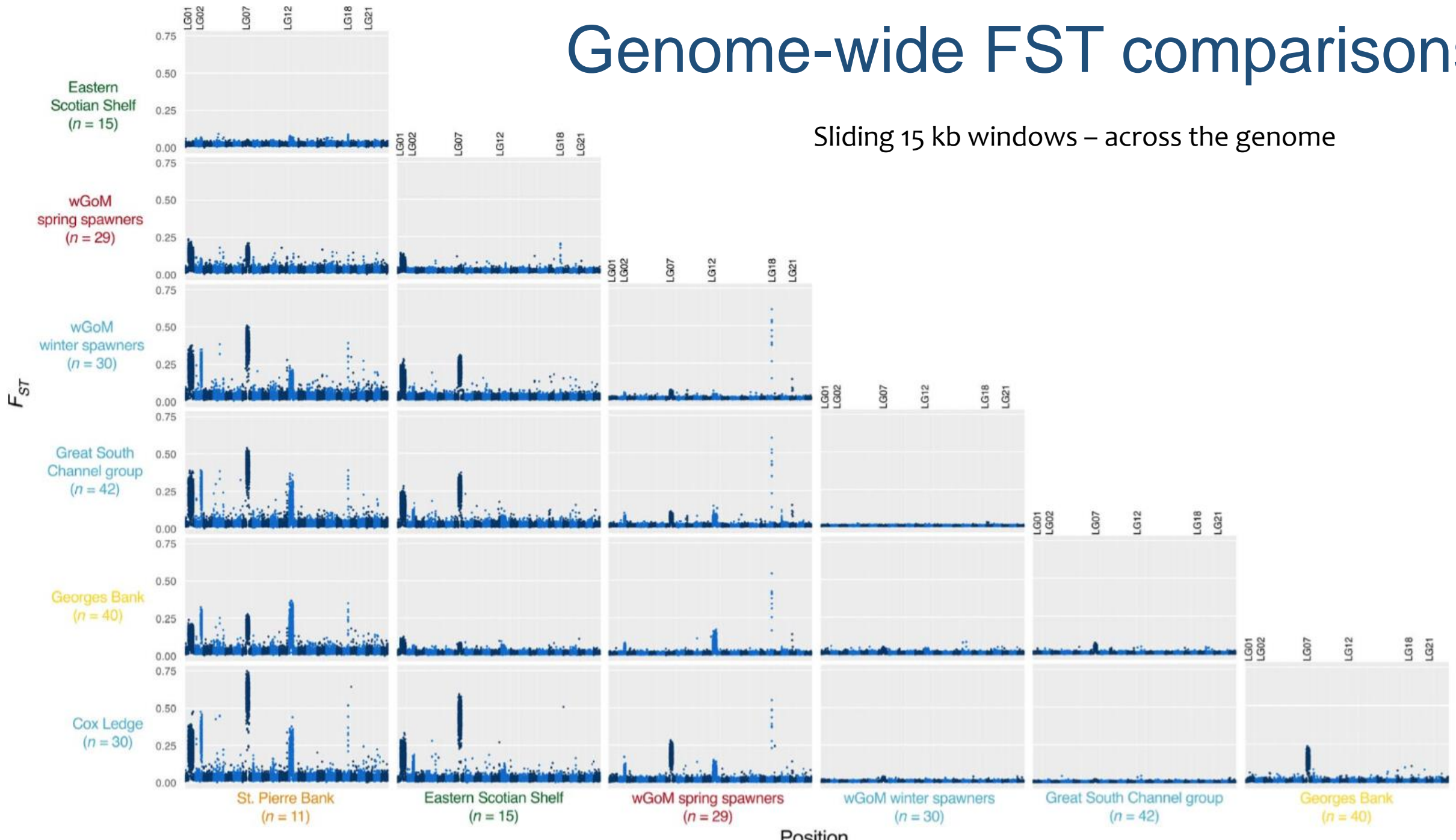
	St. Pierre Bank	Eastern Scotian Shelf	wGoM spring spawners	wGoM winter spawners	Great South Channel group	Cox Ledge	Georges Bank	Eastern GoM
St. Pierre Bank	***	0.0168	0.0158	0.0166	0.0140	0.0153	0.0138	0.0145
Eastern Scotian Shelf	0.0168	***	0.0119	0.0124	0.0102	0.0111	0.0101	0.0125
wGoM spring spawners	0.0158	0.0119	***	0.0089	0.0070	0.0080	0.0067	0.0071
wGoM winter spawners	0.0166	0.0124	0.0089	***	0.0070	0.0079	0.0075	0.0079
Great South Channel group	0.0140	0.0102	0.0070	0.0070	***	0.0059	0.0054	0.0056
Cox Ledge	0.0153	0.0111	0.0080	0.0079	0.0059	***	0.0061	0.0066
Georges Bank	0.0138	0.0101	0.0067	0.0075	0.0054	0.0061	***	0.0054
Eastern GoM	0.0145	0.0125	0.0071	0.0079	0.0056	0.0066	0.0054	***

Neutral differentiation is weak

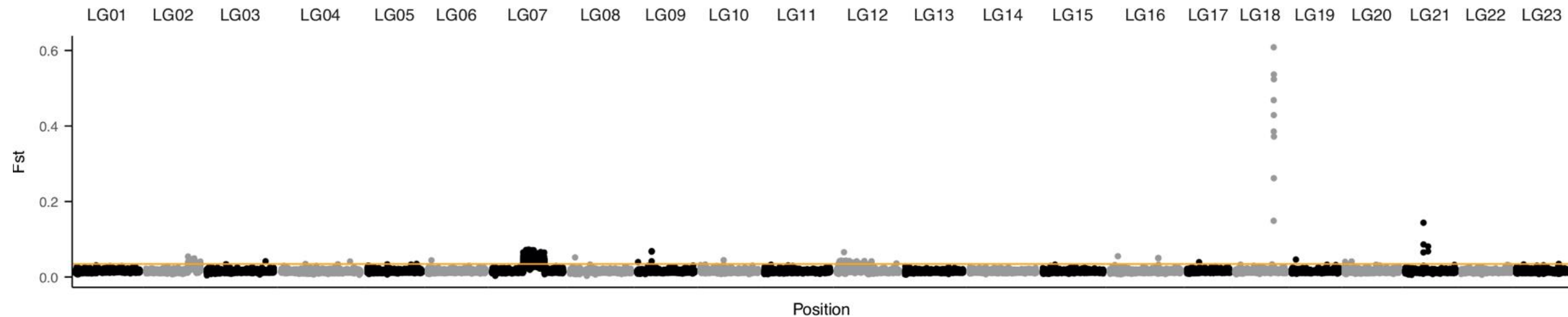


Genome-wide FST comparisons

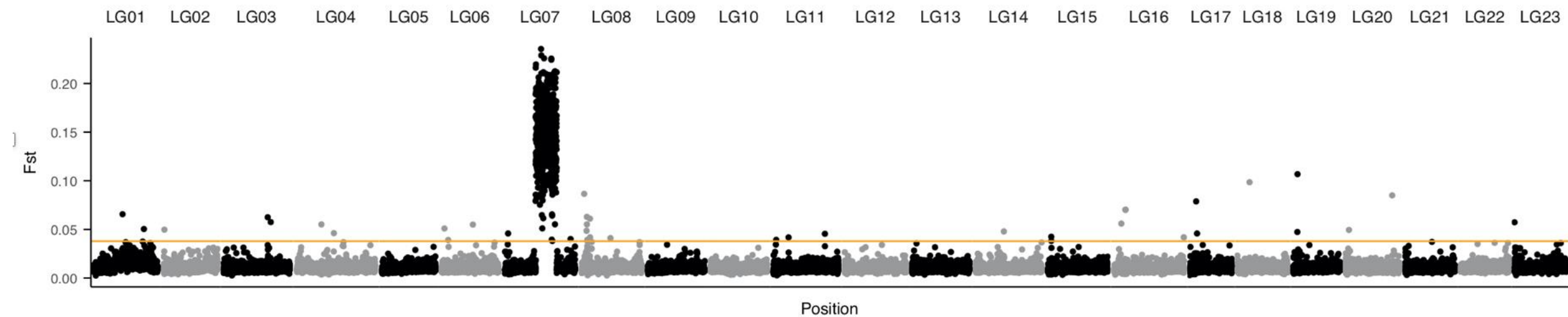
Sliding 15 kb windows – across the genome



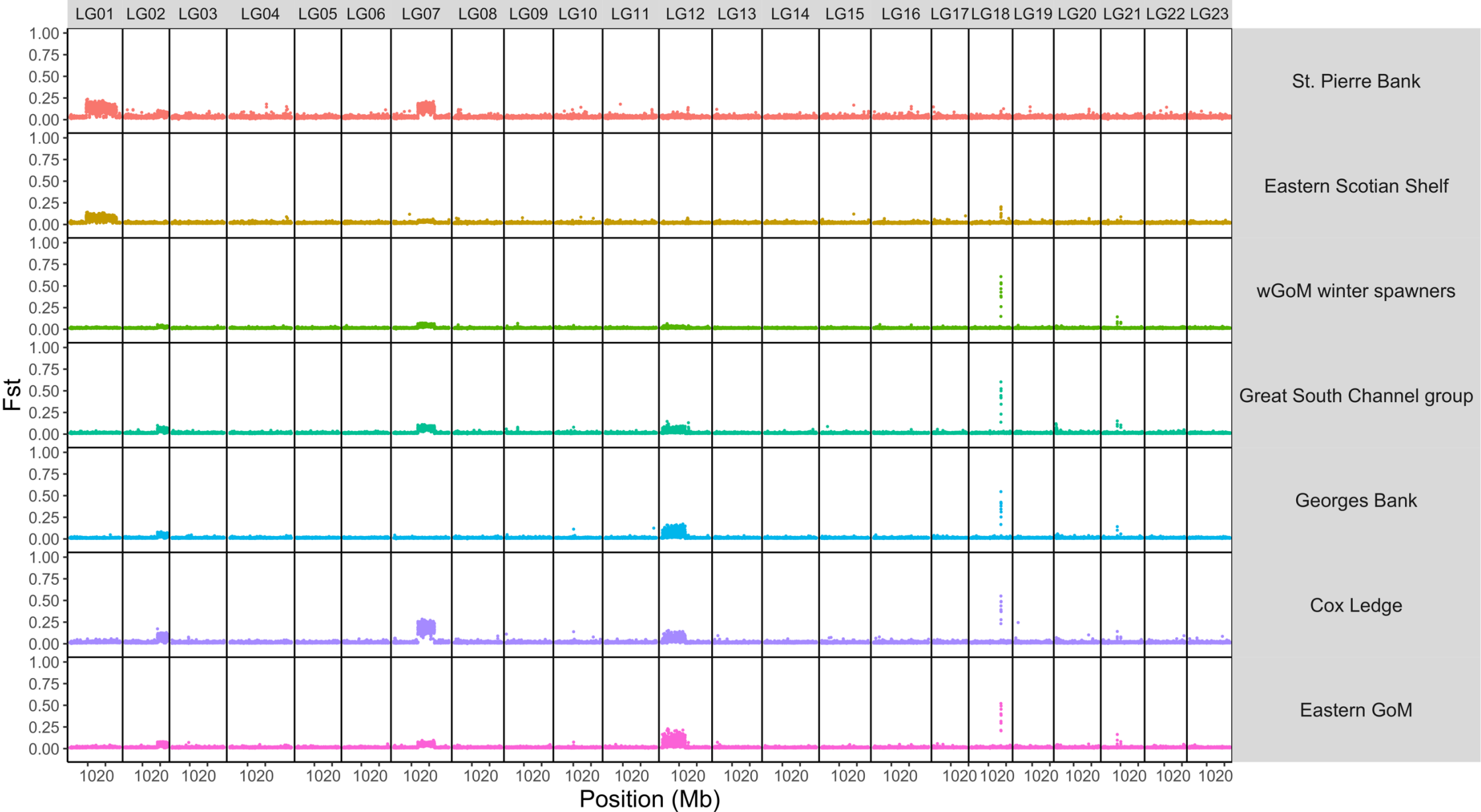
Spring spawners (n = 29) vs. winter spawners (n = 30)



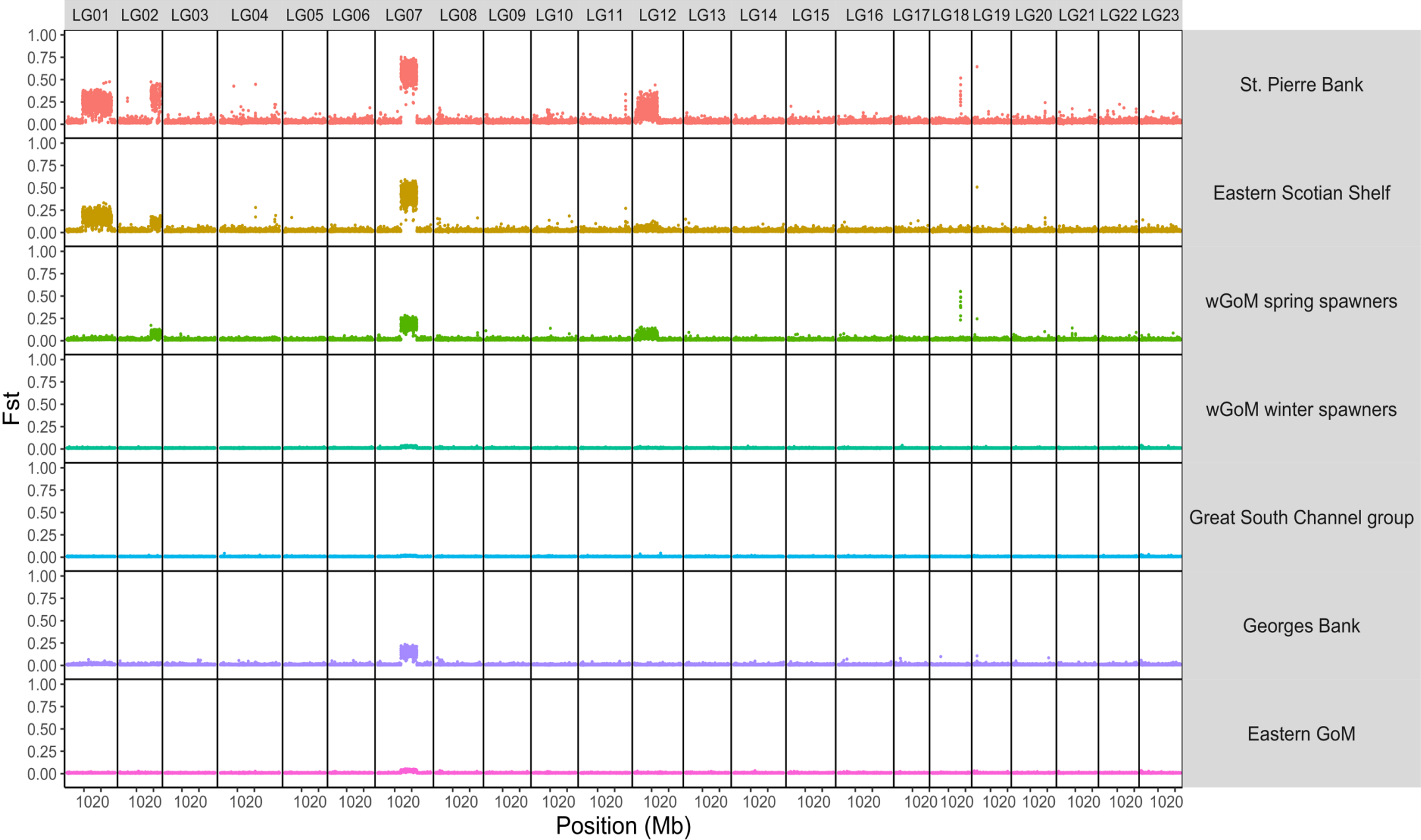
Georges Bank (n = 40) vs. Cox Ledge (n = 30)



wGoM spring spawners



Cox Ledge



Different patterns for different genome regions

- 4 chromosomal inversions + outlier regions on other LGs (adaptive)

