Mapping Horizontal Sea Level Rise using Vegetation Communities in the Coastal Zone of Delaware

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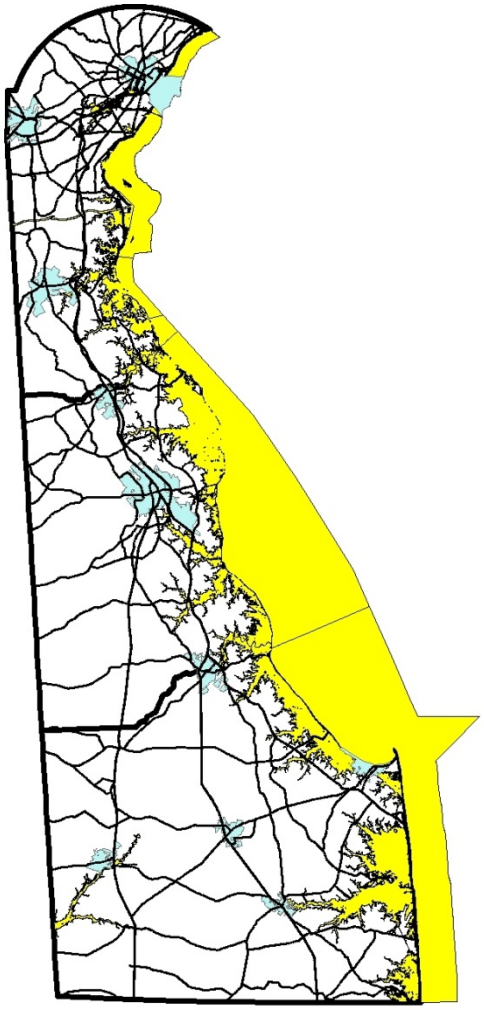
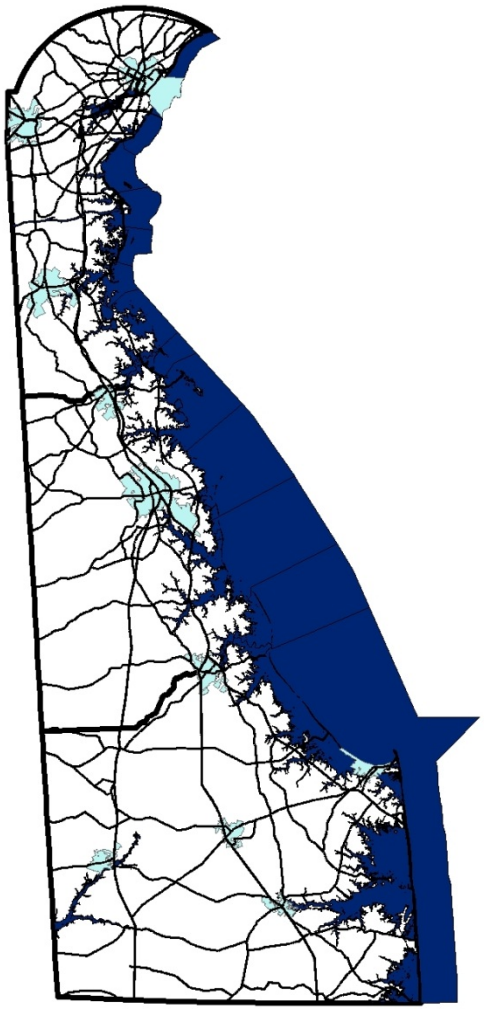
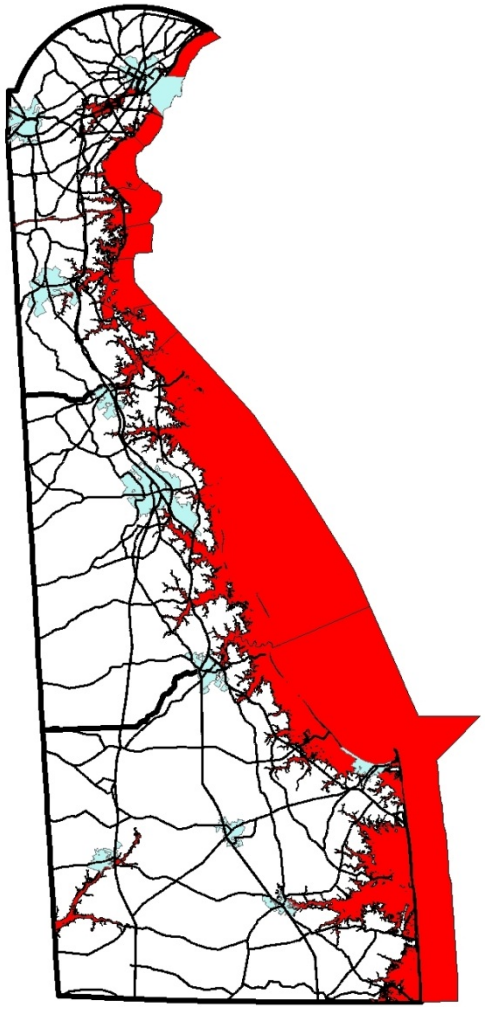
Sea-level Rise Scenarios



0.5 m



1 m



1.5 m

History of Sea Level Rise

- BC 100 to AD 950: sea level stable*
- AD 950 to 1400: + 0.6 mm/y*
- 1400 to ~1900: sea level stable*
- 1880 to 1920: +2.1 mm/y*
- Present: 3.24 mm/y (Lewes), 3.73 mm/y (IR inlet)—PSML gauge data

*Kemp, et al 2011

Components of Sea Level Rise

Rise Classification	Amount
Eustatic Rise	**1.45 mm/y**
Addition of water to system	1.2 mm/y
Groundwater depletion	0.8 mm/y
Impounded water	-0.55 mm/y
Isostatic Rise	**1.6 mm/y**
Land subsidence	1.6 mm/y
Stearic Rise	**0.9 mm/y**
Thermal expansion	0.9 mm/y
Total Sea Level Rise	**3.95 mm/y**

Methods

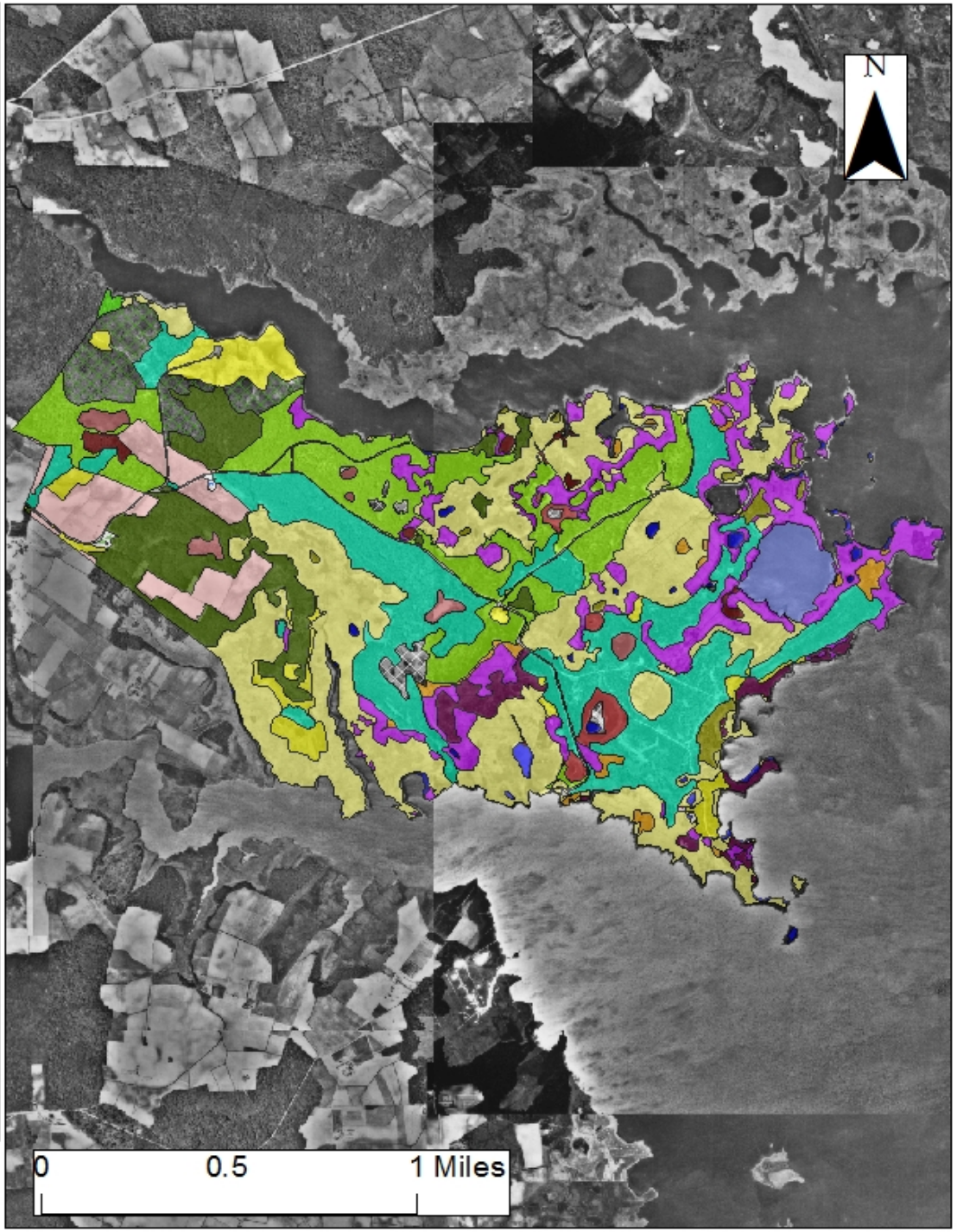
- **Vegetation communities/land covers were mapped for each aerial imagery set (1937, 1954, 1997, 2002, and 2007) following the *Guide to Delaware Vegetation Communities* for each managed area.**
  - **Most areas were mapped using 1937 aerial imagery, but some had to be mapped using 1954 or 1997 aerial imagery because of image quality geo-referencing. All areas were mapped using 2002 and 2007 imagery and were ground truthed between 2010 and the present (2012).**

- **Maps were then compared for changes in vegetation communities/land covers.**

Miller Neck Vegetation Communities

- Agricultural Field
- Beach
- Cattail Brackish Tidal Marsh
- Clear-cut
- Coastal Loblolly Pine Wetland Forest
- Creeping Rush Boltonia Coastal Plain Pond
- Cultivated Lawn
- Early to Mid-Successional Loblolly Pine Forest
- Eastern Reed Marsh
- Impervious Surface
- Impoundment
- Irregularly Flooded Eastern Tidal Salt Shrub
- Mid-Atlantic Coastal Plain Maritime Forest
- Modified Land
- Needlerush High Marsh
- North Atlantic High Salt Marsh
- North Atlantic Low Salt Marsh
- Northeastern Old Field
- Northeastern Successional Shrubland
- Red Maple-Sweetgum Swamp
- Reed Tidal Marsh
- Semi-impervious Surface
- Successional Maritime Forest
- Tidal Mudflat
- Water

1937 Imagery



Miller Neck Vegetation Communities

- Agricultural Field
- Beach
- Brackish Tidal Creek Shrubland
- Coastal Loblolly Pine Wetland Forest
- Creeping Rush Boltonia Coastal Plain Pond
- Cultivated Lawn
- Early to Mid-Successional Loblolly Pine Forest
- Eastern Reed Marsh
- Farm Pond/Artificial Pond
- Impervious Surface
- Impoundment
- Irregularly Flooded Eastern Tidal Salt Shrub
- Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland
- Maritime Red Cedar Woodland
- Mesic Coastal Plain Oak Forest
- Mid-Atlantic Coastal Plain Martiime Forest
- Modified Land
- Needlerush High Marsh
- North Atlantic High Salt Marsh
- North Atlantic Low Salt Marsh
- Northeastern Old Field
- Northeastern Successional Shrubland
- Overwash Dune Grassland
- Red Maple-Sweetgum Swamp
- Reed Tidal Marsh
- Semi-impervious Surface
- Southern Red Oak/Heath Forest
- Successional Maritime Forest
- Successional Sweetgum Forest
- Tidal Mudflat
- Upland Switchgrass Vegetation
- Water

2002 Imagery

Miller Neck Vegetation Communities

- Agricultural Field
- Beach
- Brackish Tidal Creek Shrubland
- Coastal Loblolly Pine Wetland Forest
- Creeping Rush Boltonia Coastal Plain Pond
- Cultivated Lawn
- Early to Mid-Successional Loblolly Pine Forest
- Eastern Reed Marsh
- Farm Pond/Artificial Pond
- Impervious Surface
- Impoundment
- Irregularly Flooded Eastern Tidal Salt Shrub
- Loblolly Pine/Wax-myrtle/Salt Meadow Cordgrass Woodland
- Maritime Red Cedar Woodland
- Mid-Atlantic Coastal Plain Maritime Forest
- Modified Land
- Needlerush High Marsh
- North Atlantic High Salt Marsh
- North Atlantic Low Salt Marsh
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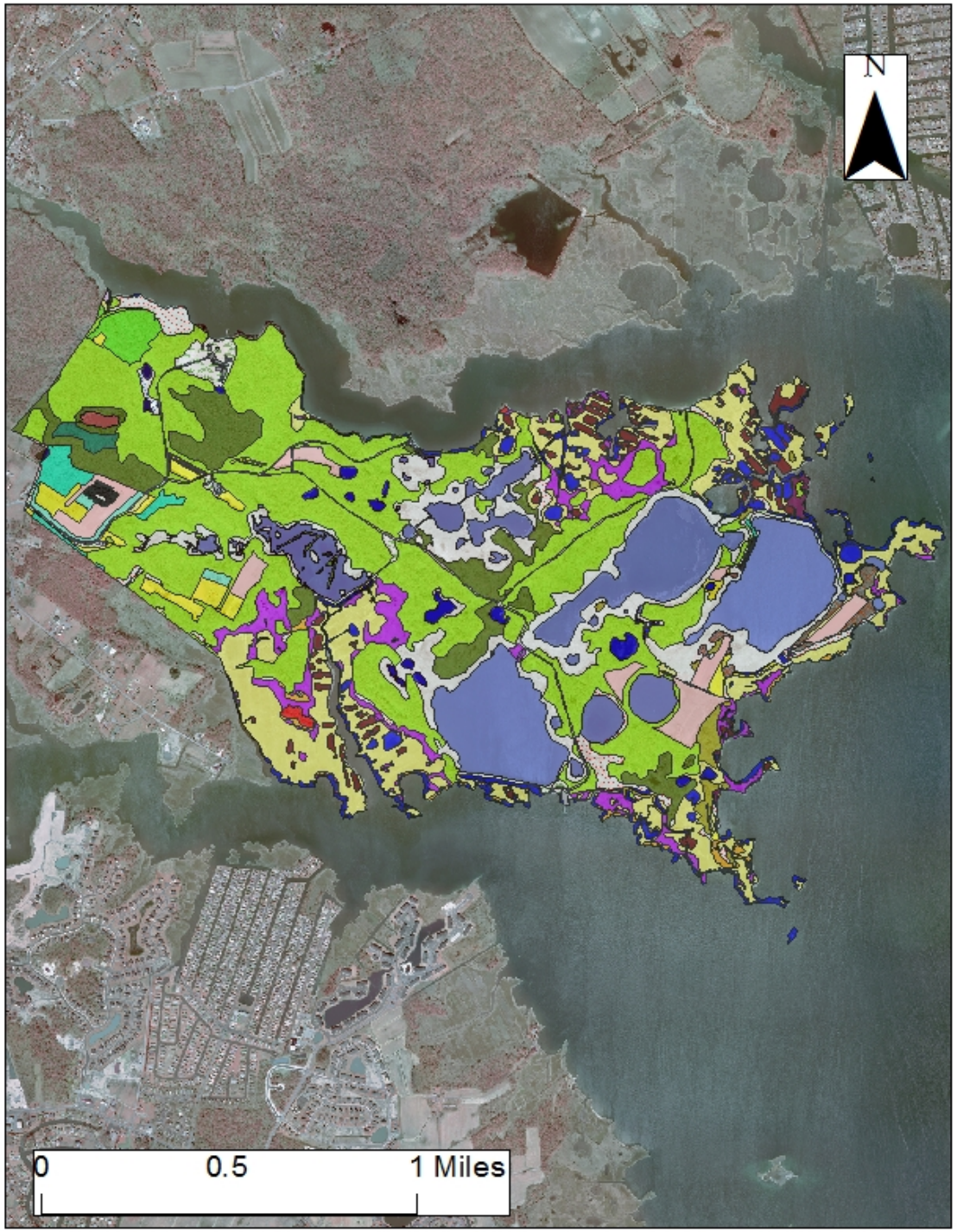
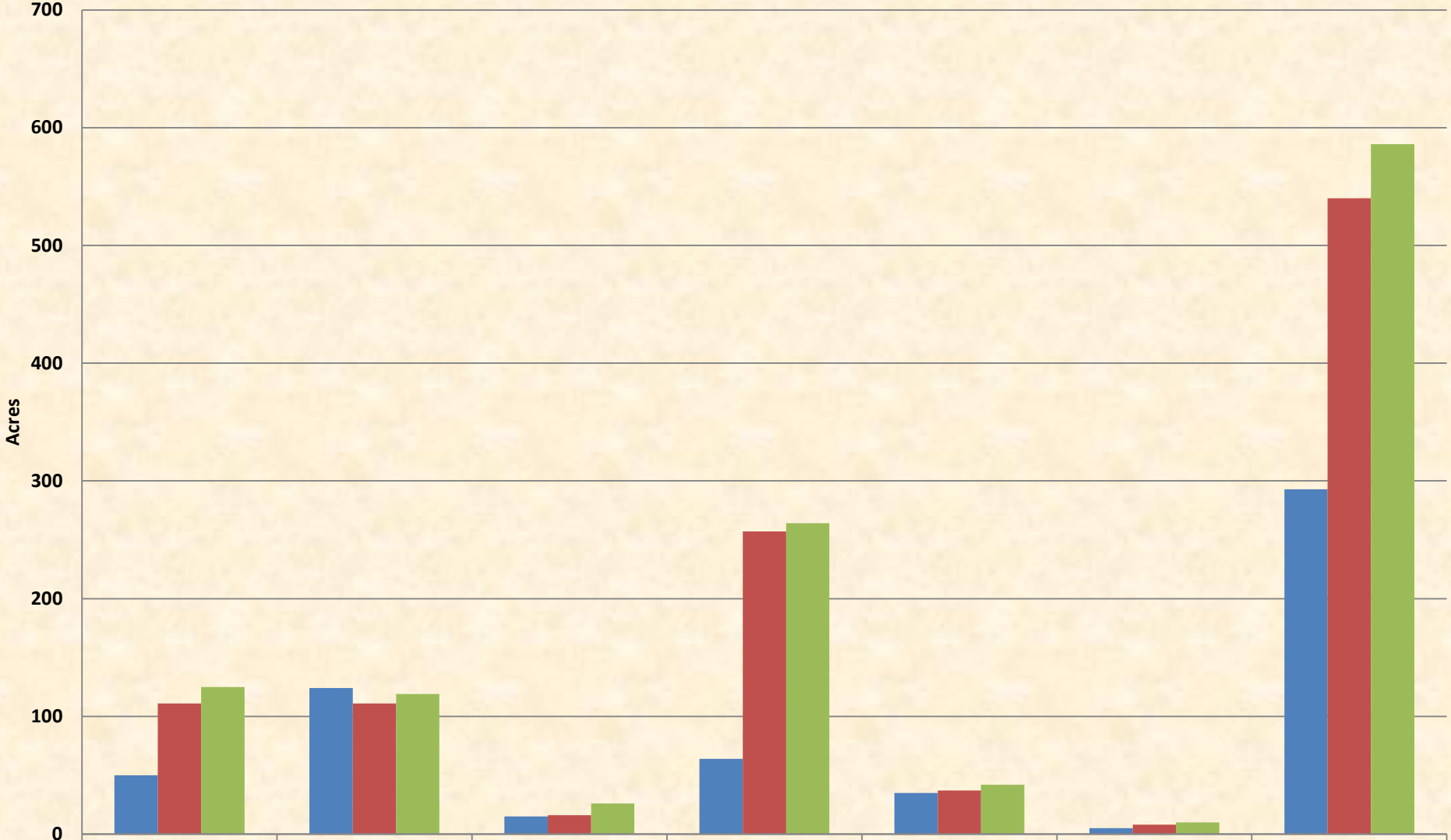
- Northeastern Successional Shrubland
- Red Maple-Sweetgum Swamp
- Reed Tidal Marsh
- Semi-impervious Surface
- Southern Red Oak/Heath Forest
- Successional Maritime Forest
- Successional Sweetgum Forest
- Tidal Mudflat
- Upland Switchgrass Vegetation
- Water



2007 Imagery

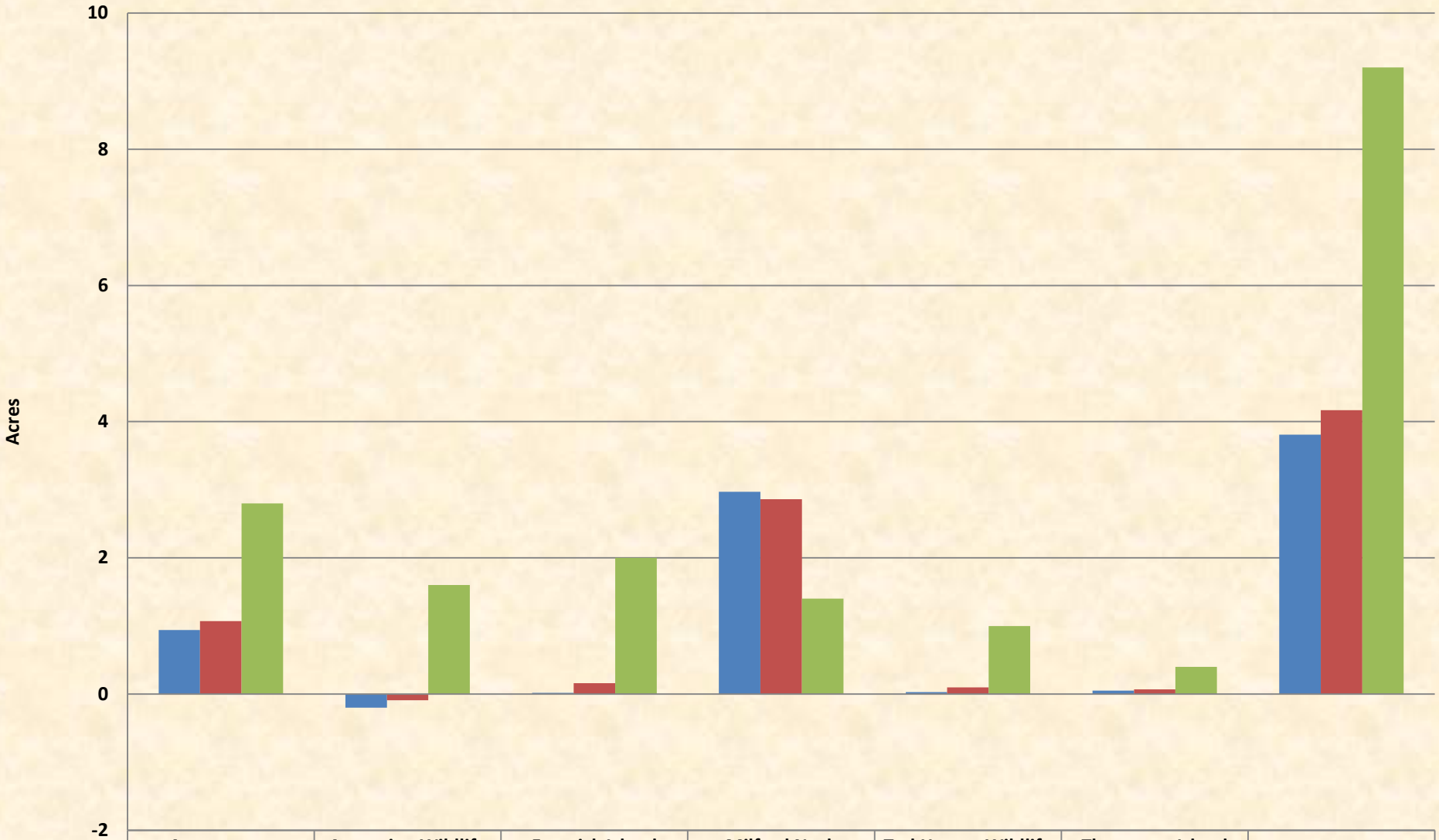
Water

Water Coverage
1937-2007



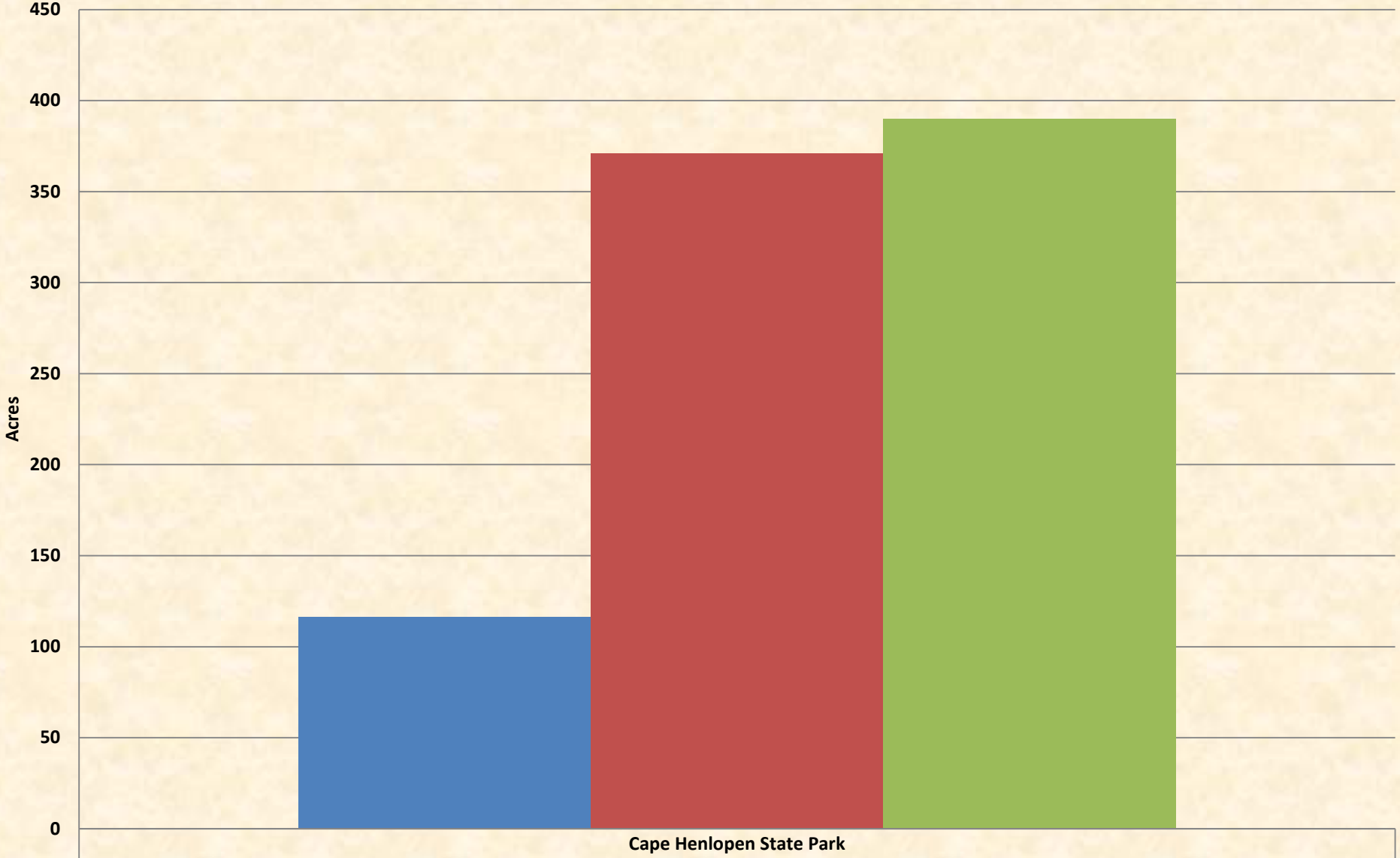
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937	50	124	15	64	35	5	293
2002	111	111	16	257	37	8	540
2007	125	119	26	264	42	10	586

Average acres/year Inundated by Water
1937-2007



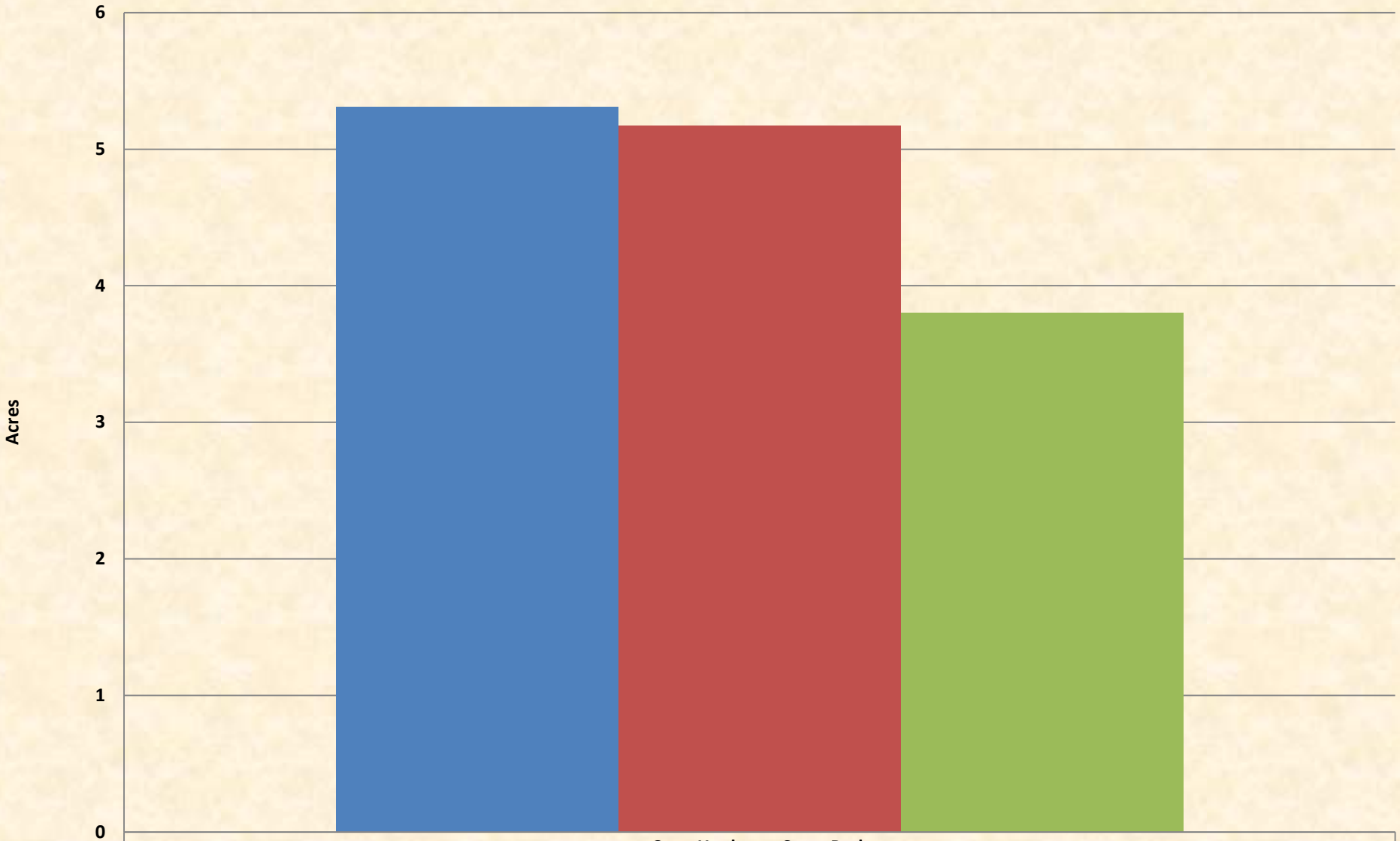
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937-2002	0.94	-0.2	0.02	2.97	0.03	0.05	3.81
1937-2007	1.07	-0.09	0.16	2.86	0.1	0.07	4.17
2002-2007	2.8	1.6	2	1.4	1	0.4	9.2

Water Coverage
1954-2007



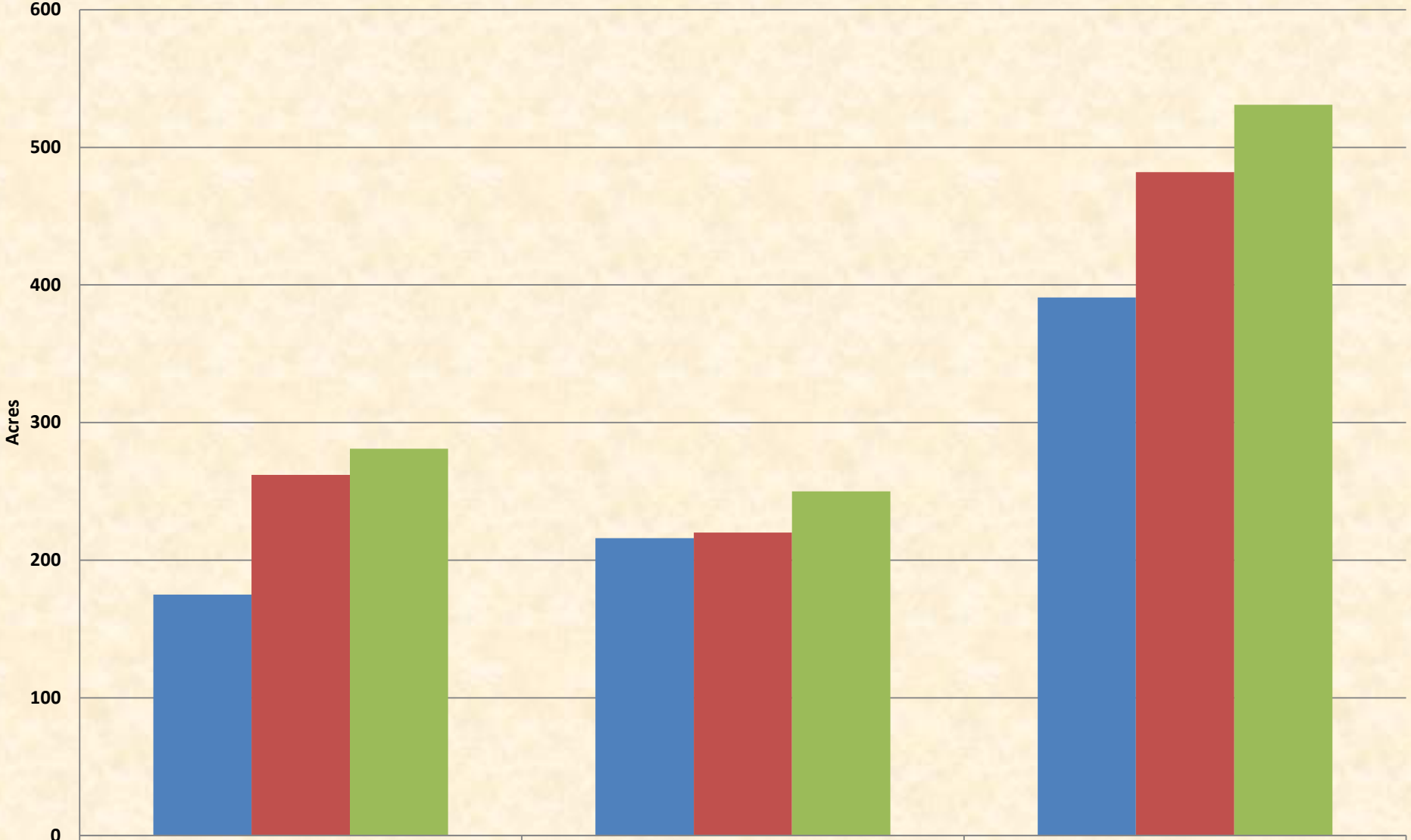
	Cape Henlopen State Park
1954	116
2002	371
2007	390

Average acres/year Inundated by Water
1954-2007



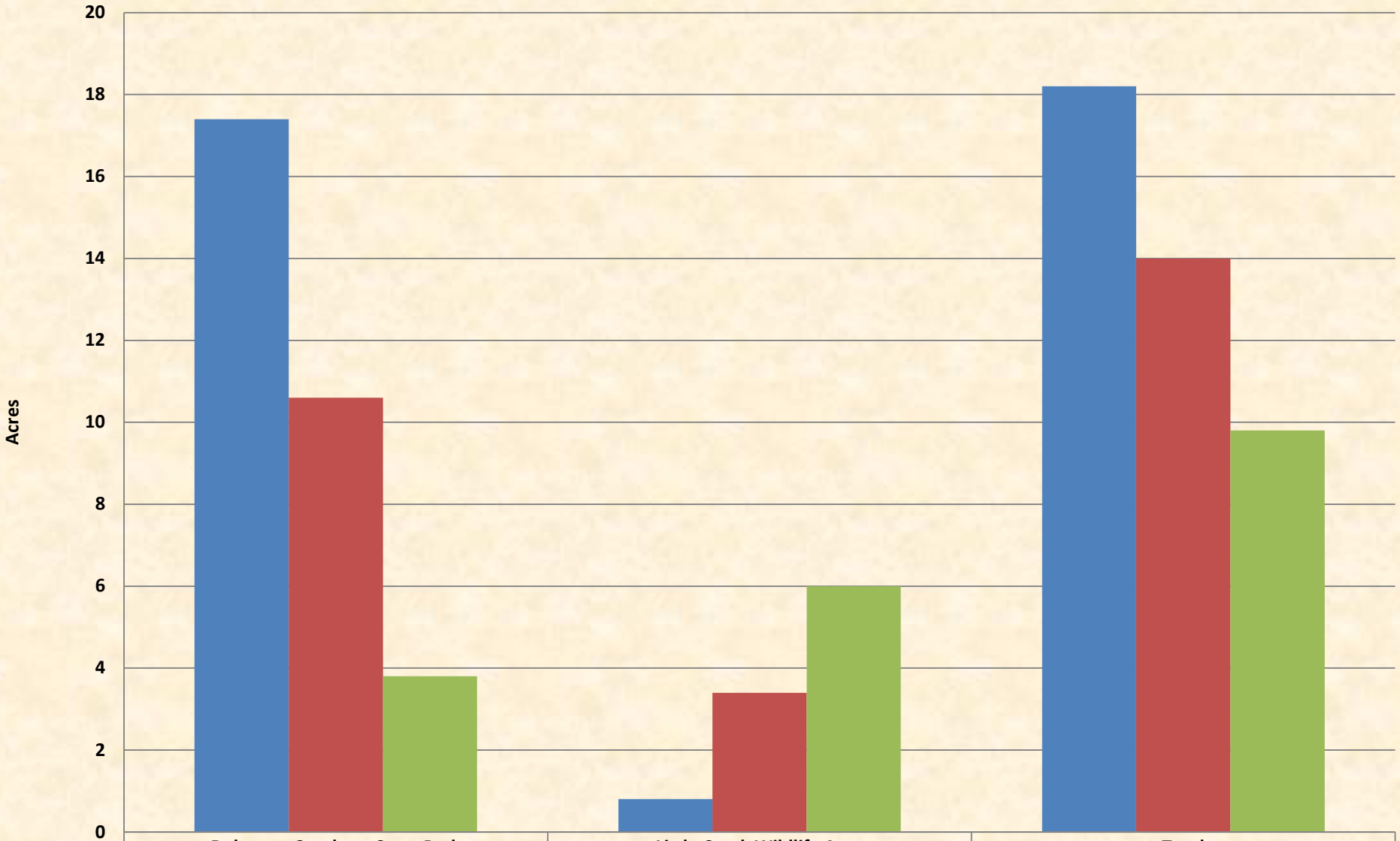
	Cape Henlopen State Park
1954-2002	5.31
1954-2007	5.17
2002-2007	3.8

Water Coverage
1997-2007



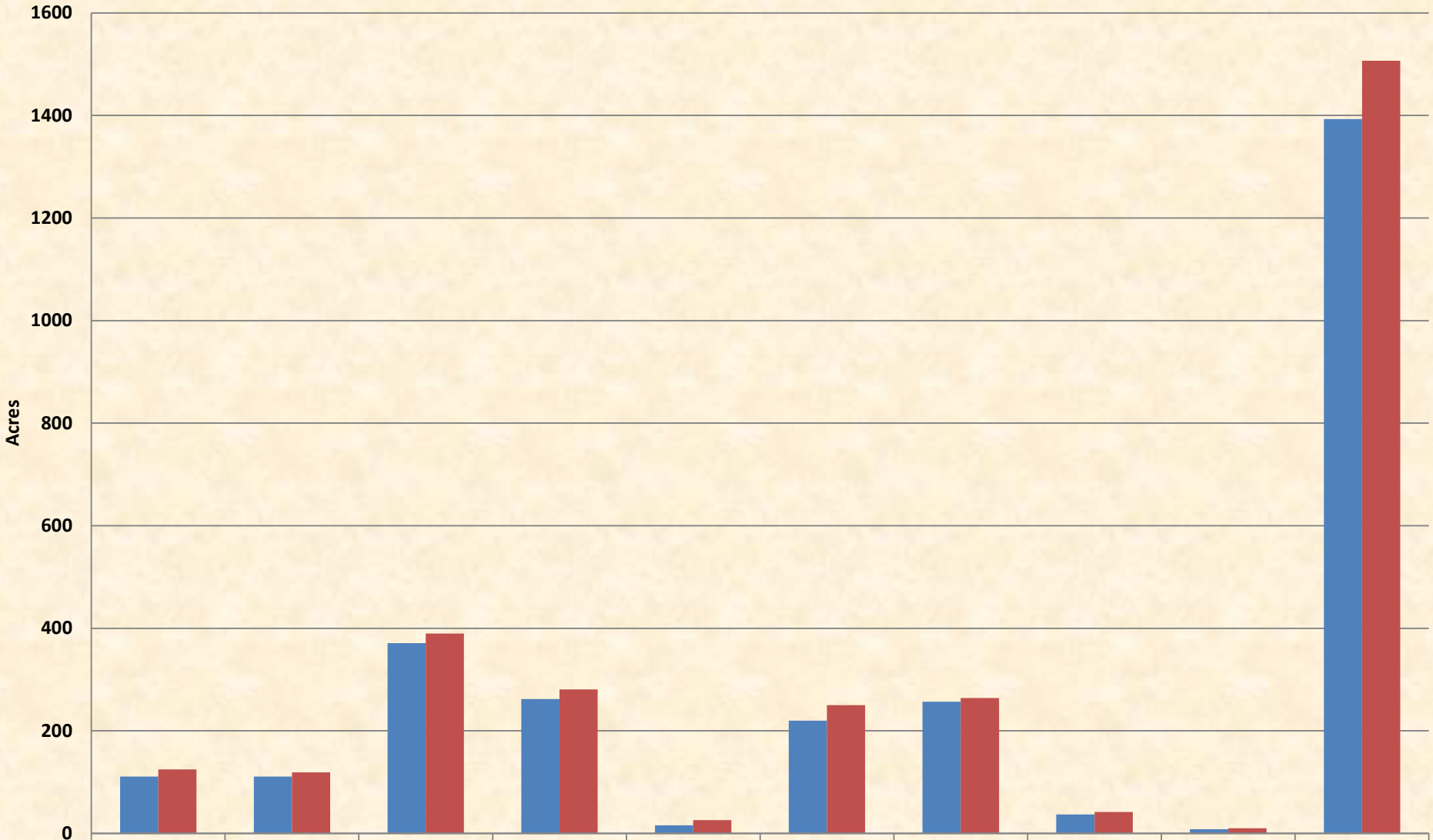
	Delaware Seashore State Park	Little Creek Wildlife Area	Total
1997	175	216	391
2002	262	220	482
2007	281	250	531

Average acres/year Inundated by Water
1997-2007



	Delaware Seashore State Park	Little Creek Wildlife Area	Total
1997-2002	17.4	0.8	18.2
1997-2007	10.6	3.4	14
2002-2007	3.8	6	9.8

Water Coverage
2002-2007



	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002	111	111	371	262	16	220	257	37	8	1393
2007	125	119	390	281	26	250	264	42	10	1507

Average acres/year Inundated by Water
2002-2007

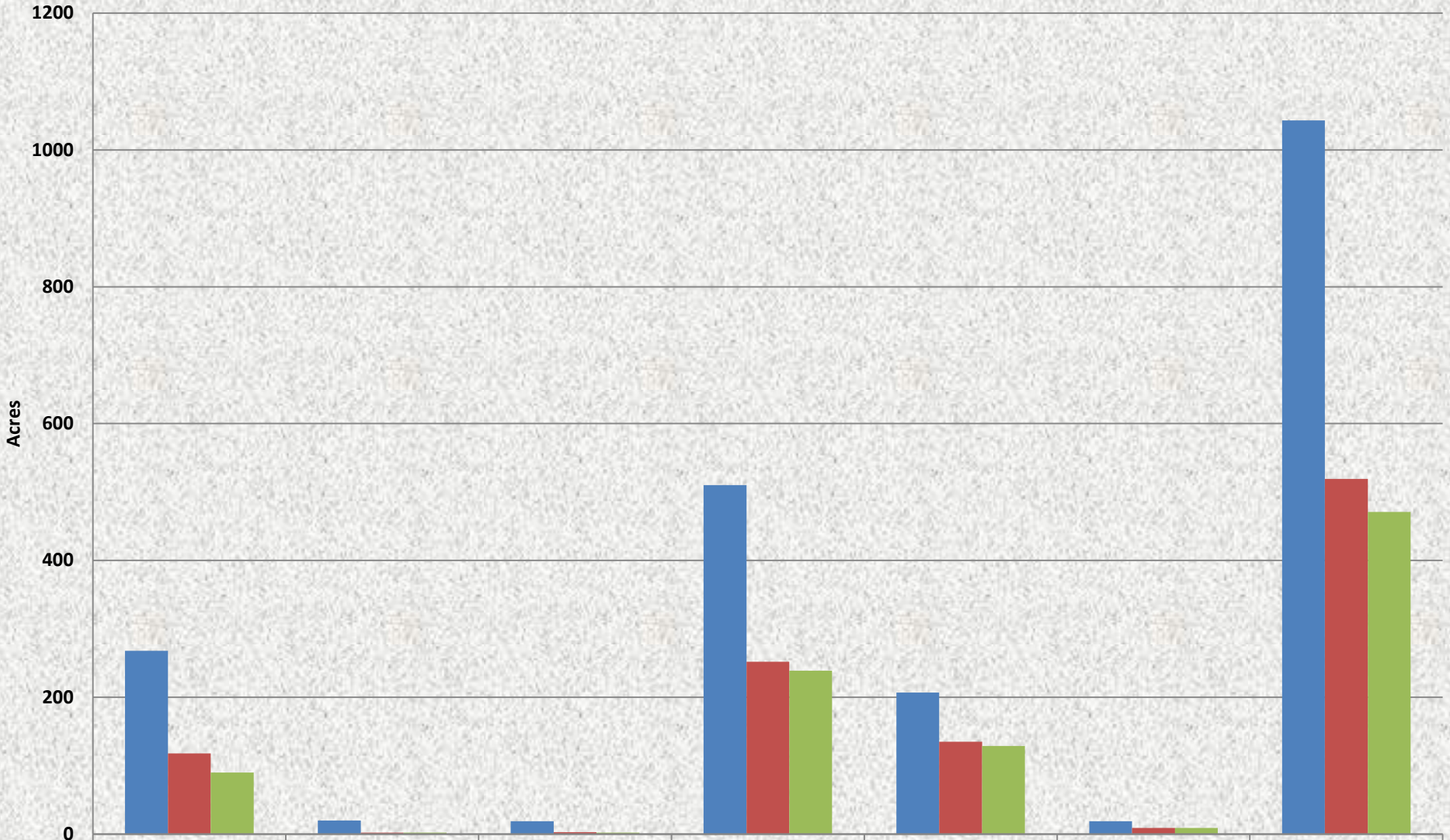
	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002-2007	2.8	1.6	3.8	3.8	2	6	1.4	1	0.4	22.8

Water
1937-2007

Changed to water		Water changed to	
North Atlantic Low Salt Marsh	476 acres	Water	456 acres
Water	456 acres	North Atlantic Low Salt Marsh	84 acres
North Atlantic High Salt Marsh	111 acres	Beach	30 acres
Beach	109 acres	Sand	22 acres
Beachgrass-Panicgrass Dune Grassland	35 acres	Reed Tidal Marsh	15 acres

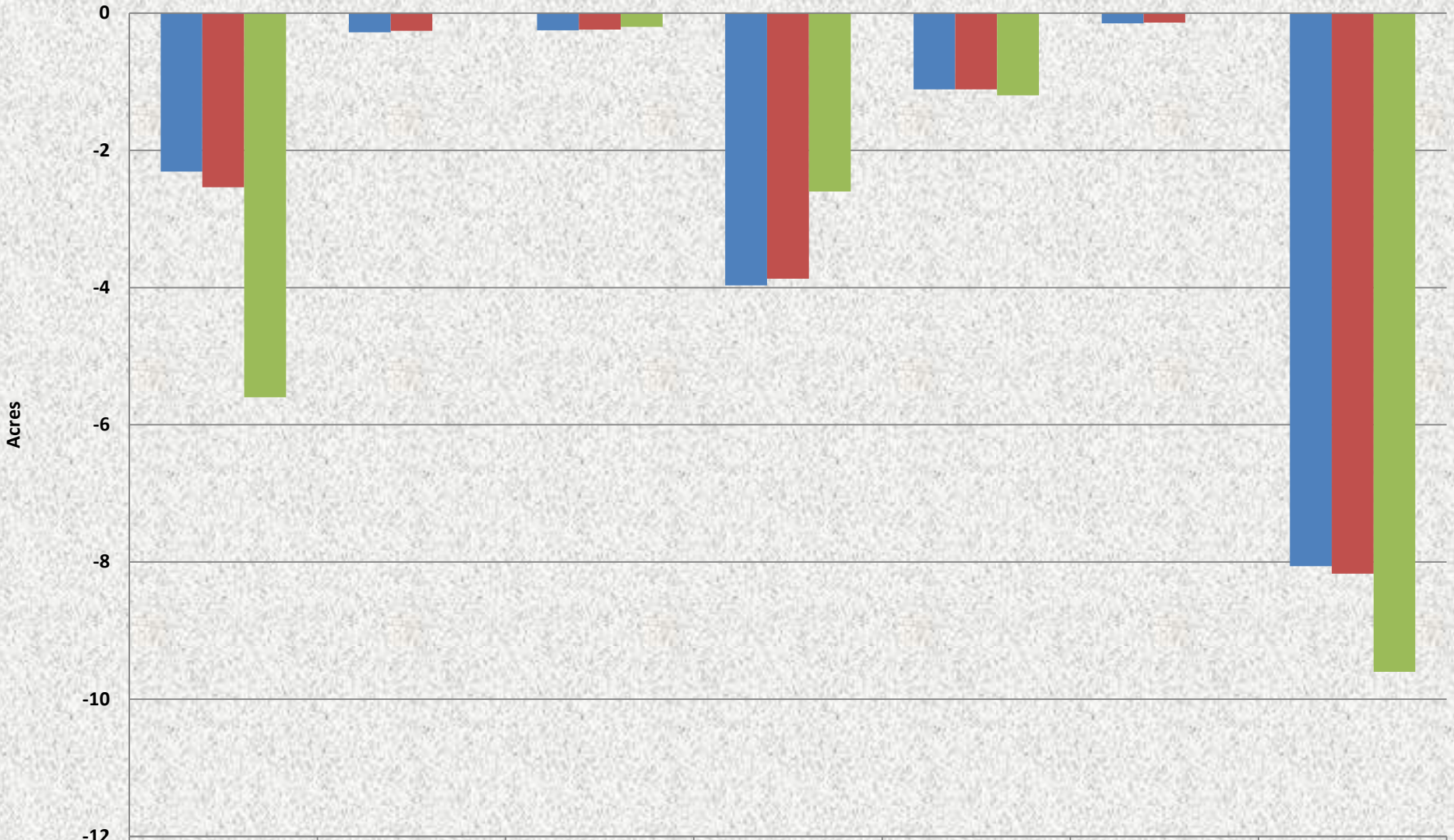
North Atlantic High Salt Marsh

North Atlantic High Salt Marsh
1937-2007



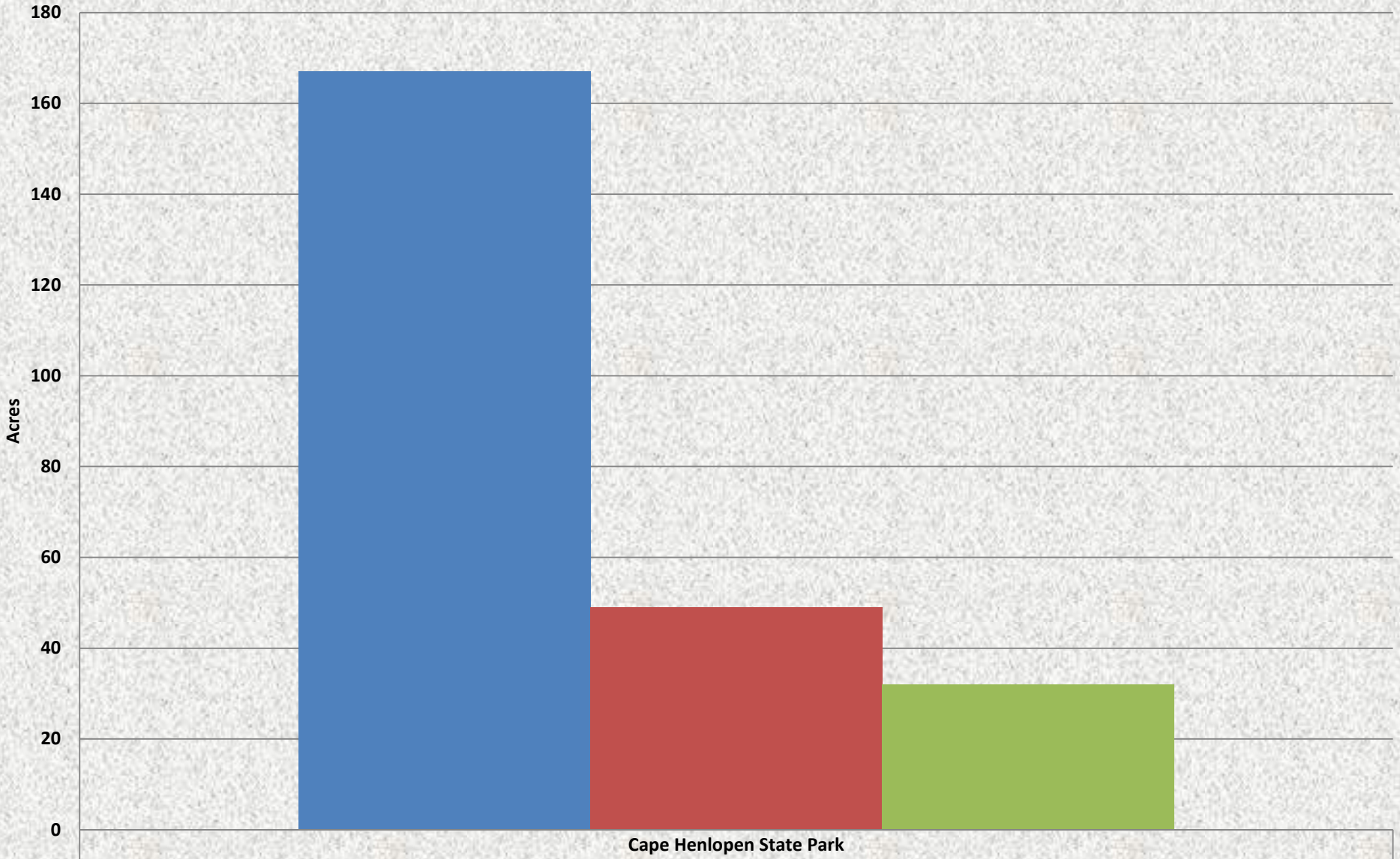
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937	268	20	19	510	207	19	1043
2002	118	2	3	252	135	9	519
2007	90	2	2	239	129	9	471

Average acres/year Lost of North Atlantic High Salt Marsh 1937-2007



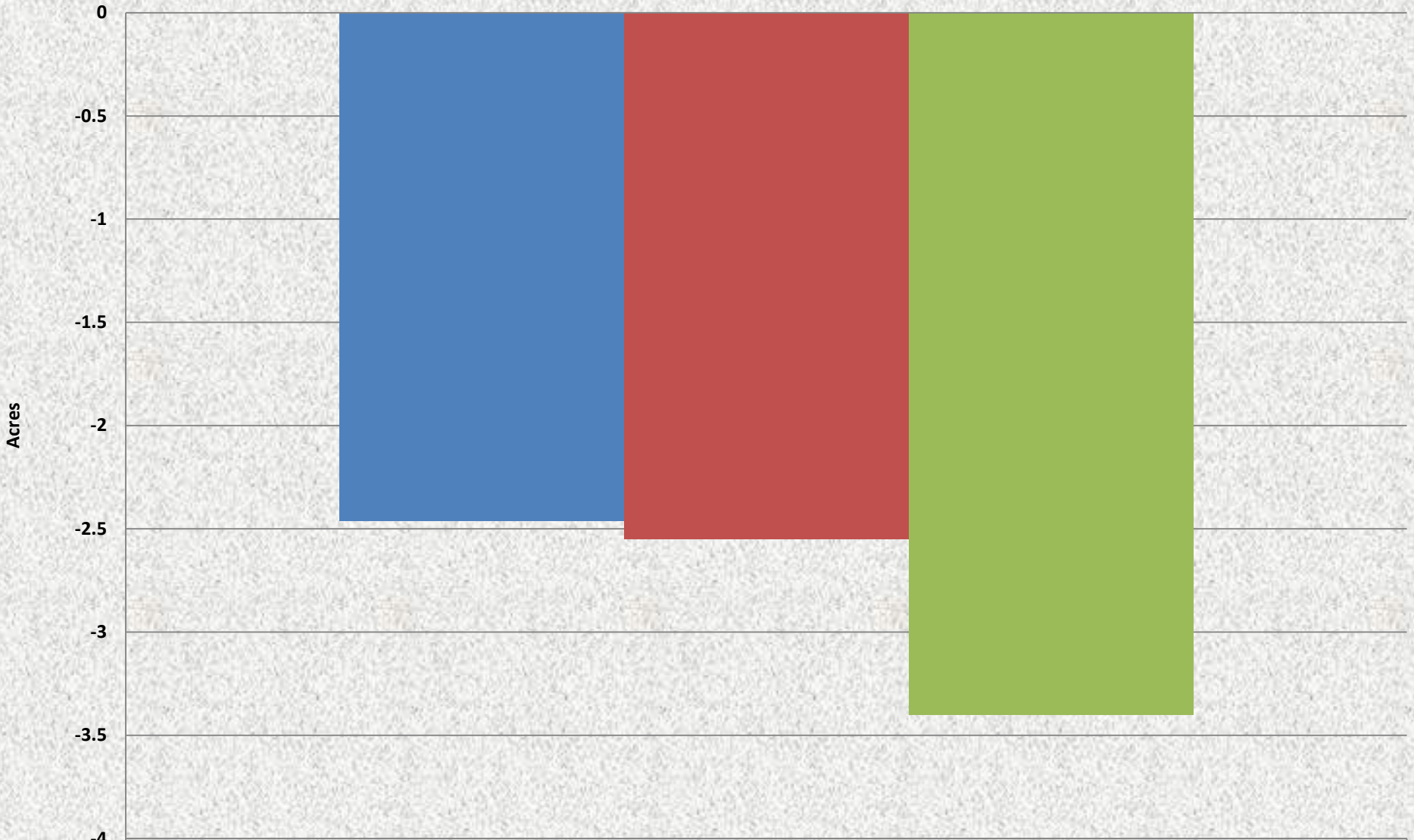
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937-2002	-2.31	-0.28	-0.25	-3.97	-1.11	-0.15	-8.06
1937-2007	-2.54	-0.26	-0.24	-3.87	-1.11	-0.14	-8.17
2002-2007	-5.6	0	-0.2	-2.6	-1.2	0	-9.6

North Atlantic High Salt Marsh
1954-2007



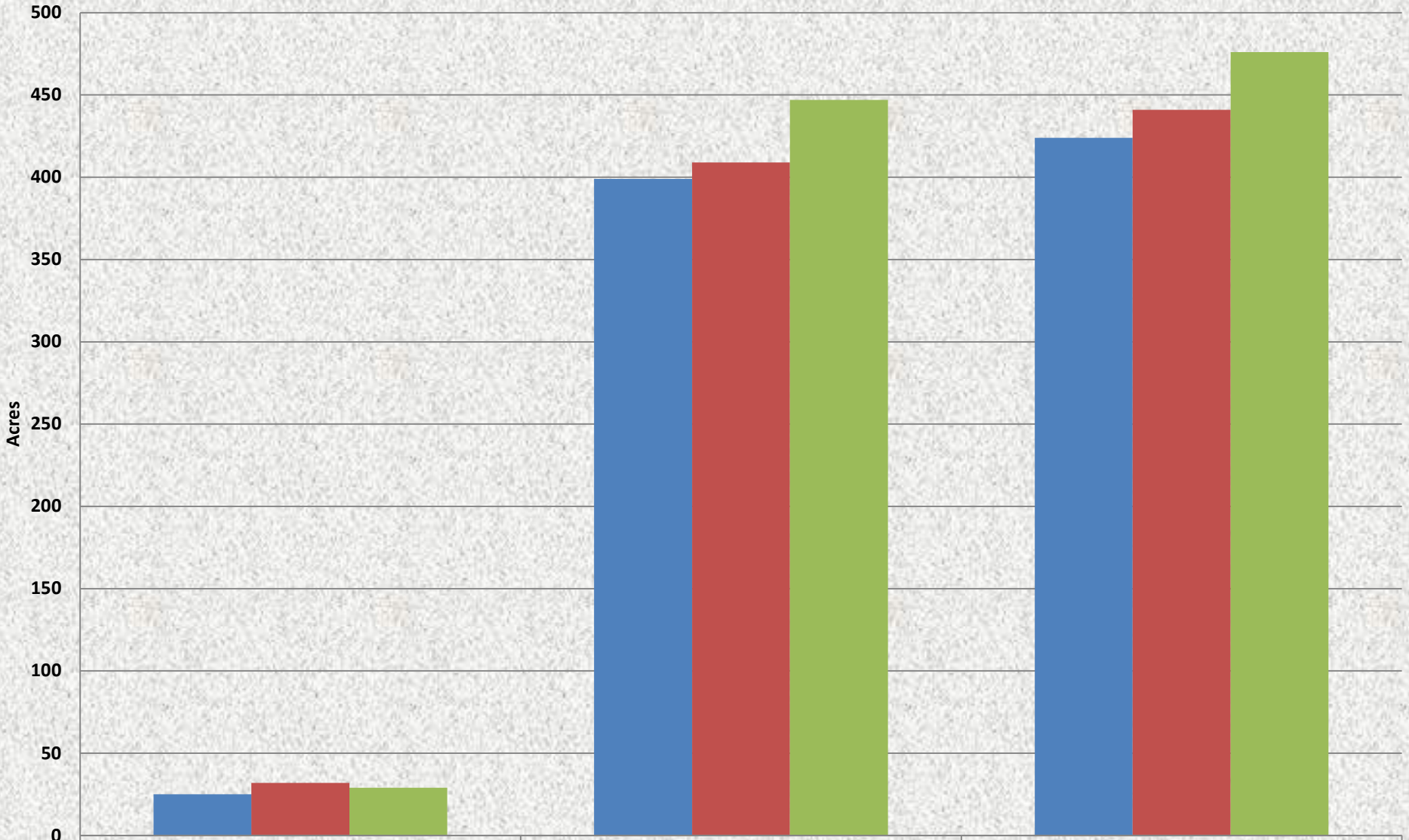
	Cape Henlopen State Park
1954	167
2002	49
2007	32

Average acres/year Lost of North Atlantic High Salt Marsh 1954-2007



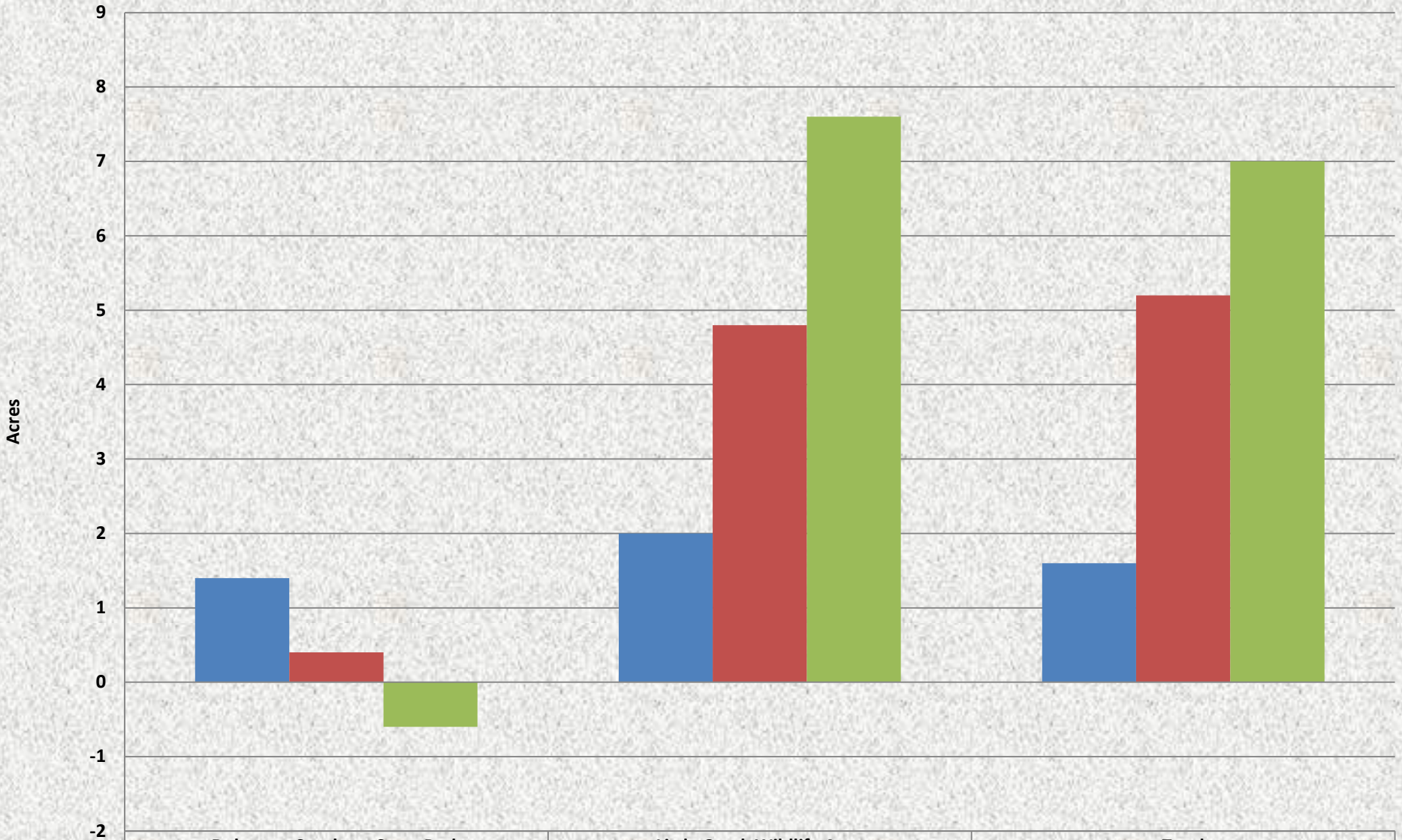
	Cape Henlopen State Park
1954-2002	-2.46
1954-2007	-2.55
2002-2007	-3.4

North Atlantic High Salt Marsh
1997-2007



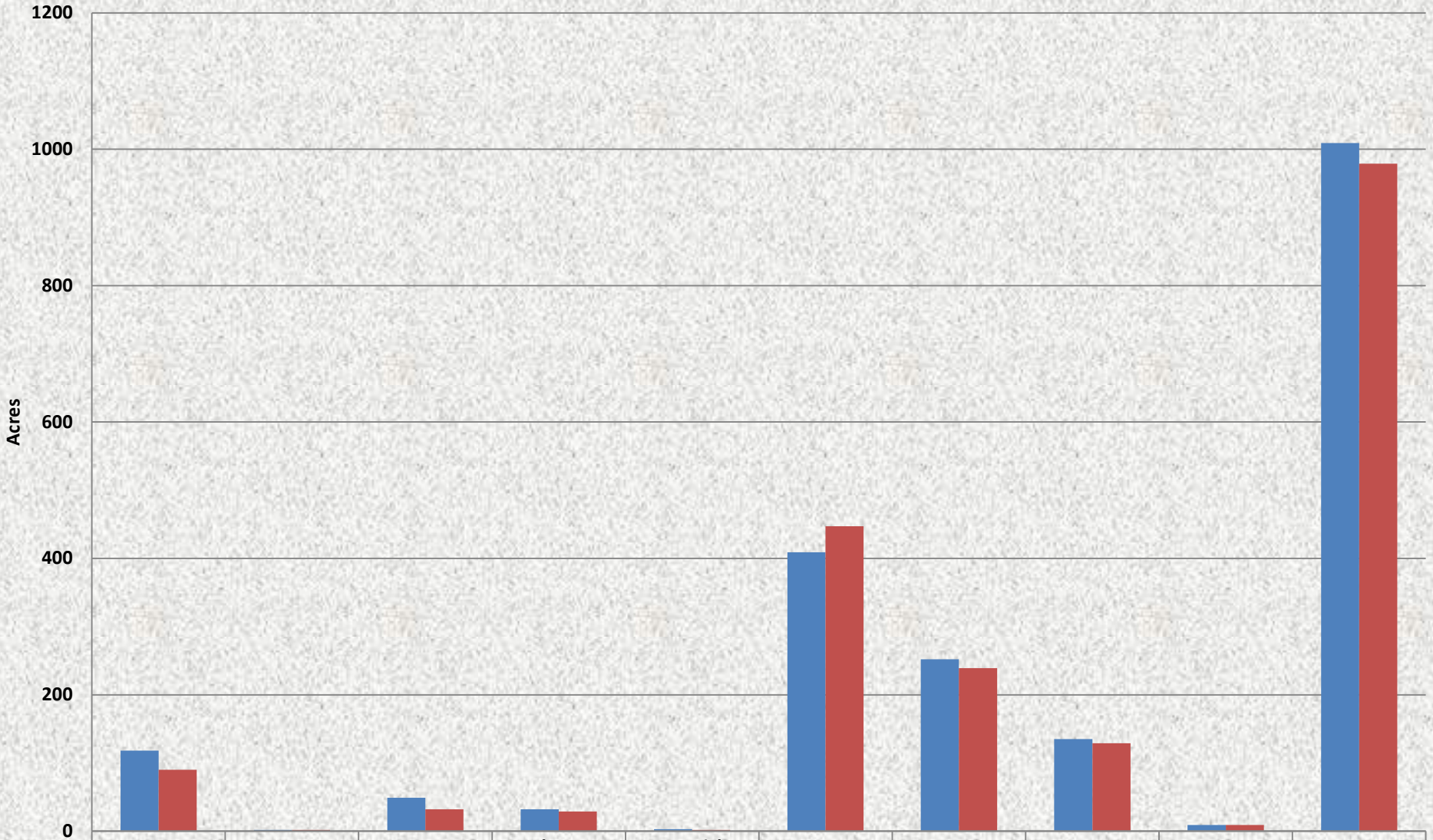
	Delaware Seashore State Park	Little Creek Wildlife Area	Total
1997	25	399	424
2002	32	409	441
2007	29	447	476

Average acres/year Gained or Lost of North Atlantic High Salt Marsh 1997-2007



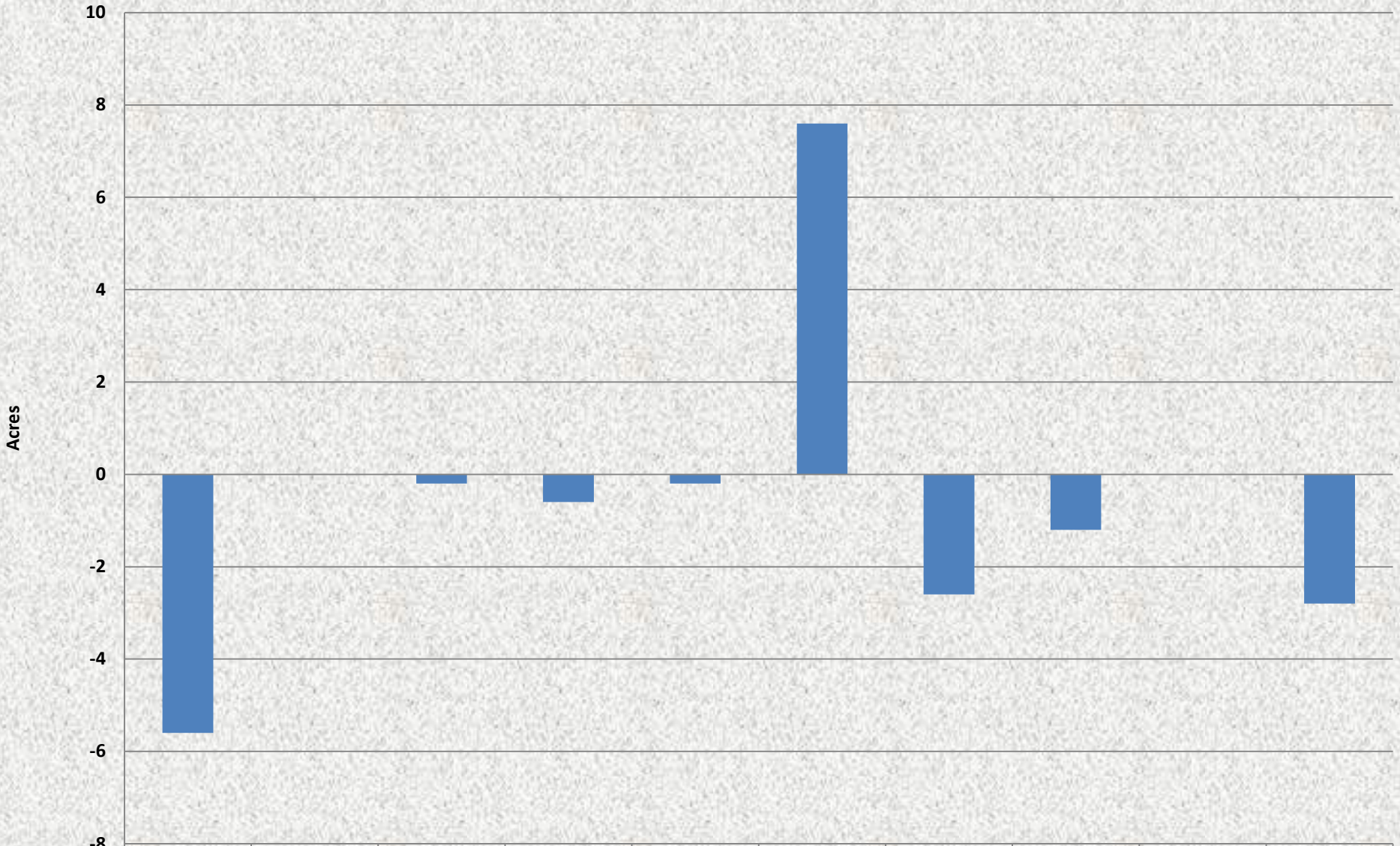
	Delaware Seashore State Park	Little Creek Wildlife Area	Total
1997-2002	1.4	2	1.6
1997-2007	0.4	4.8	5.2
2002-2007	-0.6	7.6	7

North Atlantic High Salt Marsh
2002-2007



	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002	118	2	49	32	3	409	252	135	9	1009
2007	90	2	32	29	2	447	239	129	9	979

Average acres/year Gained or Lost of North Atlantic High Salt Marsh 2002-2007



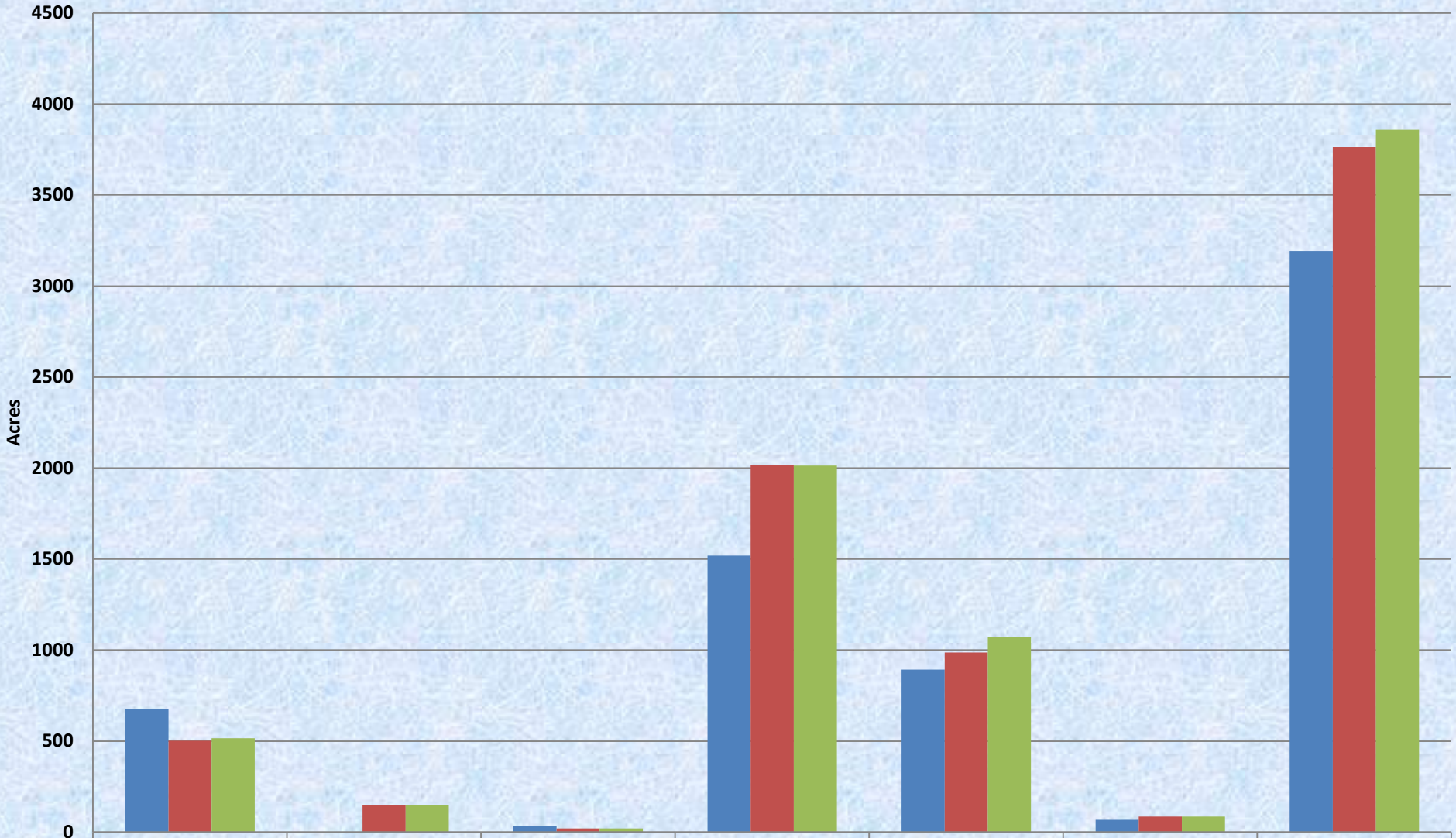
	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002-2007	-5.6	0	-0.2	-0.6	-0.2	7.6	-2.6	-1.2	0	-2.8

North Atlantic High Salt Marsh 1937-2007

North Atlantic High Salt Marsh converted to		Converted to North Atlantic High Salt Marsh	
North Atlantic Low Salt Marsh	841 acres	North Atlantic High Salt Marsh	432 acres
North Atlantic High Salt Marsh	432 acres	North Atlantic Low Salt Marsh	272 acres
Water	112 acres	Northeastern Old Field	96 acres
Reed Tidal Marsh	65 acres	Reed Tidal Marsh	84 acres
Eastern Reed Marsh	37 acres	Irregularly Flooded Eastern Tidal Salt Shrub	31 acres

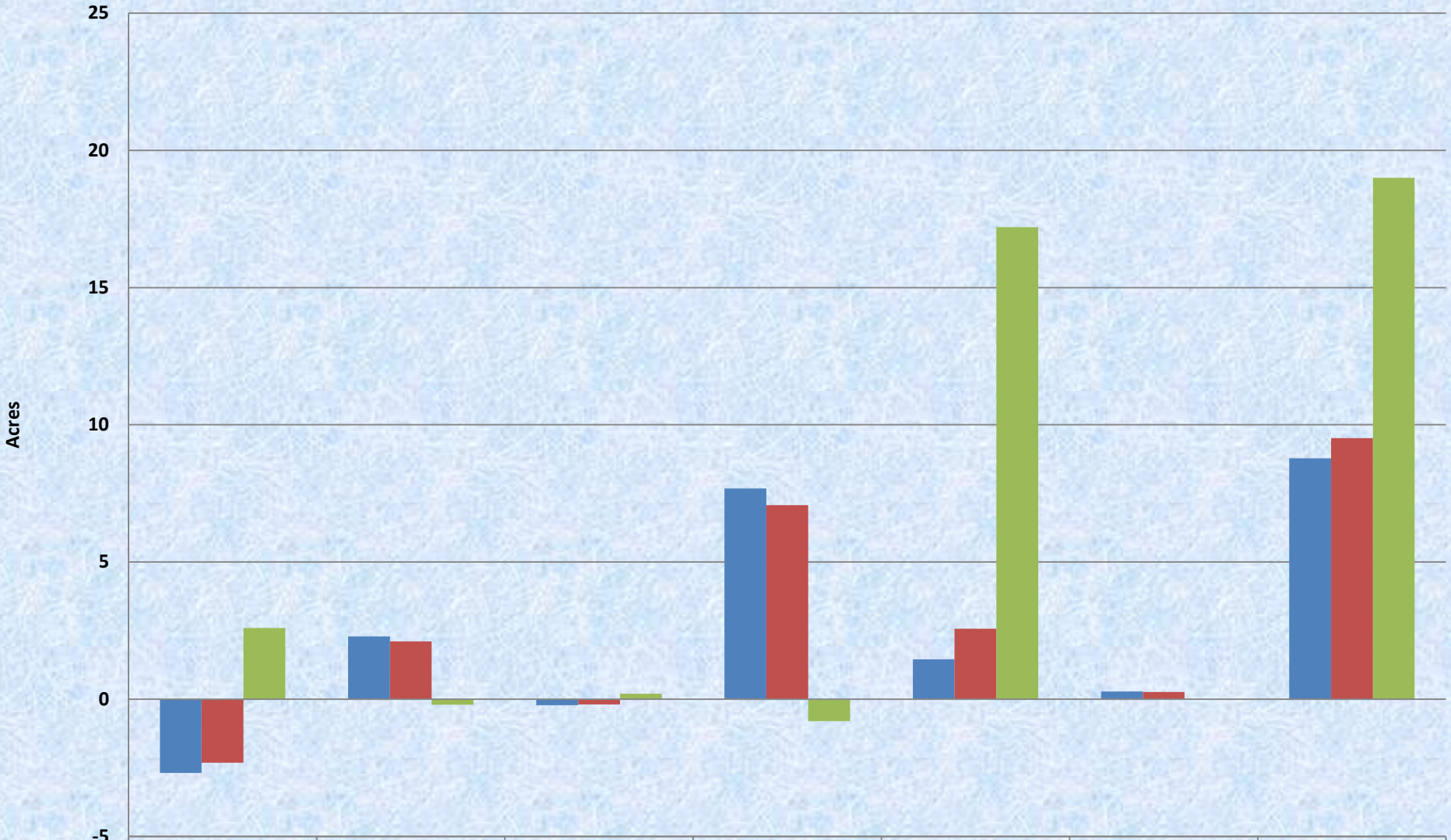
North Atlantic Low Salt Marsh

North Atlantic Low Salt Marsh
1937-2007



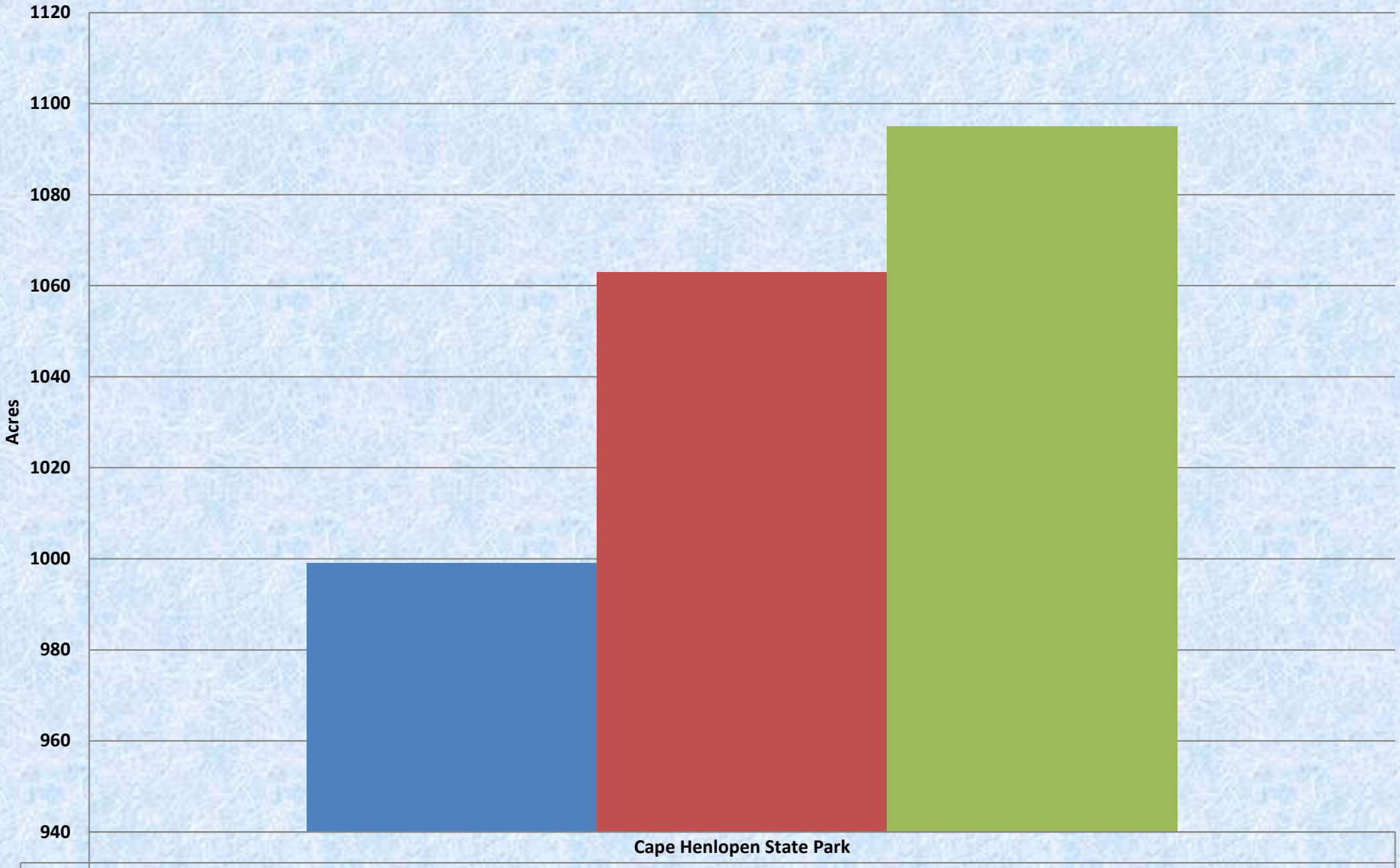
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937	678	0	34	1519	893	68	3192
2002	503	149	20	2018	987	86	3763
2007	516	148	21	2014	1073	86	3858

Average acres/year Gained or Lost of North Atlantic Low Salt Marsh 1937-2007



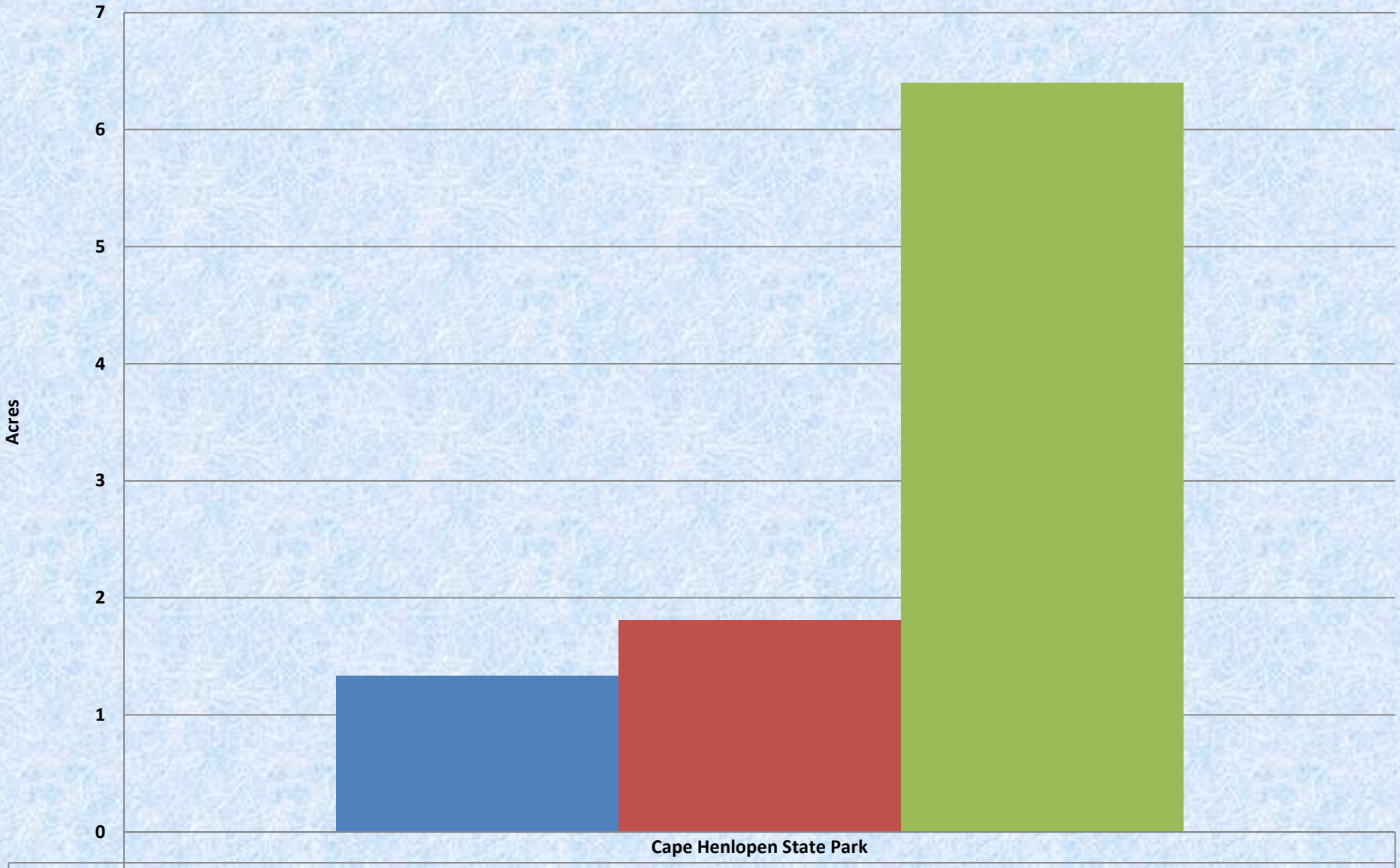
	Assawoman Wildlife Area	Augustine Wildlife Area	Fenwick Island State Park	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
1937-2002	-2.69	2.29	-0.22	7.68	1.45	0.28	8.78
1937-2007	-2.31	2.11	-0.19	7.07	2.57	0.26	9.51
2002-2007	2.6	-0.2	0.2	-0.8	17.2	0	19

North Atlantic Low Salt Marsh
1954-2007



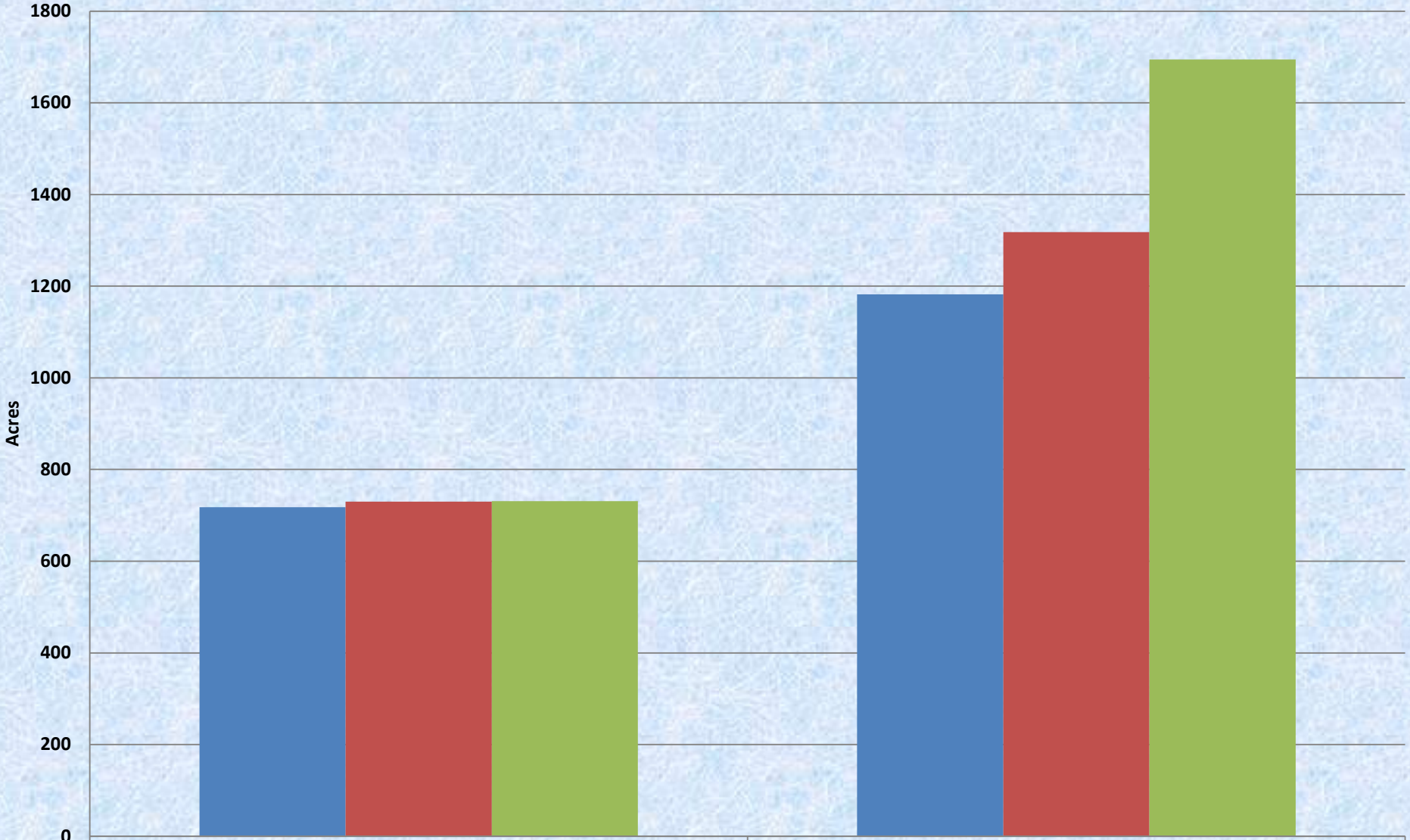
	Cape Henlopen State Park
1954	999
2002	1063
2007	1095

Average acres/year Gained of North Atlantic Low Salt Marsh 1954-2007



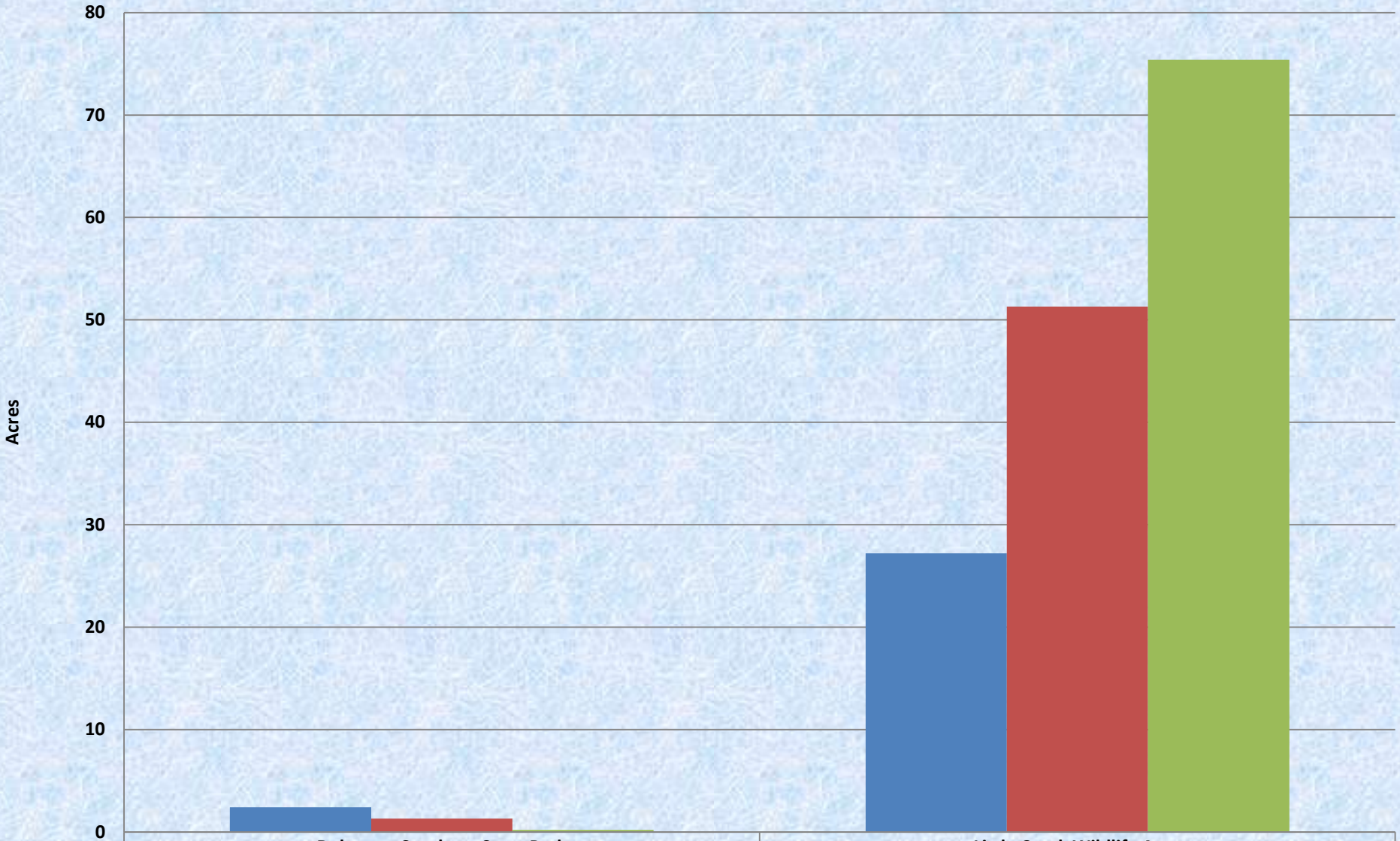
	Cape Henlopen State Park
1954-2002	1.33
1954-2007	1.81
2002-2007	6.4

North Atlantic Low Salt Marsh
1997-2007



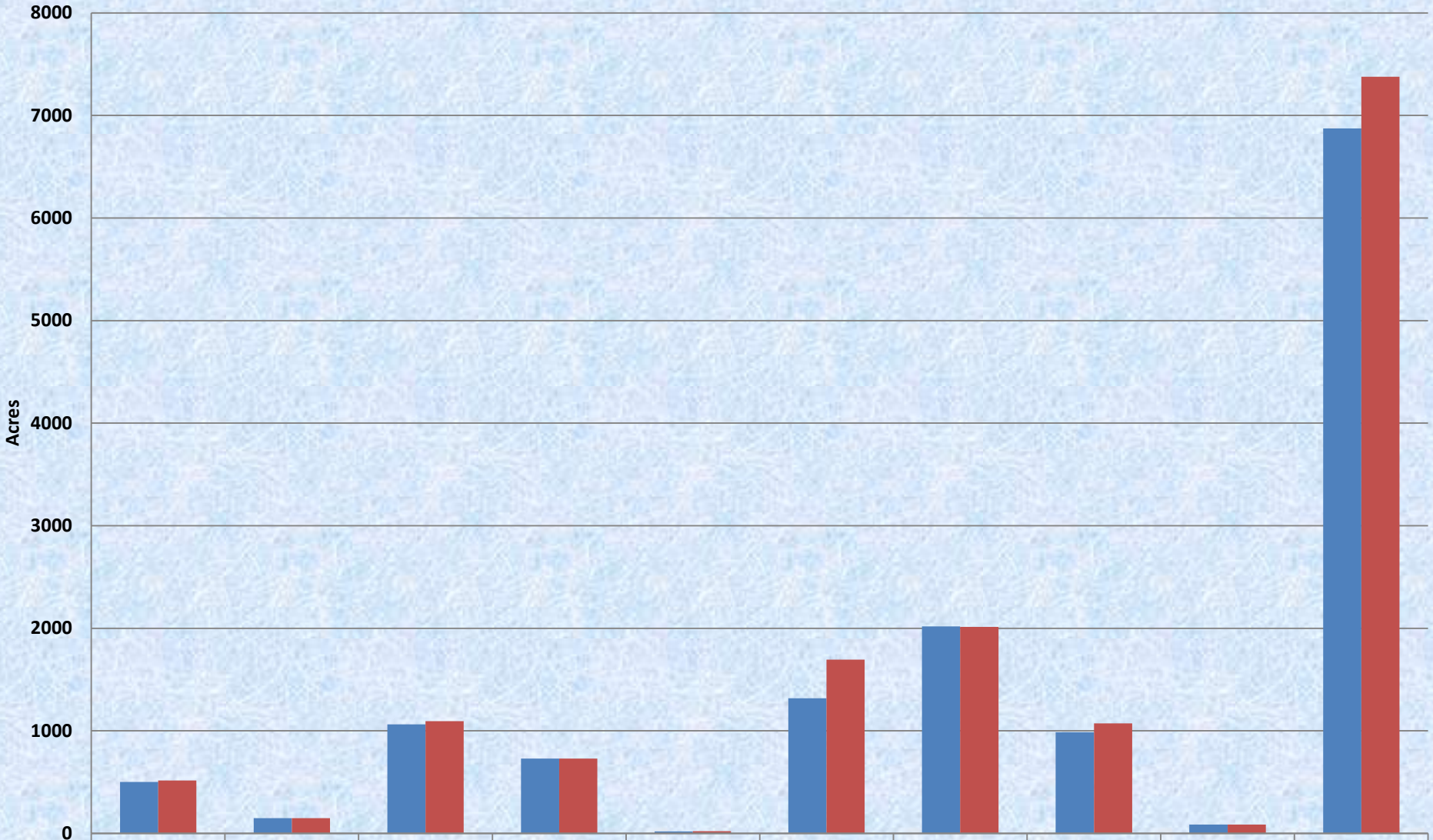
	Delaware Seashore State Park	Little Creek Wildlife Area
1997	718	1182
2002	730	1318
2007	731	1695

Average acres/year Gained of North Atlantic Low Salt Marsh 1997-2007



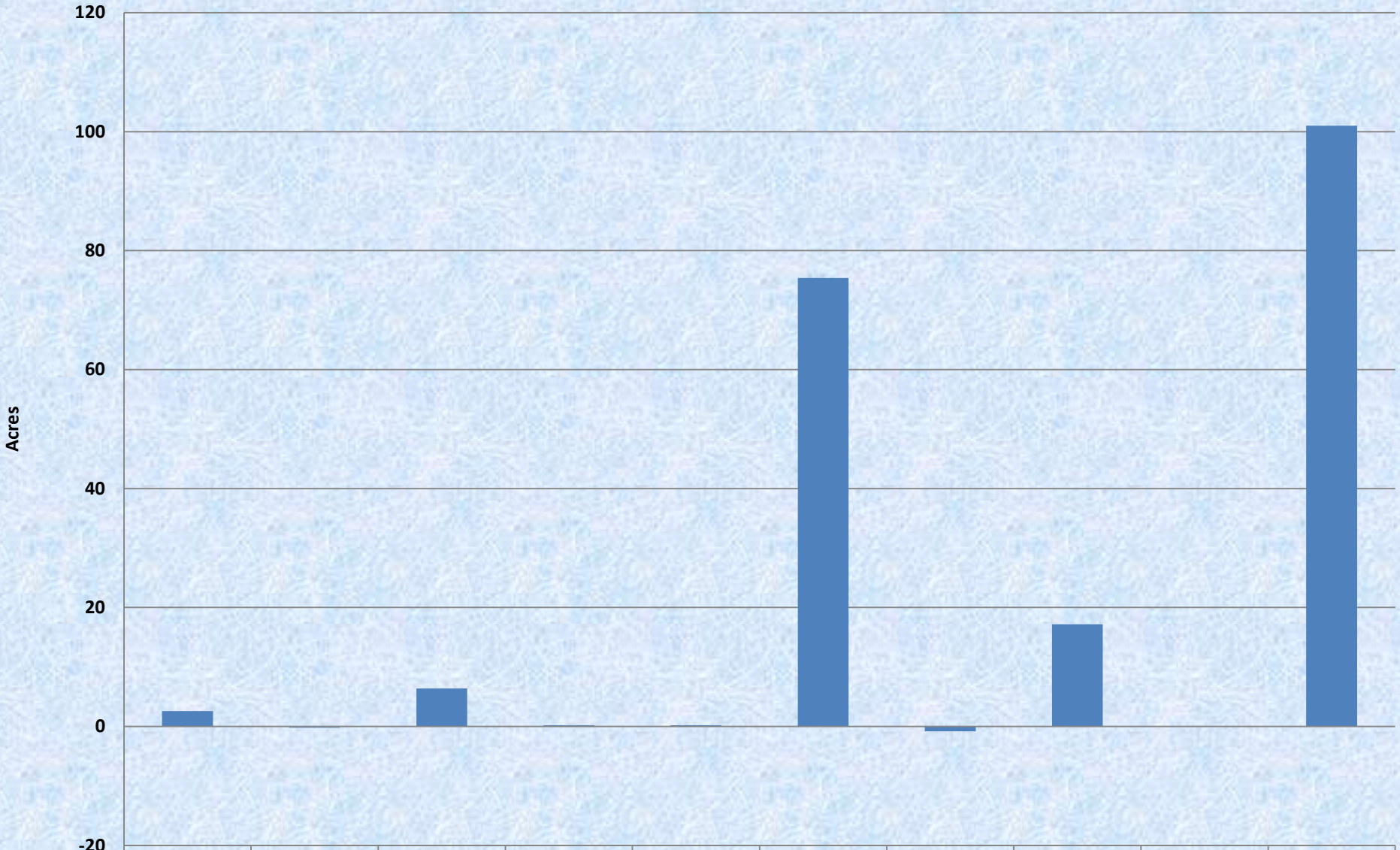
	Delaware Seashore State Park	Little Creek Wildlife Area
1997-2002	2.4	27.2
1997-2007	1.3	51.3
2002-2007	0.2	75.4

North Atlantic Low Salt Marsh
2002-2007



	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002	503	149	1063	730	20	1318	2018	987	86	6874
2007	516	148	1095	731	21	1695	2014	1073	86	7379

Average acres/year Gained or Lost of North Atlantic Low Salt Marsh 2002-2007



	Assawoman Wildlife Area	Augustine Wildlife Area	Cape Henlopen State Park	Delaware Seashore State Park	Fenwick Island State Park	Little Creek Wildlife Area	Milford Neck Wildlife Area	Ted Harvey Wildlife Area	Thompson Island NP	Total
2002-2007	2.6	-0.2	6.4	0.2	0.2	75.4	-0.8	17.2	0	101

North Atlantic Low Salt Marsh 1937-2007

North Atlantic Low Salt Marsh converted to		Converted to North Atlantic Low Salt Marsh	
North Atlantic Low Salt Marsh	4,599 acres	North Atlantic Low Salt Marsh	4,599 acres
Water	476 acres	North Atlantic High Salt Marsh	842 acres
Impoundment	359 acres	Impoundment	414 acres
North Atlantic High Salt Marsh	230 acres	Reed Tidal Marsh	282 acres
Eastern Reed Marsh	146 acres	Irregularly Flooded Eastern Tidal Salt Shrub	266 acres

Conclusions

- Water is currently inundating about 23 acres/year in the management areas studied.
- North Atlantic High Marsh is declining in most of the managed areas in Delaware and has a net loss of 2.8 acres/year.
- North Atlantic Low Salt Marsh is currently gaining 101 acres a year in the management areas studied but may start to decline once all of the North Atlantic High Salt Marsh and other marshes are converted to North Atlantic Low Salt Marsh.

Useful Websites

- NASA Climate Change: http://climate.nasa.gov
- Permanent Service for Mean Sea Level (www.psml.org)
- Additional information: 302-735-8672
  - Robert.Coxe@state.de.us

Questions?