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Cover Photo: The Scarlet Rose Mallow (also known as the Scarlet Swamp Hibiscus) is now blooming in our garden in Homewood. Its beautiful red flowers not only attract hummingbirds but also provide a rich source of nectar that gives hummingbirds their abundant energy. (Photo August 2, 2025, by W. Mike Howell)

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Editorial Comment:
On behalf of the Alabama Academy of Science, I would like to express my gratitude and appreciation to the reviewers for their valuable contributions in reviewing the manuscripts of this issue.

Thanks!
Brian Toone
Editor: Alabama Academy of Science Journal

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EXTRA

GENETIC IDENTIFICATION OF KEMP'S RIDLEY SEA TURTLE FROM EGGSHELLS FOUND AT A DEPREDATED NEST AT A NOVEL NESTING SITE

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ABSTRACT

Many sea turtles return to the same nesting grounds each year but due to factors such as climate change and anthropogenic development are forced to find new and novel nesting sites. Identifying sea turtle species using these novel sites is key to conservation. A depredated sea turtle nest was found at a novel nesting site in Alabama in the Summer of 2019. Based on the reproductive biology and natural history of turtle species inhabiting the region, this nest is most likely to have been one of four species known to inhabit the Northern Gulf of Mexico: Loggerhead, Kemp's ridley, or Green. Predation left limited evidence including relative size of the nest and eggshells devoid of any other tissues that could be used to determine turtle identification. Genomic DNA extraction from eggshells returned low yields due to limited amounts of DNA found within eggshells as well as the storage conditions of samples prior to extraction. Isolation required use of liquid nitrogen and an extended incubation in lysis buffer to maximize yield. A portion of the mitochondrial DNA was then amplified, and the turtle identified as a Kemp's ridley sea turtle (*Lepidochelys kempii*, Garman 1880).

INTRODUCTION

Sea turtles are known to exhibit natal homing for nesting beaches and there are increasing and emergent threats to nesting grounds (Bowen and Karl 2007, Lamont et al. 2023, Robinson et al. 2023), therefore determining nesting locations is vital to conservation efforts (Lamont et al. 2023, Scott et al. 2022). The Kemp's ridley (*Lepidochelys kempii*) is currently listed as critically endangered and their primary nesting site is located along the Gulf of Mexico (GOM) within 30.2 km of Rancho Nuevo area in Tamaulipas, Mexico (Bevan et al. 2016, Wibbels and Bevan 2019). Since the 1970's, a head start program has been in place to aid in species recovery and a second viable nesting location at Padre Island National Seashore in Texas, USA has been established. However, between 1989-2014, 118 Kemp's ridley nests were documented outside these primary nesting grounds (Shaver et al. 2016, Shaver and Caillouet 2015) suggesting potential for exploratory nesting similar to what has been seen in loggerhead sea turtles (*Caretta caretta*) in the Mediterranean (Hochscheid et al. 2022). Sea turtle rookeries are ephemeral over geologic time and breakdown of fidelity to natal homing grounds is required for new rookeries to be established perhaps in the face of *L. kempii* recovery (Johnson et al. 1999). It is imperative to monitor potential new nesting areas in the face of a changing climate, anthropogenic disturbance, and the complex population dynamics of this critically endangered species (Bevan et al. 2016, Wibbels and Bevan 2019).

Developing methodologies and strategies for how to recognize the presence of a rare and endangered species without direct visual confirmation of the mother or hatchlings is an important step in these monitoring efforts. With live specimens not always available for DNA extraction, alternative DNA sources have been used to identify species and haplotypes including bones (Krestoff et al. 2021), dead hatchlings or, eggshells collected within 15 hours of deposition with their contents discarded (Lamont et al. 2023, Shamblin, Dodd, Bagley, et al. 2011, Shamblin et al. 2012). Egg shells are expected to have lower DNA concentrations that tissues such as skin or blood (Schmaltz et al. 2006). Multiple studies have successfully used unincubated eggs for amplification of RFLPs, mtDNA, and microsatellites(Lamont et al. 2023, Moore et al. 2003, Shamblin, Dodd, Williams, et al. 2011). Shamblin et al. (2011) reported unsuccessful amplification of DNA samples from swabs of the outer portion shells described in Schmaltz et al. (2006). This study aimed to (i) develop a method for successfully extracting template DNA from eggshells that had been opened and exposed for more than 15 hours and little to no associated membranes or other tissues and (ii) identify the species of turtle nesting at a novel site discovered by volunteers working with a local sea turtle conservation group.

METHODS

The eggs used in this study were found in a depredated nest near Cedar Point, Mobile County, Alabama in July 2019 (Figure 1). This location is within the northeast portion of the Mississippi Sound and part of the northern Gulf of Mexico. Volunteers with Share the Beach and Alabama Coastal Foundation found and collected the eggshell fragments from the nest site within 24 hours of depredation. After collection, the eggshells were stored in dry bags at -20°C for 4 years and finally in 95% ethanol at -80°C.

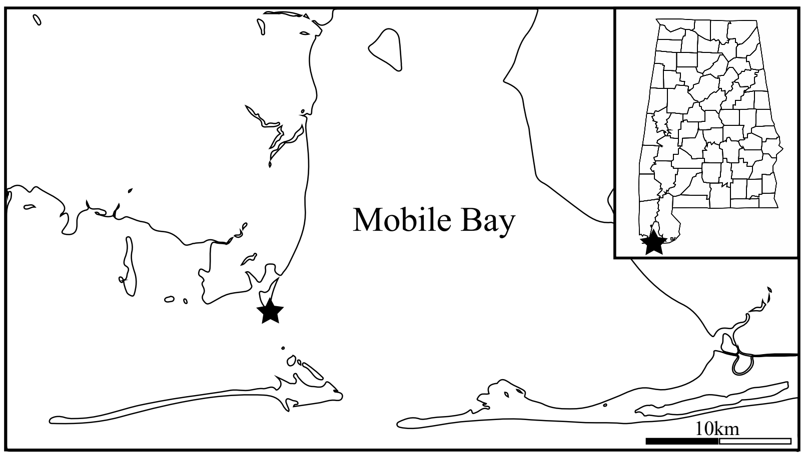

Figure 1: Location of depredated nest found in July 2019

A PureLink™ Genomic DNA Mini Kit (Thermo Fisher Scientific) was used for extraction per the protocol with modification. The eggshells were flash frozen using liquid nitrogen, minced with a pestle and finally, incubated in lysis buffer for 24 h at 55°C. Extraction continued per the protocol following lysis. A positive control was created using loggerhead sea turtle tissue. All extractions were quantified using ThermoScientific NanoDrop Lite Spectrophotometer and TECAN infinite M200 PRO.

An amplicon from the mitochondrial NADH:ubiquinone oxidorecutase core subunit 4 (MT-NAD4) was generated for species identification. The 371 bp long MT-NAD4 amplicon was generated with the primers: F–5′AAGCTCATGTAGAAGCCCCA3′ and R–5′TGTTCGGCTGTGAGTTCGTT-3′ (Krestoff et al. 2021). PCR reactions were conducted in 26.5 µL volumes of 1.5 µL $MgCl_2$, 9.5 µL H2O, 12.5 µL Phusion TAQ, 1 µL F primer, 1 µL R primer, 1 µL template DNA under the following conditions: 2 min at 94˚C; 15 s at 95˚C, 1 min at 55˚C, and 20 s at 72˚C for 30 cycles; 10 min at 72˚C, and hold at 4˚C. Amplification was verified using a 1% agarose gel before sequencing. Alignment, trimming of primers and extraction of consensus sequences was done in Geneious Prime software v.24.0.3. Sequences were then compared to reference sequences within NCBI for species identification.

RESULTS AND DISCUSSION

Modifying the manufacturer protocol to include both a flash freezing step and an extended incubation provided the best results in relation to quantity and purity of DNA. We obtained a mean yield of 17.37 ng/µL and a mean purity of 1.639 (260/280). However, yield and purity data were not indicative of DNA quality and positive amplification was independent of samples demonstrating high yield or purity or both.

Additionally, sequence quality scores were typically low and required multiple rounds of resequencing. Sequencing and subsequent BLAST searches confirmed the species was Kemp's ridley sea turtle (*Lepidochelys kempii*).

The positive species identification using degraded eggshell tissue validates another technique for genetic identification of sea turtles and an additional tool for use in surveying novel nesting locations. This technique extends methodologies previously developed for fresh eggshells by Shamblin and others. Aerial and ground surveys have been used for such identification (Lamont et al. 2023; Scott et al. 2022). Ground truthing in these surveys included collection of tissues for genetic identification including undeveloped eggs, embryos, and/or dead hatchlings in some combination. This study provides additional methodologies for identification when those more DNA rich samples are not available due to predation events.

After four years of storage of a suboptimal tissue source, DNA was extracted and amplified for use in species identification. We recommend incorporating use of liquid nitrogen in eggshell processing as well as increased incubation times and temperatures as others have suggested (Shamblin, Dodd, Williams, et al. 2011). The larger conclusion and next steps are to engage nesting beach monitoring programs to ensure early and proper storage of any shells found. This could include providing these patrols with collection kits that include 50 mL conical tubes with 95% ethanol along with directions for storage in a freezer and a phone number of a research group to contact.

The results of this study also document a novel nesting site for a Kemp's ridley sea turtle in the bay system of Alabama. Kemp's ridley nests are periodically documented in low numbers along the coast of Alabama, but this is the first report of nest within the bay system (i.e. eastern portion of the Mississippi Sound).

DATA AVAILABILITY AND ETHICS STATEMENT

The sequence data presented in this study can be found in online repositories. The name of the repository and accession number are: https://www.ncbi.nlm.nih.gov/genbank, PP858890. Ethical review and approval were not required for the animal study as there were no materials acquired from living individuals. Egg shell samples were obtained postmortem (Alabama Coastal Foundations FWS permit 100012).

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AN EXAMINATION OF THE SUNSPOT AREAL DATASET, 1875–2023: PAPER III, THE MAGNETIC COMPLEXITY OF SUNSPOTS

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ABSTRACT

This is the third paper in a three-part study of the sunspot areal dataset, 1875–present. Paper I (Wilson 2020) provided an overview of the areal dataset and gave some predictions for annual minimum and maximum amplitudes of specific parameters, noting that the minimum between solar cycles (SCs) 24 and 25 would likely be prolonged. Paper II (Wilson 2021) examined areal hemispheric differences, noting that SC12 had the smallest northern hemispheric annual maximum sunspot area (SSA(N)), while SC19 had the largest SSA(N), and that SC14 had the smallest southern hemispheric annual maximum sunspot area (SSA(S)), while SC18 had the largest SSA(S). Furthermore, the average time from minimum to maximum SSA was found to be about 3.8 years for SSA(N) and about 4.8 years for SSA(S). In Paper III, the magnetic complexity of sunspot groups is examined in terms of the: (1) Zurich visual classes (1875–1976), (2) Mount Wilson magnetic classes (MWC, 1982–2023), and (3) McIntosh modified Zurich visual classes (MMZ, 1982–2023). (No visual or magnetic classification of sunspot groups is available for the interval 1977–1981 in the solar areal dataset.)

INTRODUCTION

As noted in the Abstract, this is the third part of a three-part study of the sunspot areal dataset, 1875–present (http://solarcyclescience.com/activeregions.html). It will examine the variation of simple and complex spot groups over the sunspot cycle and the relationship between the MWC and MMZ for sunspot groups. Also examined are: (1) the number of single spots (N(SS)) in comparison to the number of types A and A+H spots, where A and H refer to the magnetic classification using MWC and MMZ, and (2) the annual area of simple and complex spot groups and the mean yearly area per spot group of simple and complex spots over the sunspot cycle (1982–2023).

A sunspot first appears as a tiny pore measuring only a few arc seconds in diameter (Kiepenheuer 1953). Rapid growth usually follows, increasing both in size (to several square degrees) and number (of individual spots forming the spot group). Many spots last no more than a day, while others continue to grow and develop into more complex entities. Waldmeier (1947) developed a classification scheme used to describe the development process of sunspot groups called the Zurich classification system for sunspot groups, consisting of nine classes, A–J (with no type I), numbered 1–9 in the solar areal dataset. (The areal dataset also includes a class 0, which is similar in areal size to class A spot groups, although the exact meaning of class 0 is uncertain; Hathaway 2023).

Based on the Zurich classification system (Kiepenheuer 1953), as well as the MMZ classification system (McIntosh 1990), a spot group classified as type A (i.e., 1) is one consisting of one or more tiny spots of unipolar magnetic field with no penumbra (the shadowy part outside the darker umbral region of a sunspot). A spot group classified as type B (i.e., 2) is one that has bipolar magnetic field and no penumbra. A spot group classified as type C is a bipolar spot group of two or more individual spots with one of the spots having penumbra. Type D spot groups are bipolar spots with both the leading and following spots having penumbra and the spots spread out <10 degrees of solar longitude. Type E spot groups are like type D spot groups but are spread over a longer solar longitude (10–15 degrees). Type F spot groups are like types D and E except they are spread out >15 degrees of solar longitude. A type G spot group is a large bipolar group spread out >10 degrees in solar longitude, but without small spots between the two major spots. A type H spot group is a unipolar spot with penumbra and sometimes with complicated structure and a diameter >2.5 degrees. A type J spot group is like a type H spot, but it is round in shape with a diameter <2.5 degrees. (The MMZ scheme is the same as the Zurich scheme, but omits types G and J, incorporating them instead into other Zurich types. The MMZ system also uses additional descriptors regarding the largest spot and the degree of spottiness within the group interior and is based on the spot group's appearance in white light (McIntosh 1990).)

In contrast, the MWC is a system based on the magnetic polarities of individual sunspots in the group and the distribution of the surrounding plage (the bright region around active regions observed in strong chromospheric lines, such as Hα (Martres and Bruzek 1977), rather than the visual appearance of the spot group (Hale, Ellerman, Nicholson, and Joy 1919; Greatrix and Curtis 1973; Jaeggli and Norton 2016). Three major classes form the MWC, including alpha (a unipolar spot group, identified as A in the solar areal dataset), beta (a bipolar spot group, identified as B, and gamma (a complex spot group, identified as G). The complex group is further divided into several sub-classifications, including BG, BD, GD, and BGD, where D indicates a delta configuration which exists when an inversion line separates umbrae of opposite polarity within the same penumbral area. (In the solar areal dataset, the MWC is identified using A, B, G, BG, BD, GD, and BGD. Spot groups identified as types A and B are considered simple spot groups, while those identified as types G, BG, BD, GD, and BGD are considered complex spot groups (Martres and Bruzek 1977).)

The description of spot groups in the sunspot areal dataset uses the Zurich classification system during the Royal Greenwich Observatory (RGO) portion, May 1874–December 1976. For the interval January 1977–December 1981, the sunspot areal dataset has no magnetic or visual classifications given for spot groups. For the interval starting in January 1982 through the present, the classification of spot groups in the sunspot areal dataset uses both the MWC and the MMZ magnetic/visual classification systems. (A discussion of the errors associated with the RGO dataset can be found in Willis, Coffey, Henwood, Erwin et al. 2013; Willis, Henwood, Wild, Coffey et al. 2013; Foukal 2013; and by David Hathaway in http://solarcyclescience.com/activeregions.html.)

METHODS AND MATERIALS

Annual sunspot number (SSN) is taken from https://www.sidc.be/SILSO/datafiles, while all other parameters are determined from http://solarcyclescience.com/activeregions.html. In this study, complex spot groups are taken to be Zurich types 4–7 during the RGO timeframe 1875–1976 (i.e., D, E, F, and G), while they are taken to be G, BG, BD, GD, and BGD based on MWC and D, E, and F based on MMZ during the interval 1982–2023. No determination of magnetic or visual complexity for sunspot groups is included in the sunspot areal dataset for the interval 1977–1981.

RESULTS AND DISCUSSION

Table 1 displays yearly values and counts for: (1) SSN, (2) SSA (corrected sunspot area in millionths of a solar hemisphere), (3) NARE (number of active region entries where each entry in the solar areal dataset indicates the daily occurrence of an individual spot group), (4) Zurich group types 1–9 (corresponding to Waldmeier's A, B, C, etc.) and 0, and (5) N(S) and N(C), where N(S) is the number of simple spot groups, types 0–3, 8, and 9, and N(C) is the number of complex spot groups, types 4–7 for the interval 1875–1976. Cyclic means are given for each sunspot cycle SC12–20, as well as for the overall interval 1875–1976. (The meaning of type 0 is uncertain (Hathaway 2023).)

Table 1. Royal Greenwich Observatory (RGO) Zurich Group Type distribution, 1875–1976.

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
SC11															
1875	28.3	213.1	394	144	51	90	8	44	0	0	44	13	0	306	88
1876	18.9	109.3	265	117	22	34	16	9	0	0	65	0	2	191	74
1877	20.7	92.9	229	70	53	53	9	7	0	0	37	0	0	185	44
SC12															
1878m	5.7	22.2	81	45	8	15	2	11	0	0	0	0	0	70	11
1879	10.0	36.3	117	41	26	8	2	30	0	0	8	2	0	79	38
1880	53.7	446.8	775	256	172	48	49	147	30	18	47	8	0	533	242
1881	90.5	679.5	1423	541	202	161	28	100	128	54	175	34	0	966	457
1882	99.0	968.0	1622	545	268	236	107	102	82	18	220	16	28	1200	422
1883M	106.1	1148.9	1792	604	387	199	84	58	66	15	304	33	42	1349	443
1884	105.8	1034.1	2039	813	268	222	159	60	88	30	337	38	24	1524	515
1885	86.3	810.2	1522	492	248	187	110	49	83	13	297	30	13	1080	442
1886	42.4	379.4	750	284	85	103	46	32	98	12	57	19	14	551	199
1887	21.8	177.3	452	158	54	91	55	24	27	1	25	17	0	375	77

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
1888	11.2	87.9	265	86	44	32	38	34	20	0	6	5	0	205	60
mean	57.5	526.4	985	351	160	118	62	59	57	15	134	18	11	721	264
sd	41.2	422.0	716	261	125	86	49	41	43	16	135	14	15	524	196
sum	-	-	10838	3865	1762	1302	680	647	622	161	1476	202	121	7932	2906
SC13															
1889m	10.4	76.7	191	84	24	12	19	6	10	2	10	11	13	163	28
1890	11.8	98.8	258	72	27	63	27	8	16	10	3	12	20	221	37
1891	59.5	566.4	1252	363	200	121	79	129	56	78	61	21	144	928	324
1892	121.7	1211.3	2321	723	271	174	130	284	279	95	142	9	214	1521	800
1893M	142.0	1460.6	3071	850	338	284	86	240	423	236	142	11	461	2030	1041
1894	130.0	1281.5	2740	840	399	228	93	152	371	218	105	10	324	1894	846
1895	106.6	973.4	2134	448	240	199	54	131	326	265	109	48	314	1303	831
1896	69.4	547.4	1182	259	154	135	11	157	96	122	38	52	158	769	413
1897	43.8	511.7	903	165	233	64	0	34	51	46	104	4	202	668	235
1898	44.4	374.7	777	174	93	74	7	69	85	87	69	14	105	467	310
1899	20.2	110.0	384	100	79	38	0	44	60	29	2	3	29	249	135
1900	15.7	74.3	273	86	39	21	7	4	8	0	33	0	75	228	45
mean	63.5	607.2	1291	347	175	118	43	87	148	99	68	16	172	870	420
sd	50.3	506.5	1227	300	126	88	44	86	154	94	52	17	139	670	364
sum	-	-	15486	4164	2097	1413	513	1258	1781	1188	818	195	2059	10441	5045
SC14															
1901m	4.6	27.9	78	40	13	10	0	0	0	0	15	0	0	63	15
1902	8.5	59.5	134	31	13	24	0	12	30	7	7	0	10	78	56
1903	40.8	338.6	760	201	94	76	2	110	94	52	46	7	78	458	302
1904	70.1	488.2	1374	242	163	84	11	263	195	100	135	10	171	681	693
1905M	105.5	1195.9	1937	237	251	115	10	341	182	191	227	34	349	996	941
1906	90.1	775.0	1859	207	285	116	36	246	257	135	189	12	376	1032	827
1907	102.8	1092.1	1951	248	356	90	47	278	136	124	191	47	434	1222	729
1908	80.9	697.5	1686	359	247	92	15	209	51	85	150	10	468	1191	495

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
1909	73.2	691.5	1442	268	201	58	55	185	125	127	168	25	230	837	605
1910	30.9	266.0	766	114	103	54	19	90	34	83	86	5	178	473	293
1911	9.5	64.4	279	82	40	27	2	14	5	14	16	13	66	230	49
1912	6.0	37.3	154	33	20	8	0	22	2	9	32	9	19	89	65
mean	51.9	477.8	1035	172	149	63	16	148	93	77	105	14	198	613	423
sd	39.5	413.6	754	108	119	39	19	121	86	62	80	14	172	441	335
sum	-	-	12420	2062	1786	754	197	1770	1111	927	1262	172	2379	7350	5070
SC15															
1913m	2.4	7.5	60	5	14	7	0	9	0	0	9	3	13	42	18
1914	16.1	152.4	436	93	42	43	0	38	25	41	15	9	130	317	119
1915	79.0	697.8	1864	512	414	130	62	89	91	182	89	96	199	1413	451
1916	95.0	725.5	2290	647	363	162	86	252	103	105	251	72	249	1579	711
1917M	173.6	1533.9	3510	929	404	274	103	524	123	280	350	63	460	2233	1277
1918	134.6	1112.6	2904	939	341	190	38	403	116	218	264	57	338	1903	1001
1919	105.7	1054.7	2249	758	315	152	80	306	60	184	162	53	179	1537	712
1920	62.7	617.3	1396	475	155	95	29	178	101	94	92	56	121	931	465
1921	43.5	419.6	943	281	120	63	14	174	73	51	86	9	72	559	384
1922	23.7	252.0	543	218	47	37	10	105	10	28	46	13	29	354	189
mean	73.6	657.3	1620	486	222	115	42	208	70	118	136	43	179	1087	533
sd	54.9	476.0	1137	334	161	82	38	165	45	93	116	32	140	749	398
sum	-	-	16195	4857	2215	1153	422	2078	702	1183	1364	431	1790	10868	5327
SC16															
1923m	9.7	54.7	244	103	32	10	1	21	24	4	20	15	14	175	69
1924	27.9	278.0	589	174	40	62	6	68	36	123	7	16	57	355	234
1925	74.0	825.1	1718	487	252	134	30	218	108	136	30	27	296	1226	492
1926	106.5	1263.2	2210	719	219	114	65	424	86	187	131	5	260	1392	828
1927	114.7	1060.8	2369	714	224	140	19	420	154	140	141	42	375	1514	855
1928M	129.7	1388.9	2613	773	218	121	67	482	164	237	167	69	315	1563	1050
1929	108.2	1238.9	2413	763	276	155	27	367	187	189	127	13	309	1543	870

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
1930	59.4	516.6	1394	431	144	78	38	297	115	76	76	6	133	830	564
1931	35.1	279.1	781	230	81	89	7	143	14	122	17	8	70	485	296
1932	18.6	163.2	471	222	43	29	10	55	20	42	13	0	37	341	130
mean	68.4	706.9	1480	462	153	93	27	250	91	126	73	20	187	942	539
sd	44.4	597.8	905	267	96	48	24	172	65	71	63	21	137	565	349
sum	-	-	14802	4616	1529	932	270	2495	908	1256	729	201	1866	9414	5388
SC17															
1933m	9.2	91.3	225	93	19	4	0	50	20	17	6	0	16	132	93
1934	14.6	118.2	337	138	32	13	5	67	9	46	0	0	27	215	122
1935	60.2	622.1	1290	439	75	79	11	301	109	134	19	0	123	727	563
1936	132.8	1140.8	2706	763	131	197	92	465	164	397	107	4	386	1573	1133
1937M	190.6	2072.8	3705	1075	266	279	126	620	111	569	150	3	506	2255	1450
1938	182.6	2015.2	3401	1143	166	357	196	441	99	391	102	14	492	2368	1033
1939	148.0	1576.8	2892	1047	236	145	128	345	100	381	156	14	340	1910	982
1940	113.0	1037.2	2118	619	166	223	7	401	54	327	151	3	167	1185	933
1941	79.2	658.1	1473	445	110	111	20	258	39	223	71	33	163	882	591
1942	50.8	427.3	1014	355	43	125	15	141	45	80	102	12	96	646	368
1943	27.1	296.8	495	186	71	31	0	33	10	83	13	5	63	356	139
mean	91.6	914.2	1787	573	120	142	55	284	69	241	80	8	216	1114	673
sd	65.7	716.9	1250	386	82	113	69	193	50	182	61	10	182	806	463
sum	-	-	19656	6303	1315	1564	600	3122	760	2648	877	88	2379	12249	7407
SC18															
1944m	16.1	124.7	370	142	21	25	0	89	0	7	16	7	63	258	112
1945	55.3	426.5	1103	405	44	150	18	163	74	47	80	11	111	739	364
1946	154.3	1823.9	2838	906	92	300	52	338	252	328	290	24	256	1630	1208
1947M	214.7	2634.1	4298	1353	315	452	111	525	362	225	205	160	590	2981	1317
1948	193.0	1974.6	3892	1295	417	418	105	367	311	121	273	27	558	2820	1072
1949	190.7	2140.0	3903	1321	344	397	107	322	310	116	291	67	628	2864	1039
1950	118.9	1227.3	2333	830	190	228	73	133	195	141	125	29	389	1739	594

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
1951	98.3	1135.3	1861	592	174	200	49	143	133	136	54	10	370	1395	466
1952	45.0	402.9	963	336	86	152	41	54	67	28	26	4	169	788	175
1953	20.1	145.1	431	178	11	80	10	34	14	22	11	7	64	350	81
mean	110.6	1203.4	2199	736	169	240	57	217	172	117	137	35	320	1556	643
sd	75.0	909.0	1488	475	145	147	41	162	133	101	117	48	220	1044	476
sum	-	-	21992	7358	1694	2402	566	2168	1718	1171	1371	346	3198	15564	6428
SC19															
1954m	6.6	34.6	166	73	7	28	0	12	0	15	0	0	31	139	27
1955	54.2	552.4	1183	326	86	147	50	139	76	40	22	5	292	906	277
1956	200.7	2394.7	3820	1008	363	273	83	373	329	254	134	37	966	2730	1090
1957M	269.3	3048.5	4855	1252	357	336	114	441	331	278	337	65	1344	3468	1387
1958	261.7	3011.3	5016	1300	385	259	197	766	688	160	413	0	848	2989	2027
1959	225.1	2872.9	4514	943	586	190	203	549	371	251	392	12	1017	2951	1563
1960	159.0	1641.2	3259	742	438	88	82	427	329	27	483	17	526	1993	1266
1961	76.4	613.5	1586	499	143	62	49	198	151	39	216	8	221	982	604
1962	53.4	463.5	1027	306	59	33	38	147	95	43	91	8	207	651	376
1963	39.9	287.8	819	284	77	15	45	65	136	0	70	0	127	548	271
mean	134.6	1492.0	2625	673	250	140	86	312	251	121	216	15	558	1736	889
sd	99.6	1236.6	1859	437	198	116	67	240	201	109	178	21	454	1225	669
sum	-	-	26245	6733	2501	1431	861	3117	2506	1207	2158	152	5579	17357	8888
SC20															
1964m	15.0	53.9	390	138	29	41	18	56	15	0	26	0	67	293	97
1965	22.0	113.3	506	126	66	56	0	73	3	0	182	0	0	248	258
1966	66.8	592.6	1498	382	106	219	9	199	45	0	512	12	14	742	756
1967	132.9	1519.1	3390	1198	355	408	92	275	129	51	820	37	25	2115	1275
1968M	150.0	1569.8	2963	975	394	206	120	452	85	26	641	55	9	1759	1204
1969	149.4	1450.1	2932	572	695	105	48	662	81	47	659	9	54	1483	1449
1970	148.0	1601.3	3379	720	588	152	85	953	90	27	761	3	0	1548	1831
1971	94.4	990.2	2229	632	327	134	29	507	66	0	498	13	23	1158	1071

				Zurich Group Type											
Year	**SSN**	**SSA**	**NARE**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N(S)**	**N(C)**
1972	97.6	916.7	2263	550	305	187	14	535	29	18	605	20	0	1076	1187
1973	54.1	457.6	1203	274	247	69	35	246	13	9	310	0	0	625	578
1974	49.2	398.9	1096	391	119	73	18	204	29	4	243	7	8	616	480
1975	22.5	166.4	473	117	112	14	3	119	17	12	79	0	0	246	227
mean	83.5	819.2	1860	506	279	139	39	357	50	16	445	13	17	992	868
sd	52.4	600.8	1143	341	210	108	39	271	39	18	269	17	22	630	549
sum	-	-	22322	6075	3343	1664	471	4281	602	194	5336	156	200	11979	10413
SC21 (incomplete)															
1976m	18.4	169.8	426	82	151	10	7	56	22	0	98	0	0	250	176
1875-1976															
mean	78.4	780.7	1581	455	182	126	45	206	105	97	153	19	191	1020	561
sd	62.3	721.2	1235	361	148	102	48	192	118	111	173	25	242	807	465

Notes: m denotes year of SSN minimum
M denotes year of SSN maximum
SSN means annual sunspot number
SSA means annual sunspot area
NARE means number of active region entries
N(S) means number of simple regions (i.e., 0+1+2+3+8+9)
N(C) means number of complex regions (i.e., 4+5+6+7)

Similarly, Table 2 displays yearly values, counts, cyclic means, and overall interval means for SSN, SSA, NARE, and the MWC types A, B, G, BG, BD, GD, and BGD for the interval 1977–2023, where types A and B are considered simple spot groups and types G, BG, BD, GD, and BGD are considered complex spot groups. Table 3 gives the yearly values, counts, cyclic means, and overall means for the interval 1977–2023 for the MMZ classes, where simple spot groups are considered to be types A, B, C, and H, and complex spot groups are considered to be types D, E, and F. (As stated earlier, no magnetic classification values are given for MWC and MMZ for the interval 1977–1981.)

Table 2. Distribution of USAF/NOAA MWC magnetic classes, 1977–2023.

					USAF/NOAA Group Type								
Year	**SSN**	**SSA**	**NARE**	**NC**	**A**	**B**	**G**	**BG**	**BD**	**GD**	**BGD**	**N(S)**	**N(C)**
SC21 (continued)													
1977	39.3	347.0	926	926	-	-	-	-	-	-	-	-	-
1978	131.0	1368.5	4035	4035	-	-	-	-	-	-	-	-	-

					USAF/NOAA Group Type								
Year	**SSN**	**SSA**	**NARE**	**NC**	**A**	**B**	**G**	**BG**	**BD**	**GD**	**BGD**	**N(S)**	**N(C)**
1979M	220.1	2194.5	5439	5439	-	-	-	-	-	-	-	-	-
1980	218.9	2160.7	3965	3965	-	-	-	-	-	-	-	-	-
1981	198.9	2270.2	3920	3920	-	-	-	-	-	-	-	-	-
1982	162.4	2220.1	3686	88	1386	1836	1	181	51	19	124	3222	376
1983	91.0	919.5	2371	37	941	1219	0	101	30	1	42	2160	174
1984	60.5	811.7	1474	14	532	812	5	36	26	0	49	1344	116
1985	20.6	179.0	604	7	244	327	0	7	5	0	14	571	26
mean	116.1*	1182.1*	2685*	2048	776	1049	2	81	28	5	57	1824	173
sd	80.9*	961.3*	1753*	2238	497	639	2	77	19	9	47	1135	148
sum	-	-	26846*	18431	3103	4194	6	325	112	20	229	7297	692
SC22													
1986m	14.8	124.7	394	2	185	188	1	11	6	0	1	373	19
1987	33.9	296.8	938	0	402	520	0	12	4	0	0	922	16
1988	123.0	1345.3	2900	0	1135	1617	0	94	12	2	40	2752	148
1989M	211.1	2579.2	4734	1	1716	2738	0	143	39	1	96	4454	279
1990	191.8	2048.7	4751	1	1943	2630	0	114	23	1	39	4573	177
1991	203.3	2470.2#	4715	3	1836	2578	2	150	66	2	78	4414	297
1992	133.0	1349.2	3314	0	1387	1759	1	95	29	2	41	3146	168
1993	76.1	696.2	1886	0	858	959	0	48	11	0	10	1817	69
1994	44.9	340.4	1205	0	519	652	0	22	7	0	5	1171	34
1995	25.1	159.6	707	4	297	384	2	13	2	0	5	681	22
mean	105.7	1141.0	2554	1	1028	1403	1	70	20	1	32	2430	123
sd	77.2	959.8	1761	1	669	994	1	56	20	1	34	1659	108
sum	-	-	25544	11	10278	14025	6	702	199	8	315	24303	1229
SC23													
1996m	11.6	81.9	306	0	126	162	0	13	2	0	3	288	18
1997	28.9	210.2	686	0	233	400	0	39	0	0	14	633	53
1998	88.3	763.1	1937	0	587	1206	0	113	11	1	19	1793	144
1999	136.3	1162.0	2733	0	751	1754	2	176	5	0	45	2505	228

					USAF/NOAA Group Type								
Year	**SSN**	**SSA**	**NARE**	**NC**	**A**	**B**	**G**	**BG**	**BD**	**GD**	**BGD**	**N(S)**	**N(C)**
2000M	173.9	1614.2	3587	0	1043	2263	0	226	14	4	37	3306	281
2001	170.4	1704.1	3476	0	1043	2000	1	306	7	0	119	3043	433
2002	163.6	1828.7	3528	0	1023	2030	0	317	16	0	142	3053	475
2003	99.3	1099.2	2145	0	600	1243	0	211	5	2	84	1843	302
2004	65.3	683.8	1311	0	403	680	1	139	8	0	80	1083	228
2005	45.8	542.6	973	0	287	517	0	116	19	0	34	804	169
2006	24.7	245.1	600	0	212	308	0	61	1	0	18	520	80
2007	12.6	133.3	308	0	123	162	0	12	1	0	10	285	23
mean	85.1	839.0	1799	0	536	1061	0	144	7	1	50	1596	203
sd	62.9	635.2	1281	-	359	790	1	105	6	1	46	1147	151
sum	-	-	21590	0	6431	12725	4	1728	89	7	605	19156	2434
SC24													
2008m	4.2	22.8	122	0	40	82	0	0	0	0	0	122	0
2009	4.8	26.6	123	0	29	89	0	4	1	0	0	118	5
2010	24.9	214.3	623	0	247	347	0	26	1	0	2	594	29
2011	80.8	751.2	1788	0	536	1036	0	154	8	0	54	1572	216
2012	84.5	796.9	1848	1	571	1089	0	137	6	0	44	1660	187
2013	94.0	860.8	2121	0	694	1078	0	249	15	0	85	1772	349
2014M	113.3	1252.2	2442	0	703	1217	0	364	22	0	136	1920	522
2015	69.8	618.8	1544	0	474	824	0	177	18	0	51	1298	246
2016	39.9	225.2	910	0	302	561	0	33	5	0	9	863	47
2017	21.7	217.5	477	0	223	208	0	33	1	0	12	431	46
2018	7.0	24.4	161	0	55	99	0	6	1	0	0	154	7
mean	49.5	455.5	1105	0	352	603	0	108	7	0	36	973	150
sd	40.0	418.9	867	0	256	457	-	120	8	-	44	730	171
sum	-	-	12159	1	3874	6630	0	1184	78	0	393	10704	1654
SC25 (incomplete)													
2019m	3.6	37.9	97	0	50	43	0	1	2	0	1	93	4
2020	8.8	85.1	224	0	116	100	0	8	0	0	0	216	8

					USAF/NOAA Group Type								
Year	**SSN**	**SSA**	**NARE**	**NC**	**A**	**B**	**G**	**BG**	**BD**	**GD**	**BGD**	**N(S)**	**N(C)**
2021	29.6	249.2	729	0	287	383	0	47	8	0	4	670	59
2022	83.2	863.3	1788	0	577	1050	0	106	22	0	33	1627	161
2023	125.3	1143.6	2703	0	950	1388	0	229	68	0	61	2345	358
1982-2023													
mean@	85.4	879.6	1942	-	611	965	0	105	14	1	39	1577	157
sd@	68.0	767.5	1507	-	501	776	1	96	17	3	41	1263	144

Notes: m denotes year of SSN minimum
M denotes year of SSN maximum
SSN means annual sunspot number
SSA means annual sunspot area
NARE means number of active region entries
means one entry (11/19/1991, region 6924B) had an erroneous areal measurement, which has been excluded
NC means number with no USAF/NOAA Group Type classification
* means it includes 1976 values (SSN, SSA, and NARE)
N(S) means number of simple regions (i.e., A+B)
N(C) means number of complex regions (i.e., G+BG+BD+GD+BGD)
@ denotes that mean/sd for SSN, SSA, and NARE are for 1977−2023

Table 3. Distribution of MMZ magnetic classes, 1982–2023.

Year	**A**	**B**	**C**	**D**	**E**	**F**	**H**	**NARE**	**N(S)**	**N(C)**
SC21 (incomplete)										
1982	658	583	649	652	347	91	706	3686	2596	1090
1983	586	426	466	359	137	47	350	2371	1828	543
1984	335	308	275	222	104	53	177	1474	1095	379
1985	173	109	141	84	24	1	72	604	495	109
mean	225	357	383	329	153	48	326	2034	1504	530
sd	271	200	222	243	138	37	278	1317	910	414
sum	1752	1426	1531	1317	612	192	1305	8135	6014	2121
SC22										
1986m	114	53	80	60	10	4	73	394	320	74
1987	246	205	165	95	84	2	141	938	757	181
1988	692	524	483	375	270	119	437	2900	2136	764
1989M	1047	946	891	617	398	223	612	4734	3496	1238
1990	1155	926	804	644	356	140	726	4751	3611	1140

Year	**A**	**B**	**C**	**D**	**E**	**F**	**H**	**NARE**	**N(S)**	**N(C)**
1991	1155#	856#	825	721	336	197	625	4715#	3461	1254
1992	852	531	571	497	238	85	540	3314	2494	820
1993	520	276	287	300	131	37	335	1886	1418	468
1994	296	232	215	171	69	12	210	1205	953	252
1995	215	147	135	83	37	0	90	707	587	120
mean	629	470	446	356	193	82	379	2554	1904	647
sd	407	339	312	252	144	84	242	1761	1307	457
sum	6292	4696	4336	3563	1929	819	3789	25424	19113	6311
SC23										
1996m	88	74	52	34	20	0	38	306	252	54
1997	149	152	138	89	56	16	86	686	525	161
1998	293	436	408	279	154	67	300	1937	1437	500
1999	313	488	584	443	305	159	441	2733	1826	907
2000M	320	460	787	779	392	122	727	3587	2294	1293
2001	267	275	709	877	376	191	781	3476	2032	1444
2002	268	258	717	1006	380	138	761	3528	2004	1524
2003	171	161	479	647	185	68	434	2145	1245	900
2004	106	122	230	323	164	63	303	1311	761	550
2005	65	53	189	325	99	20	222	973	529	444
2006	90	52	161	124	50	4	119	600	422	178
2007	38	45	57	66	14	3	85	308	225	83
mean	181	215	376	416	183	71	326	1799	1129	670
sd	105	167	273	336	145	67	287	1281	767	535
sum	2168	2576	4511	4992	2047	851	3594	21590	13552	8038
SC24										
2008m	23	36	22	23	2	0	16	122	97	25
2009	25	49	13	21	10	1	4	123	91	32
2010	98	106	112	102	40	15	150	623	466	157
2011	162	254	361	429	181	29	372	1788	1149	639
2012	150	165	402	513	160	36	422	1848	1139	709

Year	A	B	C	D	E	F	H	NARE	N(S)	N(C)
2013	176	208	498	526	166	29	518	2121	1400	721
2014M	208	235	551	622	260	68	498	2442	1492	950
2015	168	180	400	277	142	70	307	1544	1055	489
2016	87	132	236	192	46	0	217	910	672	238
2017	52	44	83	68	36	23	171	477	350	127
2018	47	44	35	27	0	0	8	161	134	27
mean	109	132	247	255	95	25	244	1105	731	374
sd	67	82	203	230	89	26	193	867	535	337
sum	1196	1453	2713	2800	1043	238	2683	12159	8045	4114
SC25 (incomplete)										
2019m	18	15	21	9	2	0	32	97	86	11
2020	32	33	51	12	7	5	84	224	200	24
2021	105	102	161	157	22	0	182	729	550	179
2022	159	199	420	352	204	37	417	1788	1195	593
2023	278	250	622	576	263	44	670	2703	1820	883
1982-2023										
mean	286	256	345	308	149	53	320	1737	1207	530
sd	302	239	260	268	130	61	240	1371	962	447

Notes: # means includes 3 Xs, 2 counted as As (1991–01–24 and 1991–01–26) and 1 counted as a B (1991–01–29)
1 B was ignored due to bad areal entry (1991–11–19)
N(S) means number of simple regions (i.e., A+B+C+H)
N(C) means number of complex regions (i.e., D+E+F)

Figure 1 displays the yearly variation of SSN, SSA, and NARE for the overall interval 1875–2023 (late SC11 to early SC25). The unfilled triangles across the top display the occurrence of SSN maximum for SC12–24. Plainly, the parameters are highly correlated, although subtle differences exist. For example, comparison of SSN and SSA reveals that all minimum yearly values occurred simultaneously for SC12–25, while maximum yearly values of SSA were delayed by two years for SC20, 21, and 23. Similarly, comparison of SSN and NARE reveals that all minimum yearly values occurred simultaneously for SC12–25, while maximum yearly values of NARE were delayed by one year for SC12, 19, and 22, and by two years for SC14 and 20. Between SC12 and 19, values of SSN, SSA, and NARE trended upward, while they trended downward in value after SC19. Also, SC25, the current ongoing SC, is now known to be of larger SSN and NARE yearly values in comparison to the maximum values for SC24. (SSA for SC25 has not as yet exceeded the maximum observed yearly value for SC24, although it is expected to do so in 2024.)

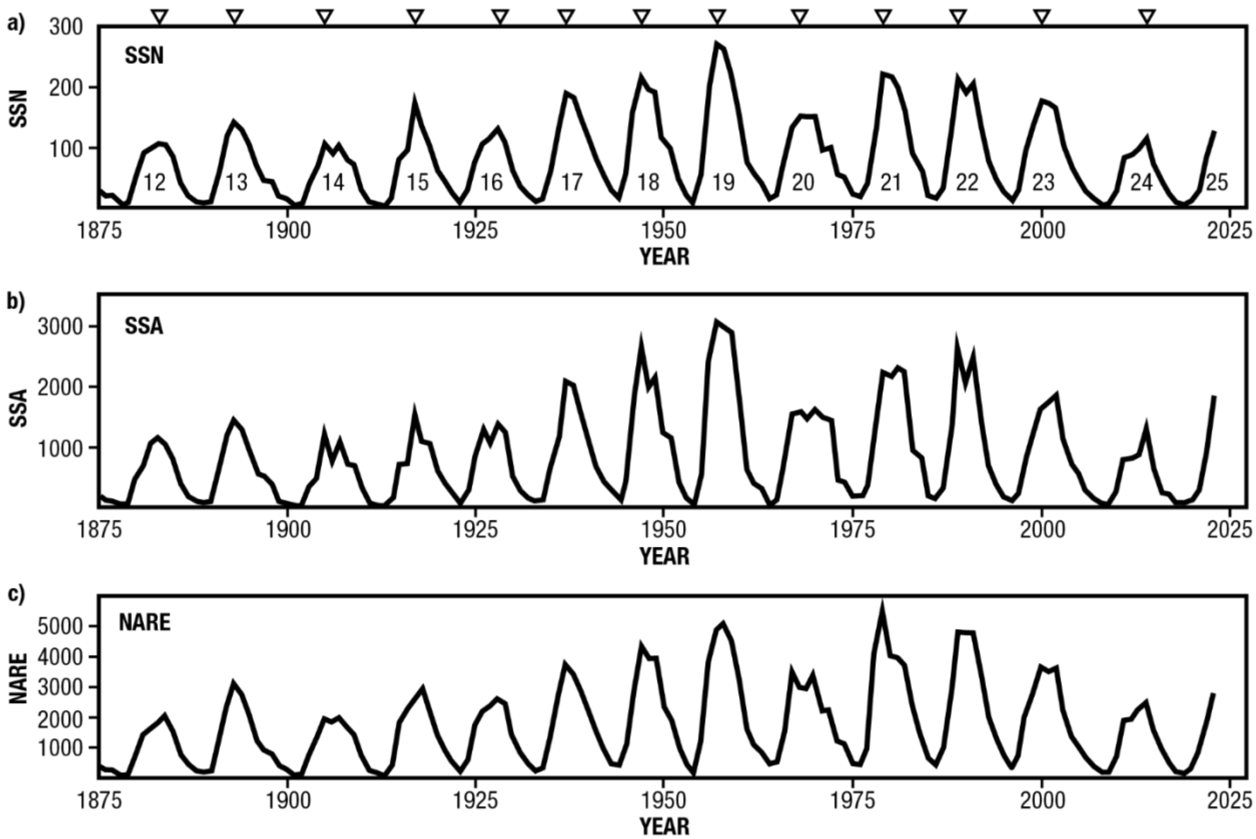

Figure 1. Yearly variation of (a) SSN, (b) SSA, and (c) NARE, 1875–2023.

From Figure 1 (and Tables 1 and 2), one finds the mean maximum value for SSN for SC12–24 to be 153.8, with a standard deviation (sd) equal to 62.8. For SSA, its mean maximum value and sd are 1,847.3 millionths of a solar hemisphere and 620 millionths of a solar hemisphere, respectively, and for NARE to be 3,280 and 1,421, respectively.

Figure 2 shows the annual variation of N(S) and N(C) for the overall interval of 1875–2023 based on the combined Zurich and MMZ determinations. Recall that N(S) for the RGO interval (1875–1976) includes types 0–3 plus 8 and 9, while for the MMZ interval (1982-2023) N(S) includes types A–C plus H, and N(C) includes types 4–7 for the RGO interval and types D–F for the MMZ interval. No determination of N(S) and N(C) appears in the sunspot areal dataset for the interval 1977–1981. Plainly, N(S) and N(C) increase between SC12 and 19 and decrease after SC19 (like that found for SSN, SSA, and NARE). Interestingly, SC23 is found to have had more complex spot groups than SC22, an SC of much larger SSN maximum yearly value (211.1 vs. 173.9, respectively). Minimum yearly values of N(S) and N(C) almost always occur simultaneously with SSN minimum occurrence (only SC21 had its N(S) minimum value one year earlier). On the other hand, the maximum yearly value of N(S) appears one year later for SC12, 17, and 22, and the maximum value of N(C) occurs one year later than SSN maximum for SC12 and 19 and two years later for SC20, 22, and 23. Also, N(C) for SC25, the current ongoing SC, has not as yet had a yearly value larger than was seen for SC24, although it is a larger cycle in comparison (125.3 in 2023 for SC25 as compared to 113.3 in 2014 for SC24). The mean maximum value and sd for N(S) for SC12–24 are 2,442 and 969, respectively (excluding SC21), and the maximum value and sd for N(C) for SC12–24 are 1,062 and 549, respectively.

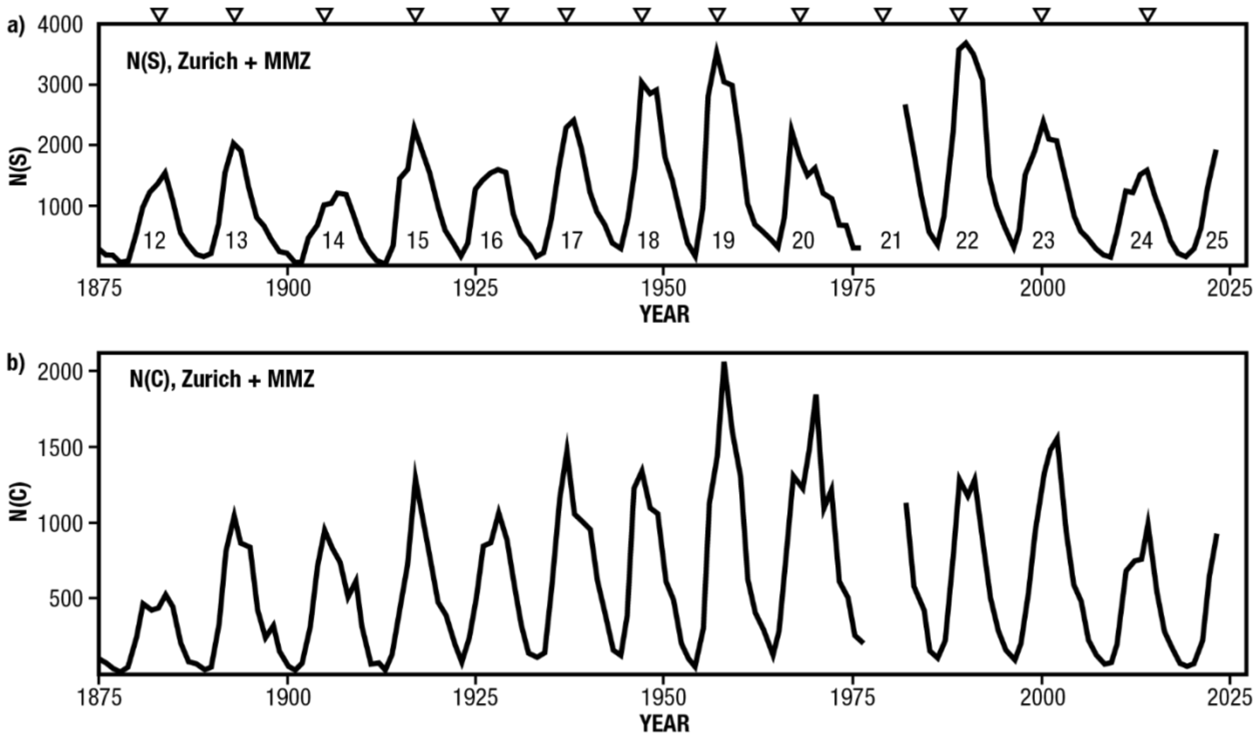

Figure 2. Yearly variation of (a) N(S) and (b) N(C) based on Zurich and MMZ, 1875–2023.

Figure 3 depicts the yearly variation of N(S) and N(C) for the interval 1982–2023 based on the MWC. Interestingly, complex spot groups increased in number between SC22 and 24, while simple spot groups decreased in number. Minimum yearly values of N(S) and N(C) usually occur simultaneously with SSN minimum occurrence (the exception being N(S) for SC21, which occurred one year earlier), while the maximum yearly value for N(S) occurs one year later for SC22, and the maximum value for N(C) occurs two years later for SC22 and 23. In contrast with MMZ N(C) values, SC24 had the larger N(C) yearly value as compared with SC23 (based on the MWC, 522 vs. 475) and was considerably larger than the SC22 N(C) maximum yearly value (298). (SC25 had N(C) = 358 in 2023 and measured 258 between January and June 2024, suggesting that N(C) for SC25 likely will exceed its 2023 value.)

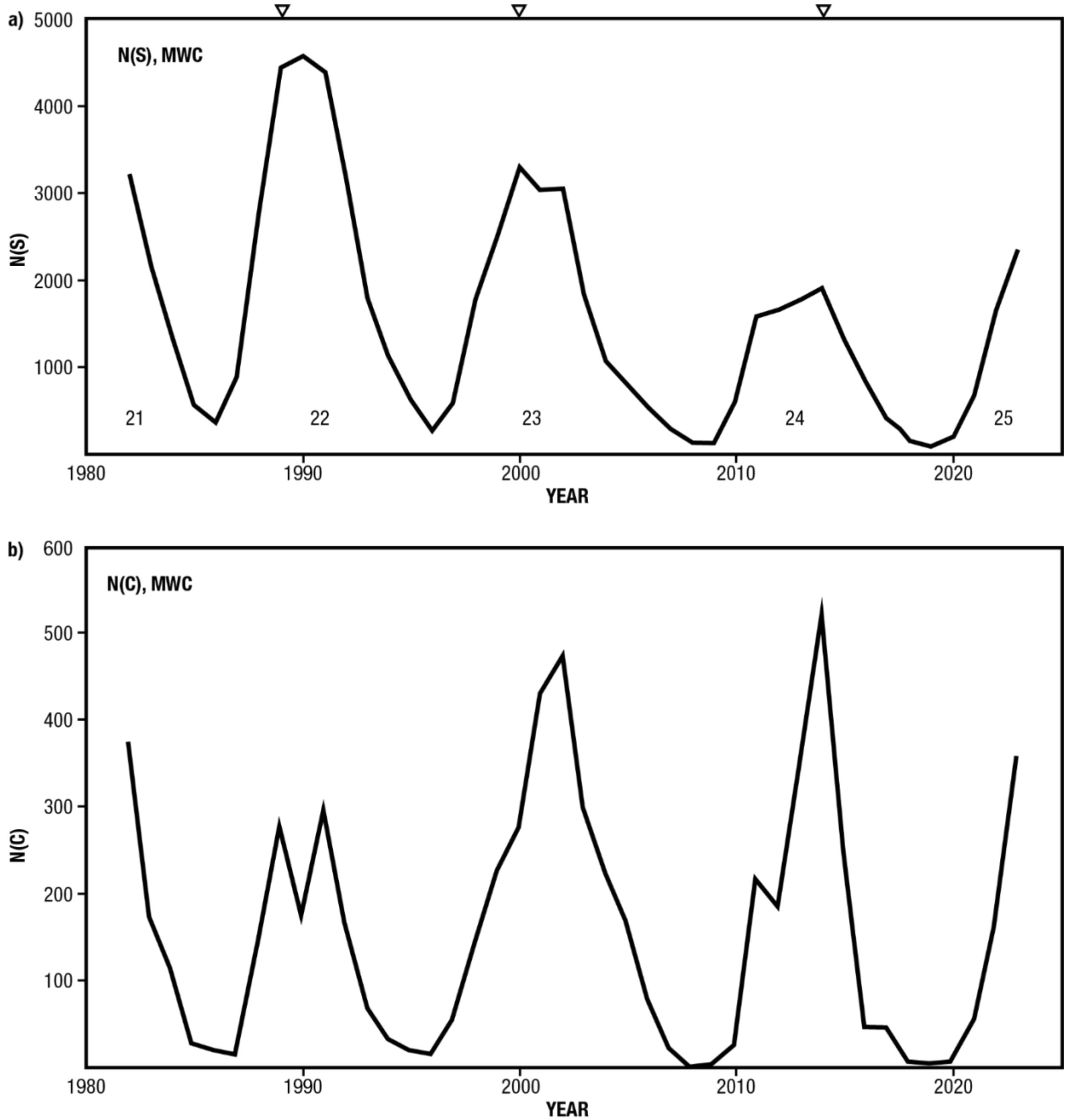

Figure 3. Yearly variation of (a) N(S) and (b) N(C) based on MWC, 1982–2023.

Table 4 gives the yearly parametric values and means and sds for SSN, SSA, NARE, N(S), and N(C) for SC12–24 for elapsed times t = 0–9 years, where t = 0 is the year of SSN minimum occurrence. Figure 4 compares SC25 values (the filled circles) against the means for each of the parameters. From Figure 4, one sees that SC25 values are below the mean values for all parameters (except N(C)) based on MWC at t = 4 years. The elapsed time of occurrence for SSN maximum is shown for SC12–24, where SC16, 18, 19, 21, and 22 had SSN maximum at t = three years; SC13, 14, 15, 17, 20, and 23 had SSN maximum at t = 4 years; SC12 had SSN maximum at t = 5 years; and SC24 had SSN maximum at t = 6 years. (SSN for SC25 measures

125.3 at t = 4 years. SSN maximum for SC25 is expected to occur in 2024 or 2025 at t = 5 or 6, respectively (Wilson 2019 a, b, 2022 and 2023).)

Table 4. Yearly parametric values for t = 0–9.

SSN														
t	**SC12**	**SC13**	**SC14**	**SC15**	**SC16**	**SC17**	**SC18**	**SC19**	**SC20**	**SC21**	**SC22**	**SC23**	**SC24**	**<SSN>/sd**	**SC25**
0	5.7	10.4	4.6	2.4	9.7	9.2	16.1	6.6	15.0	18.4	14.8	11.6	4.2	9.9/5.1	3.6
1	10.0	11.8	8.5	16.1	27.9	14.6	55.3	54.2	22.0	39.3	33.9	28.9	4.8	25.2/16.7	8.8
2	53.7	59.5	40.8	79.0	74.0	60.2	154.3	200.7	66.8	131.0	123.0	88.3	24.9	88.9/49.9	29.6
3	90.5	121.7	70.1	95.0	106.5	132.8	214.7	269.3	132.9	220.1	211.1	136.3	80.8	144.8/63.2	83.2
4	99.0	142.0	105.5	173.6	114.7	190.6	193.0	261.7	150.0	218.9	191.8	173.9	84.5	161.5/51.7	125.3
5	106.1	130.0	90.1	134.6	129.7	182.6	190.7	225.1	149.4	198.9	203.3	170.4	94.0	154.2/44.2	
6	105.8	106.6	102.8	105.7	108.2	148.0	118.9	159.0	148.0	162.4	133.0	163.6	113.3	128.9/24.2	
7	86.3	69.4	80.9	62.7	59.4	113.0	98.3	76.4	94.4	91.0	76.1	99.3	69.8	82.8/15.9	
8	42.4	43.8	73.2	43.5	35.1	79.2	45.0	53.4	97.6	60.5	44.9	65.3	39.9	55.7/18.5	
9	21.8	44.4	30.9	23.7	18.6	50.8	20.1	39.9	54.1	20.6	25.1	45.8	21.7	32.1/13.0	

SSA															
t	**SC12**	**SC13**	**SC14**	**SC15**	**SC16**	**SC17**	**SC18**	**SC19**	**SC20**	**SC21**	**SC22**	**SC23**	**SC24**	**<SSA>/sd**	**SC25**
0	22.2	76.7	27.9	7.5	54.7	91.3	124.7	34.6	53.9	169.8	124.7	81.9	22.8	68.7/48.7	37.9
1	36.3	98.8	59.5	152.4	278.0	118.2	426.5	552.4	113.3	347.0	296.8	210.2	26.6	208.9/162.0	85.1
2	446.8	566.4	338.6	697.8	825.1	622.1	1823.9	2394.7	592.6	1368.5	1345.3	763.1	214.3	923.0/634.9	249.2
3	679.5	1211.3	488.2	725.5	1263.2	1140.8	2634.1	3048.5	1519.1	2194.5	2579.2	1162.0	751.2	1492.1/845.1	863.3
4	968.0	1460.6	1195.9	1533.9	1060.8	2072.8	1974.6	3011.3	1569.8	2160.7	2048.7	1614.2	796.9	1651.4/602.8	1143.6
5	1148.9	1281.5	775.0	1112.6	1388.9	2015.2	2140.0	2872.9	1450.1	2270.2	2470.2	1704.1	860.8	1653.1/652.0	
6	1034.1	973.4	1092.1	1054.7	1238.9	1576.8	1227.3	1641.2	1601.3	2220.1	1349.2	1828.7	1252.2	1391.5/364.6	
7	810.2	547.4	697.5	617.3	516.6	1037.2	1135.3	613.5	990.2	919.5	696.2	1099.2	618.8	792.2/218.8	
8	379.4	511.7	691.5	419.6	279.1	658.1	402.9	463.5	916.7	811.7	340.4	683.8	225.2	521.8/212.5	
9	177.3	374.7	266.0	252.0	163.2	427.3	145.1	287.8	457.6	179.0	159.6	542.6	217.5	280.7/130.1	

NARE

t	**SC12**	**SC13**	**SC14**	**SC15**	**SC16**	**SC17**	**SC18**	**SC19**	**SC20**	**SC21**	**SC22**	**SC23**	**SC24**	**<NARE>/sd**	**SC25**
0	81	191	78	60	244	225	370	166	390	426	394	306	122	235/132	97
1	117	258	134	436	589	337	1103	1183	506	926	938	686	123	564/377	224
2	775	1252	760	1864	1718	1290	2838	3820	1498	4035	2900	1937	623	1947/1128	729
3	1423	2321	1374	2290	2210	2706	4298	4855	3390	5439	4734	2733	1788	3043/1371	1788
4	1622	3071	1937	3510	2369	3705	3892	5016	2963	3965	4751	3587	1848	3249/1077	2703

5	1792	2740	1859	2904	2613	3401	3903	4514	2932	3920	4715	3476	2121	3145/947
6	2039	2134	1951	2249	2413	2892	2333	3259	3379	3686	3314	3528	2442	2740/621
7	1522	1182	1686	1396	1394	2118	1861	1586	2229	2371	1886	2145	1544	1763/369
8	750	903	1442	943	781	1473	963	1027	2263	1474	1205	1311	910	1188/413
9	452	777	766	543	471	1014	431	819	1203	604	707	973	477	711/245

N(S), Zurich and MMZ															
t	**SC12**	**SC13**	**SC14**	**SC15**	**SC16**	**SC17**	**SC18**	**SC19**	**SC20**	**SC21**	**SC22**	**SC23**	**SC24**	**<N(S)>/sd**	**SC25**
0	70	163	63	42	175	132	258	139	293	250	320	252	97	173/93	86
1	79	221	78	317	355	215	739	906	248	-	757	525	91	378/287	200
2	533	928	458	1413	1226	727	1630	2730	742	-	2136	1437	466	1202/710	550
3	960	1521	681	1579	1392	1573	2981	3468	2115	-	3496	1826	1149	1895/942	1195
4	1200	2030	996	2233	1514	2255	2820	2989	1759	-	3611	2294	1139	2069/803	1820
5	1349	1894	1032	1903	1563	2368	2864	2951	1483	-	3461	2032	1400	2025/746	
6	1524	1303	1222	1537	1543	1910	1739	1993	1548	2596	2494	2004	1492	1762/422	
7	1080	769	1191	931	830	1185	1395	982	1158	1828	1418	1245	1055	1159/280	
8	551	668	837	559	485	882	788	651	1076	1095	953	761	672	768/195	
9	375	467	473	354	341	646	350	548	625	495	587	529	350	472/111	

N(C), Zurich and MMZ															
t	**SC12**	**SC13**	**SC14**	**SC15**	**SC16**	**SC17**	**SC18**	**SC19**	**SC20**	**SC21**	**SC22**	**SC23**	**SC24**	**<N(C)>/sd**	**SC25**
0	11	28	15	18	69	93	112	27	97	176	74	54	25	61/49	11
1	38	37	56	119	234	122	364	277	258	-	181	161	32	157/109	24
2	242	324	302	451	492	563	1208	1090	756	-	764	500	157	571/328	179
3	457	800	693	711	828	1133	1317	1387	1275	-	1238	907	639	949/309	593
4	422	1041	941	1277	855	1450	1072	2027	1204	-	1140	1293	709	1119/400	883
5	443	846	827	1001	1050	1033	1039	1563	1449	-	1254	1444	721	1056/329	
6	515	831	729	712	870	982	594	1266	1831	1090	820	1524	950	978/374	
7	442	413	495	465	564	933	466	604	1071	543	468	900	489	604/217	
8	199	235	605	384	296	591	175	376	1187	379	252	550	238	421/273	
9	77	310	293	189	130	368	81	271	578	109	120	444	127	238/156	

Note: For SC12-21, N(S), and N(C) are based on RGO; for SC21-25, N(S) and N(C) are based on MMZ.

N(S), MWC						
t	**SC21**	**SC22**	**SC23**	**SC24**	**<N(S)>/sd**	**SC25**
0	-	373	288	122	261/128	93

1	-	922	633	118	558/407	216
2	-	2752	1793	594	1713/1081	670
3	-	4454	2505	1572	2844/1471	1627
4	-	4573	3306	1660	3180/1461	2345
5	-	4414	3044	1772	3077/1321	
6	3222	3146	3053	1920	2835/614	
7	2160	1817	1843	1298	2307/731	
8	1344	1171	1083	863	1115/200	
9	571	682	804	431	622/159	

N(C),	**MWC**					
t	**SC21**	**SC22**	**SC23**	**SC24**	**<N(C)>/sd**	**SC25**
0	-	19	18	0	12/11	4
1	-	16	53	5	25/25	8
2	-	148	144	29	107/68	59
3	-	279	228	216	241/33	161
4	-	177	281	187	215/57	358
5	-	298	432	349	360/68	
6	376	168	475	522	385/157	
7	174	69	302	246	198/101	
8	116	34	228	47	106/89	
9	26	21	169	46	66/70	

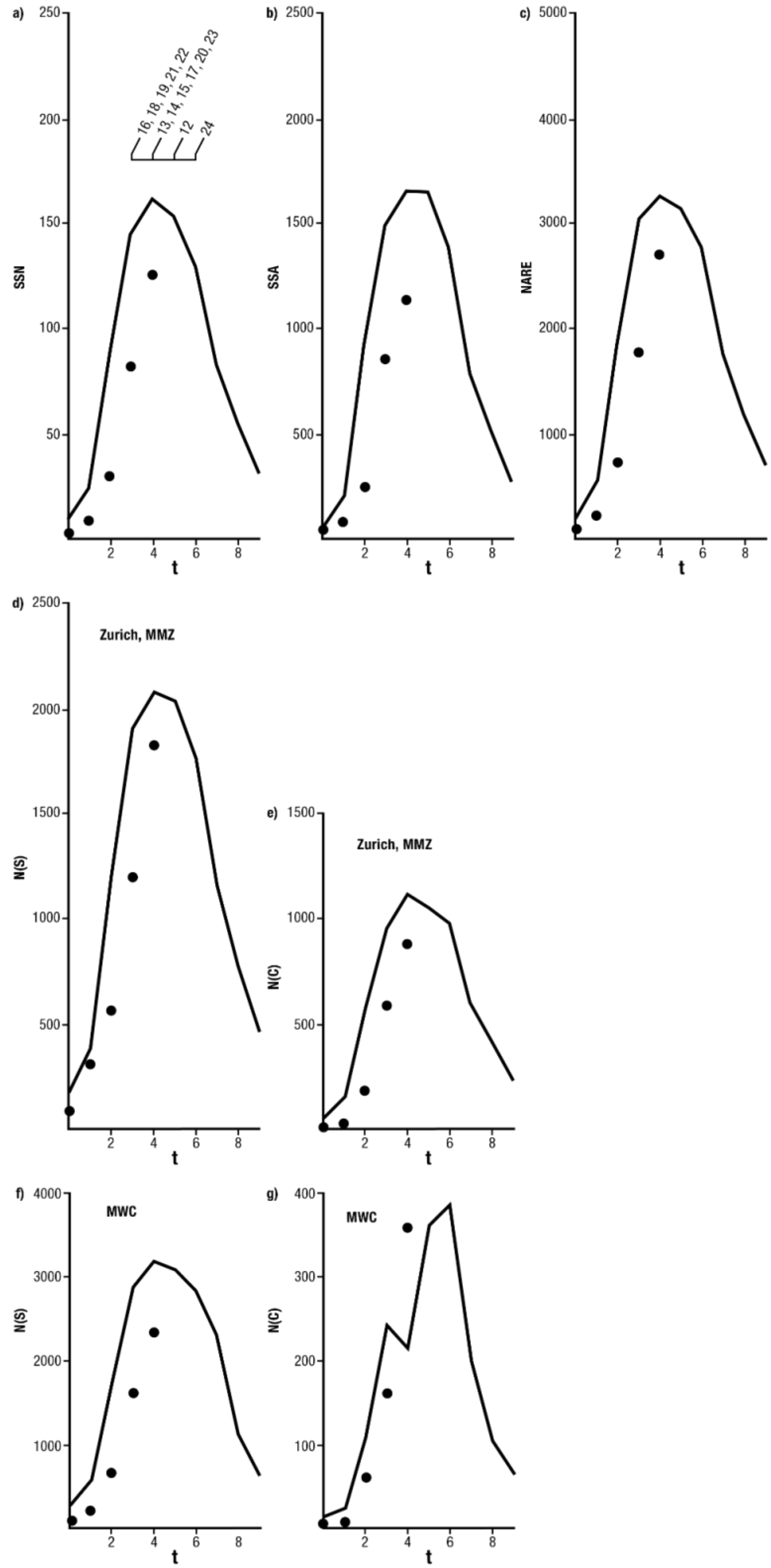

Figure 4. Comparison of SC25 parametric values (a) SSN, (b) SSA, (c) NARE, (d) N(S) based on Zurich and MMZ, (e) N(C) based on Zurich and MMZ, (f) N(S) based on MWC and (g) N(C) based on MWC for elapsed time t = 0–9 years.

Table 5 compares N(S), N(C), and N(D) values based on MWC during the interval 1982–2023, where N(D) is the number of delta spot groups (delta spots are strongly associated with great flares; Zirin and Liggett 1987; Zhongxian and Jingxiu 1994; and Sammis, Tang, and Zirin 2000. Interestingly, N(S), as a percentage of NARE, has decreased slightly between SC22 and SC24, from 95% to 86%, and the percentage of N(C) has increased from 5% to 14%. N(D) has remained fairly constant (about 3% of NARE). For SC22, 42% of the N(C) were delta configurations, with only about 29% and 28%, respectively, for SC23 and 24. For SC22 and 23, the largest yearly N(D) occurred two years after SSN maximum occurrence during the decline of the solar cycle. For SC24, yearly N(D) maximum coincided with yearly SSN maximum (at t = 6 years). (For the interval 1982–2023, N(D) comprises about 34% of the N(C).)

Table 5. Numbers and percentages of simple, complex, and delta spots based on MWC, 1982–2023.

Year	NARE	N(S)	N(C)	N(D)	P1	P2	P3	P4
SC21								
1982	3686	3222	376	194	87.4	10.2	5.3	51.6
1983	2371	2160	174	73	91.1	7.3	3.1	42.0
1984	1474	1344	116	75	91.2	7.9	5.1	64.7
1985	604	571	26	19	95.7	4.3	3.2	73.1
mean	2034	1824	173	90				
sd	1317	1135	148	74				
sum	8135	6087	692	361				
SC22								
1986m	394	373	19	7	94.7	4.8	1.8	36.8
1987	938	922	16	4	98.3	1.7	0.4	25.0
1988	2900	2752	148	54	94.9	5.1	1.9	36.5
1989M	4734	4454	279	136	94.1	5.9	2.9	48.8
1990	4751	4573	177	63	96.3	3.7	1.3	35.6
1991	4715	4414	298	146	93.6	6.3	3.1	49.0
1992	3314	3146	168	72	94.9	5.1	2.2	42.9
1993	1886	1817	69	21	96.3	3.7	1.1	30.0
1994	1205	1171	34	12	97.2	2.8	1.0	35.3
1995	707	681	22	6	96.3	3.0	0.9	28.6
mean	2554	2430	123	52				

Year	NARE	N(S)	N(C)	N(D)	P1	P2	P3	P4
sd	1761	1659	108	53				
sum	25544	24303	1230	521				
SC23								
1996m	306	288	18	5	94.1	5.9	1.6	27.8
1997	686	633	53	14	92.3	7.7	2.0	26.4
1998	1937	1793	144	31	92.6	7.4	1.6	21.5
1999	2733	2505	228	50	91.6	8.3	1.8	21.9
2000M	3587	3306	281	55	92.2	7.8	1.5	19.6
2001	3476	3043	433	126	87.6	12.4	3.6	29.2
2002	3528	3053	475	158	86.5	13.5	4.5	33.3
2003	2145	1843	302	91	85.9	14.1	4.2	30.1
2004	1311	1083	228	88	82.6	17.4	6.7	38.6
2005	973	804	169	53	82.6	17.4	5.5	31.4
2006	600	520	80	19	86.7	13.3	3.2	23.8
2007	308	285	23	11	92.5	7.5	3.6	47.8
mean	1799	1596	203	58				
sd	1281	1147	151	49				
sum	21590	19156	2434	701				
SC24								
2008m	122	122	0	0	100.0	0.0	0.0	
2009	123	118	5	1	95.9	4.1	0.8	20.0
2010	623	594	29	3	95.4	4.6	0.5	10.3
2011	1788	1572	216	62	87.9	12.1	3.5	28.7
2012	1848	1660	187	50	89.8	10.1	2.7	26.7
2013	2121	1772	349	100	83.6	16.5	4.7	28.7
2014M	2442	1920	522	158	78.6	21.4	6.5	30.3
2015	1544	1298	246	69	84.1	15.9	4.5	28.1
2016	910	863	47	14	94.8	5.2	1.5	29.8
2017	477	431	46	13	90.4	9.6	2.7	28.3
2018	161	154	7	1	95.7	4.3	0.6	14.3
mean	1105	955	150	43				

Year	NARE	N(S)	N(C)	N(D)	P1	P2	P3	P4
sd	867	710	171	51				
sum	12159	10504	1654	471				
SC25								
2019m	97	93	4	3	95.9	4.1	3.1	75.0
2020	224	216	8	0	96.4	3.6	0.0	0.0
2021	729	670	59	12	91.9	8.1	1.7	20.3
2022	1788	1627	161	55	91.0	9.0	3.1	34.2
2023	2703	2345	358	129	86.8	13.2	5.0	36.0
1982-2023								
mean	1737	1577	157	54				
sd	1371	1263	144	53				

Notes: NARE means the number of active region entries
N(S) means the number of simple spots (A+B)
N(C) means the number of complex spots (G+BG+BD+GD+BGD)
N(D) means the number of delta spots (BD+GD+BGD)
P1 is the percentage N(S)/NARE
P2 is the percentage N(C)/NARE
P3 is the percentage N(D)/NARE
P4 is the percentage N(D)/N(C)
m means minimum sunspot number occurrence
M means maximum sunspot number occurrence

Table 6 compares MMZ visual classes with MWC magnetic classes for N(C) and N(D). For the interval of 1982–2023, there were 6,600 N(C) based on MWC and 22,274 N(C) based on MMZ (from Table 3), of which 6,289 were also N(C) as determined using MWC; as stated earlier, types D–F are considered N(C) spots based on MMZ. Hence, 95.3% of the N(C) as determined using MWC were also N(C) as determined using MMZ (i.e., 6,289/6,600). Of the 22,274 N(C) as determined using MMZ, only 28.2% were also N(C) as determined using MWC (i.e., 6,289/22,274). Of the 6,600 N(C) as determined using MWC, 34.1% were also N(D) (i.e., 2,253/6,600). Of the 2,253 N(D), 97.3% were N(C) using MMZ (i.e., 2,191/2,253), while only 9.8% of the N(C) using MMZ were N(D) based on MWC (i.e., 2,191/22,274).

Table 6. Distribution of number of complex and delta spots based on MWC for MMZ, 1982–2023.

Year	class	A	B	C	D	E	F	H	total
SC21 (incomplete)									
1982	complex	1	3	15	98	190	67	2	376
	delta	1	0	6	39	94	53	1	194
1983	complex	1	2	10	65	61	35	0	174

Year	**class**	**A**	**B**	**C**	**D**	**E**	**F**	**H**	**total**
	delta	0	0	2	33	23	15	0	73
1984	complex	0	0	1	32	34	49	0	116
	delta	0	0	1	19	19	36	0	75
1985	complex	0	0	4	10	11	1	0	26
	delta	0	0	0	10	9	0	0	19
sum	complex	2	5	30	205	296	152	2	692
	delta	1	0	9	101	145	104	1	361
SC22									
1986	complex	0	1	3	9	5	1	0	19
	delta	0	0	0	4	2	1	0	7
1987	complex	0	0	2	8	6	0	0	16
	delta	0	0	0	2	2	0	0	4
1988	complex	1	0	5	33	55	54	0	148
	delta	1	0	1	9	15	28	0	54
1989	complex	1	1	9	33	102	133	0	279
	delta	1	0	3	14	53	65	0	136
1990	complex	1	0	5	38	72	61	0	177
	delta	0	0	3	12	24	24	0	63
1991	complex	2	1	15	77	92	109	2	298
	delta	1	1	8	42	37	57	0	146
1992	complex	1	1	16	45	68	37	0	168
	delta	1	0	3	24	36	8	0	72
1993	complex	1	0	4	22	23	19	0	69
	delta	1	0	1	11	6	2	0	21
1994	complex	0	0	4	11	11	8	0	34
	delta	0	0	0	7	5	0	0	12
1995	complex	0	1	2	11	8	0	0	22
	delta	0	0	0	3	4	0	0	7
sum	complex	7	5	65	287	442	422	2	1230
	delta	5	1	19	128	184	185	0	522

Year	class	A	B	C	D	E	F	H	total
SC23									
1996	complex	0	0	5	4	9	0	0	18
	delta	0	0	2	1	2	0	0	5
1997	complex	0	0	4	5	33	10	1	53
	delta	0	0	0	1	9	4	0	14
1998	complex	0	1	16	38	45	44	0	144
	delta	0	0	6	14	9	2	0	31
1999	complex	0	0	5	35	99	89	0	228
	delta	0	0	0	7	21	22	0	50
2000	complex	0	0	3	67	127	84	0	281
	delta	0	0	0	13	20	22	0	55
2001	complex	0	0	8	102	181	142	0	433
	delta	0	0	0	32	44	49	0	125
2002	complex	0	0	8	125	216	126	0	475
	delta	0	0	3	32	62	61	0	158
2003	complex	0	0	7	118	122	55	0	302
	delta	0	0	0	34	33	24	0	91
2004	complex	0	0	7	66	95	59	1	228
	delta	0	0	3	13	32	39	1	88
2005	complex	0	0	5	87	62	15	0	169
	delta	0	0	0	27	23	3	0	53
2006	complex	0	0	10	32	35	3	0	80
	delta	0	0	2	12	5	0	0	19
2007	complex	0	0	1	13	6	3	0	23
	delta	0	0	0	7	1	3	0	11
sum	complex	0	1	79	692	1030	630	2	2434
	delta	0	0	16	193	261	229	1	700
SC24									
2008	complex	0	0	0	0	0	0	0	0
	delta	0	0	0	0	0	0	0	0
2009	complex	0	0	0	4	1	0	0	5
	delta	0	0	0	0	1	0	0	1

Year	class	A	B	C	D	E	F	H	total
2010	complex	0	0	2	10	13	4	0	29
	delta	0	0	0	1	0	2	0	3
2011	complex	0	1	7	67	119	22	0	216
	delta	0	0	2	8	38	14	0	62
2012	complex	0	1	12	63	86	25	0	187
	delta	0	0	0	13	21	16	0	50
2013	complex	0	0	16	174	133	26	0	349
	delta	0	0	2	37	54	7	0	100
2014	complex	0	0	21	244	191	66	0	522
	delta	0	0	2	60	46	50	0	158
2015	complex	0	0	14	75	100	57	0	246
	delta	0	0	0	14	33	22	0	69
2016	complex	0	0	3	25	19	0	0	47
	delta	0	0	0	5	9	0	0	14
2017	complex	0	0	1	12	18	15	0	46
	delta	0	0	0	4	7	2	0	13
2018	complex	0	0	2	5	0	0	0	7
	delta	0	0	0	1	0	0	0	1
sum	complex	0	2	78	679	680	215	0	1654
	delta	0	0	6	143	209	113	0	471
SC25 (incomplete)									
2019	complex	0	0	1	2	1	0	0	4
	delta	0	0	1	2	0	0	0	3
2020	complex	0	0	0	3	1	4	0	8
	delta	0	0	0	0	0	0	0	0
2021	complex	0	0	8	38	13	0	0	59
	delta	0	0	1	8	3	0	0	12
2022	complex	0	0	7	48	83	23	0	161
	delta	0	0	1	21	25	8	0	55
2023	complex	0	0	15	145	165	33	0	358
	delta	0	0	0	58	59	12	0	129

Year	class	A	B	C	D	E	F	H	total
sum	complex	0	0	31	236	263	60	0	590
	delta	0	0	3	89	87	20	0	199
1982-2023									
	complex	9	13	283	2099	2711	1479	6	6600
	delta	6	1	53	654	886	651	2	2253

Note: Complex includes G, BG, BD, GD, and BGD
Delta includes BD, GD, and BGD only

Figure 5 displays the yearly variation of N(D) during the interval 1982–2023. Noticeable is that for SC22 and 23, the peak yearly N(D) followed SSN maximum by two years (i.e., during the declining phase of the solar cycle), while for SC24, yearly N(D) peaked simultaneously with SSN maximum (at t = 6). Also, SC21 had a larger N(D) (≥194) than SC22–24, and N(D) for both SC23 and 24 measured the same (N(D) = 158), even though SC23 was the larger SC (173.9 vs. 113.3). Yearly N(D) for SC25 is presently below that of SC21–24 but seems destined to be larger, reaching a maximum possibly in 2024–2026. (N(D) measures 110 for the interval January–June 2024.)

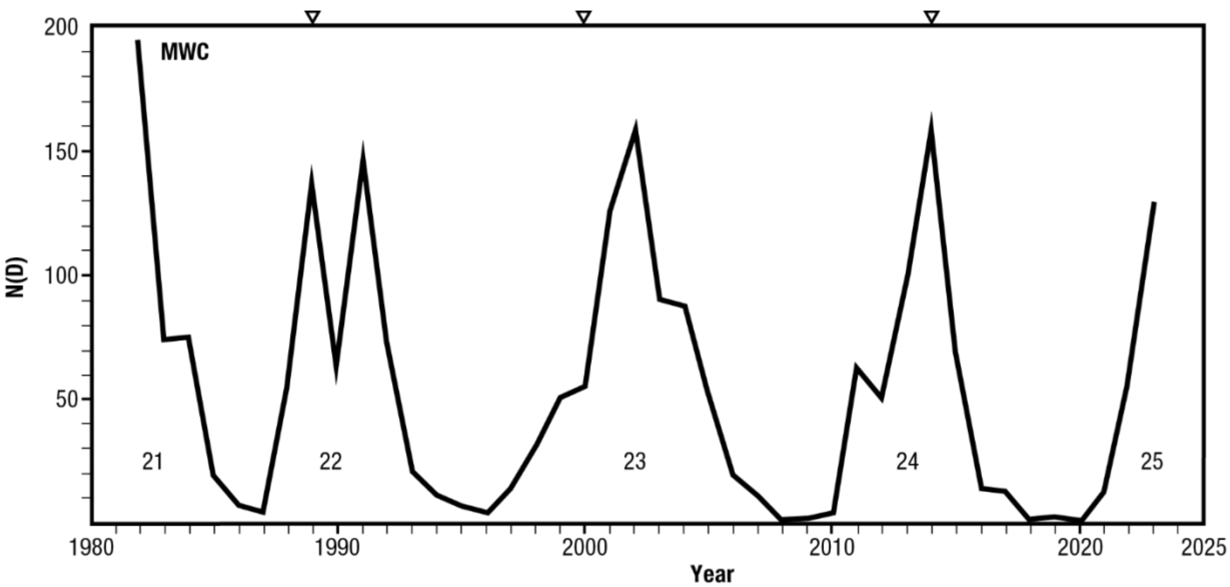

Figure 5. Yearly variation of N(D) based on MWC, 1982–2023.

Table 7 compares the number of single spots (N(SS)) against the number of type A spots (N(A)) as determined from MWC and the number of type A+H spots (N(A+H)) as determined from MMZ for the interval 1982–2023. Also given is the NARE and various percentages. During the interval 1982–2023, N(SS) totaled 16,276, which was about 22% of the NARE (16,276/72,969).

Table 7. Single spots (SS) 1982–2023.

Year	NARE	N(A)#	N(A+H)^	N(SS)	P1	P2	P3	P4	P5
SC21 (incomplete)									
1982	3686	1386	1364	879	37.6	23.9	63.4	37.0	64.4
1983	2371	941	936	572	39.7	24.1	60.8	39.5	61.1
1984	1474	532	512	337	36.1	22.9	63.4	34.7	65.8
1985	604	244	245	152	40.4	25.2	62.3	40.6	62.0
mean	2034	776	764	485					
sd	1317	497	491	314					
sum	8135	3103	3057	1940					
SC22									
1986m	394	185	187	110	47.0	27.9	59.5	47.5	58.8
1987	938	402	387	258	42.9	27.5	64.2	41.3	66.7
1988	2900	1134	1129	618	39.1	21.3	54.5	38.9	54.7
1989M	4734	1716	1659	854	36.3	18.0	49.8	35.0	51.5
1990	4751	1943	1881	905	40.9	19.0	46.6	39.6	48.1
1991	4715	1836	1780	893	38.9	18.9	48.6	37.8	50.2
1992	3314	1388	1392	695	41.9	21.0	50.1	42.0	49.9
1993	1886	859	855	468	45.6	24.8	54.5	45.3	54.7
1994	1205	519	506	301	43.1	25.0	58.0	42.0	59.5
1995	707	297	305	165	42.0	23.3	55.6	43.1	54.1
mean	2554	1028	1008	526					
sd	1761	669	648	307					
sum	25544	10279	10081	5266					
SC23									
1996m	306	126	126	82	41.2	26.8	65.1	41.2	65.1
1997	686	233	235	168	34.0	24.5	72.1	34.3	71.5
1998	1937	588	593	449	30.4	23.2	76.4	30.6	75.7
1999	2733	754	754	554	27.6	20.3	73.5	27.6	73.5

Year	**NARE**	**N(A)#**	**N(A+H)^**	**N(SS)**	**P1**	**P2**	**P3**	**P4**	**P5**
2000M	3587	1044	1047	799	29.1	22.3	76.5	29.2	76.3
2001	3476	1046	1048	809	30.1	23.3	77.3	30.2	77.2
2002	3528	1023	1029	765	29.0	21.7	74.8	29.2	74.3
2003	2145	602	605	413	28.1	19.3	68.6	28.2	68.3
2004	1311	404	409	275	30.8	21.0	68.1	31.2	67.2
2005	973	287	287	204	29.5	21.0	71.1	29.5	71.1
2006	600	212	209	135	35.3	22.5	63.7	34.8	64.6
2007	308	123	123	84	39.9	27.3	68.3	39.9	68.3
mean	1799	537	539	395					
sd	1281	360	361	280					
sum	21590	6442	15465	4737					
SC24									
2008m	122	40	39	27	32.8	22.1	67.5	32.0	69.2
2009	123	29	29	22	23.6	17.9	75.9	23.6	75.9
2010	623	247	248	174	39.7	27.9	70.5	39.8	70.2
2011	1788	536	534	438	30.0	24.5	81.7	29.9	82.0
2012	1848	571	572	434	30.9	23.5	76.0	31.0	75.9
2013	2121	694	694	507	32.7	23.9	73.1	32.7	73.1
2014M	2442	706	706	515	28.9	21.1	73.0	28.9	73.0
2015	1544	475	475	349	30.8	22.6	73.5	30.8	73.5
2016	910	304	304	207	33.4	22.8	68.1	33.4	68.1
2017	477	223	223	145	46.8	30.4	65.0	46.8	65.0
2018	161	55	55	41	34.2	25.5	74.6	34.2	74.6
mean	1105	353	353	260					
sd	867	257	257	194					
sum	12159	3880	3879	2859					
SC25 (incomplete)									
2019m	97	50	50	33	51.6	34.0	66.0	51.6	66.0
2020	224	116	116	97	51.8	43.3	83.6	51.8	83.6
2021	729	287	287	227	39.4	31.1	79.1	39.4	79.1

Year	NARE	N(A)#	N(A+H)^	N(SS)	P1	P2	P3	P4	P5
2022	1788	577	576	434	32.3	24.3	75.2	32.2	75.4
2023	2703	950	948	686	35.2	25.4	72.2	35.1	72.4
1982-2023									
mean	1714	603	606	388					
sd	1380	504	490	276					

Note: NARE means number of active region entries
N(A) is the number of Group A spots from MWC
N(A+H) is the number of Group A and H spots from MMZ
N(SS) is the number of single spots
P1 is the percentage N(A)/NARE
P2 is the percentage N(SS)/NARE
P3 is the percentage N(SS)/N(A)
P4 is the percentage N(A+H)/NARE
P5 is the percentage N(SS)/N(A+H)
m means sunspot minimum occurrence
M means sunspot maximum occurrence
means based on MWC
^ means based on MMZ

Figure 6 plots the yearly values of type 0 spot groups and N(SS) for the interval 1875–2023. Presuming type 0 spots are, perhaps, similar to single spot groups, one finds that they increased in number over time between SC12 and SC18–19, with SC14 being extremely low in number. Type 0 and N(SS) are observed to have trended downward from SC18–19, with SC24 having the smallest number of single spot groups since SC14, perhaps marking the recurrence of another Dalton-like minimum, a reflection of the Centennial Gleissberg Cycle (Gleissberg 1965; Feynman and Fougere 1984; Feynman and Ruzmaikin 2011, 2014; Wilson 2023).

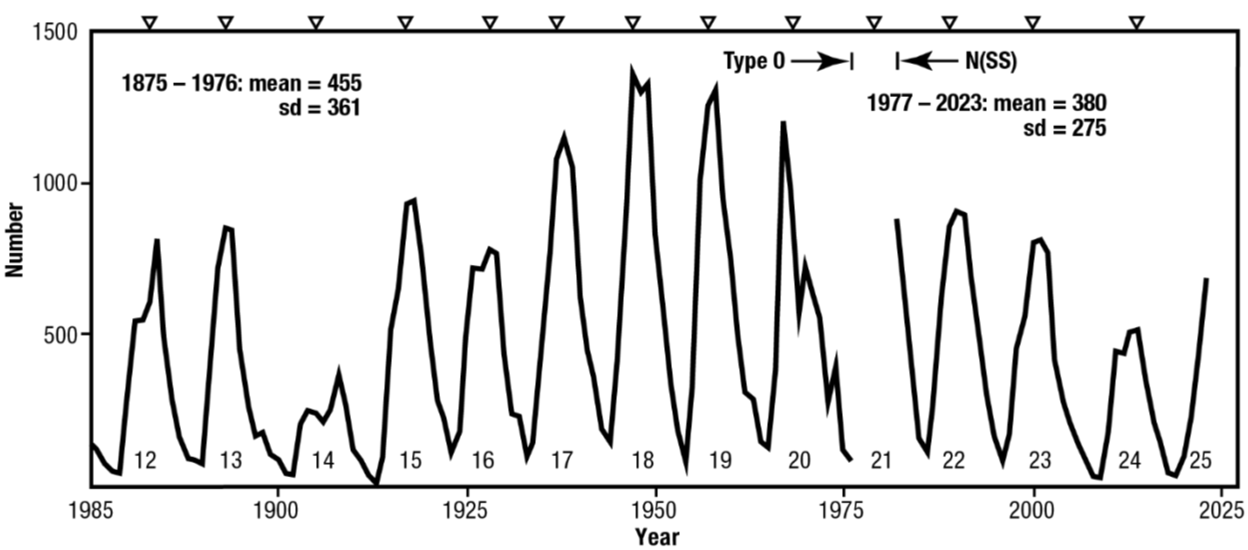

Figure 6. Yearly variation of type 0 spot groups and N(SS), 1875–2023.

During the RGO interval (1875–1976), type 0 spot groups averaged about 455 per year, with an sd of 361. During the interval 1982–2023, N(SS) averaged 380 single spots per year, with an sd of 275. The *t* statistic for independent samples is computed to be *t* = 1.21, a result suggestive that the difference in means for the two samples is not statistically significant. Hence, type 0 spot groups appear to be consistent with the hypothesis that they might possibly be related to single spot groups; strictly speaking, it remains uncertain as to whether type 0 spots are, indeed, related to single spot groups. (Close inspection of Figure 6 (seen also in Tables 1 and 7) reveals that type 0 spots and single spots behave quite similarly, with the maximum number of each typically coinciding with the maximum in SSN or the year after SSN maximum, exceptions being SC14, which peaked three years after SSN maximum and SC20, which peaked one year before SSN maximum.)

Table 8 shows the yearly variation (1982–2023) of SSA, A(C), A(S), P(C), P(S), <A(C)>, and <A(S)>, where A(C) and A(S) are the yearly mean areas of complex and simple spot groups, respectively, based on MWC; P(C) and P(S) are the percentages of complex and simple spot groups as compared to SSA; and <A(C)> and <A(S)> are the mean areas of complex and simple spot groups. Thus, on average, complex and simple spot groups contribute, respectively, about 27% and 73% each to the total yearly SSA. Also, on average, complex spot groups measure about 414.5 millionths of a solar hemisphere in size as compared to about 123.8 millionths of a solar hemisphere for simple spot groups.

Table 8. Area and percentages of simple and complex spots based on MWC, 1982–2023.

Year	**SSA**	**A(C)**	**A(S)**	**P(C)**	**P(S)**	**<A(C)>**	**<A(S)>**
SC21 (incomplete)							
1982	2220.1	697.2	1522.9	0.314	0.686	676.8	172.5
1983	919.5	229.7	689.8	0.250	0.750	481.8	116.6
1984	811.7	285.2	526.5	0.351	0.649	899.9	143.4
1985	179.0	30.9	148.1	0.173	0.827	433.8	94.7
mean	1032.6	310.8	721.8			623.1	131.8
sd	856.4	279.8	580.2			212.4	33.7
SC22							
1986m	124.7	18.6	106.1	0.149	0.851	357.3	103.8
1987	296.8	12.4	284.4	0.042	0.958	282.9	112.6
1988	1345.3	241.9	1103.4	0.180	0.820	598.2	146.7
1989M	2579.2	714.0	1865.2	0.277	0.723	930.8	152.9
1990	2048.7	320.4	1728.3	0.156	0.844	660.7	137.9
1991#	2470.2	670.2	1800.0	0.271	0.729	820.9	148.8
1992	1349.2	227.9	1121.3	0.169	0.831	496.5	130.5
1993	696.2	90.4	605.8	0.130	0.870	478.2	121.7

Year	**SSA**	**A(C)**	**A(S)**	**P(C)**	**P(S)**	**<A(C)>**	**<A(S)>**
1994	340.4	40.5	299.9	0.119	0.881	448.0	93.4
1995	159.6	9.4	150.2	0.059	0.941	156.0	80.5
mean	1141.0	234.6	906.5			523.0	122.9
sd	959.8	265.0	709.9			237.5	24.9
SC23							
1996m	81.9	12.5	69.4	0.153	0.847	191.1	190.9
1997	210.2	52.5	157.7	0.250	0.750	361.6	90.9
1998	763.1	161.5	601.6	0.212	0.788	409.4	122.5
1999	1162.0	278.1	883.9	0.239	0.761	445.2	128.8
2000M	1614.2	379.8	1234.4	0.235	0.765	498.2	136.6
2001	1704.1	561.1	1143.0	0.329	0.671	467.6	137.3
2002	1828.7	625.4	1203.3	0.342	0.658	480.6	143.9
2003	1099.2	534.3	564.9	0.486	0.514	645.8	111.9
2004	683.8	251.4	432.4	0.368	0.632	403.6	146.1
2005	542.6	199.3	343.3	0.367	0.633	430.4	155.9
2006	245.1	70.3	174.8	0.287	0.713	320.7	122.7
2007	133.3	21.8	111.5	0.164	0.837	346.0	142.8
mean	839.0	262.3	576.7			416.7	135.9
sd	635.2	218.4	439.7			110.9	24.6
SC24							
2008m	22.8	0.0	22.8	0.000	1.000	0.0	68.4
2009	26.6	2.9	23.7	0.109	0.891	211.7	73.3
2010	214.3	13.4	200.9	0.063	0.938	168.7	123.4
2011	751.2	214.8	536.4	0.286	0.714	363.0	110.5
2012	796.9	186.3	610.6	0.234	0.766	362.7	134.7
2013	860.8	265.0	595.8	0.308	0.692	277.1	122.7
2014M	1252.2	544.4	707.8	0.435	0.565	380.7	134.6
2015	618.8	225.1	393.7	0.364	0.636	334.0	110.5
2016	225.2	33.6	191.6	0.149	0.851	261.7	81.3
2017	217.5	49.4	168.1	0.227	0.773	392.0	142.4

Year	**SSA**	**A(C)**	**A(S)**	**P(C)**	**P(S)**	**<A(C)>**	**<A(S)>**
2018	24.4	1.9	22.5	0.078	0.922	99.1	53.3
mean	455.5	139.7	315.8			259.2	105.0
sd	418.9	169.5	261.0			127.7	30.7
SC25 (incomplete)							
2019m	37.9	3.0	34.9	0.079	0.921	237.8	137.0
2020	85.1	11.6	73.5	0.136	0.864	530.7	124.5
2021	249.2	41.3	207.9	0.166	0.834	255.5	113.3
2022	863.3	174.9	688.4	0.203	0.797	396.5	154.4
2023	1143.6	310.3	833.3	0.271	0.729	316.4	129.7
1982-2023							
mean	785.7	209.9	575.8			414.5	123.8
sd	713.9	217.2	518.8			197.6	28.0

Note: SSA is sunspot area in millionths of a solar hemisphere
A(C) is the area of complex spots (G+BG+BD+GD+BGD)
A(S) is the area of simple spots (A+B)
P(C) is the percentage A(C)/SSA
P(S) is the percentage A(S)/SSA
<A(C)> is the mean size of a complex spot group
<A(S)> is the mean size of a simple spot group
m means SSN minimum occurrence
M means SSN maximum occurrence
means one entry considered bad data and is not included in tally: region 6924B on 19 November 1991, a beta region, listed as having a corrected area of 8020, up from 10 on 17 November 1991

Figure 7 shows plots A(S) and A(C) during the interval 1982–2023. Noticeable is that A(S) appears to have trended downward since SC21–22, at least through SC24. Likewise, A(C) appears to have trended downward slightly. As yet, SC25 has not had a yearly A(C) that has exceeded that of SC24, although its A(S) is now greater than that observed for SC24.

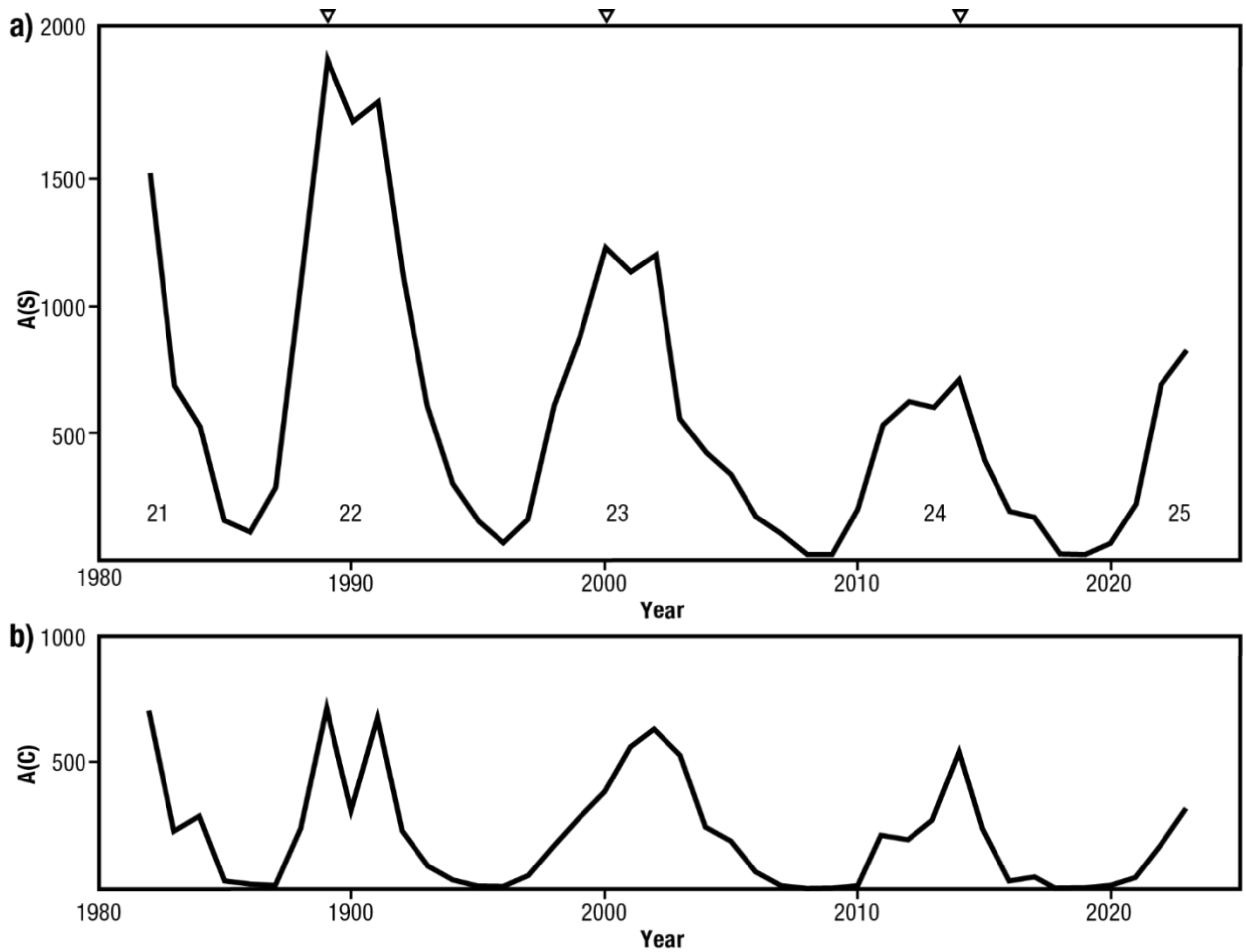

Figure 7. Yearly variation of (a) A(S) and (b) A(C), 1982–2023.

Figure 8 depicts the yearly variation of <A(S)> and <A(C)> for the interval 1982–2023. Both <A(S)> and <A(C)> appear to have trended downward, at least through SC24. (The filled triangle across the top of the chart shows the occurrences of SSN minimum for SC22–25.)

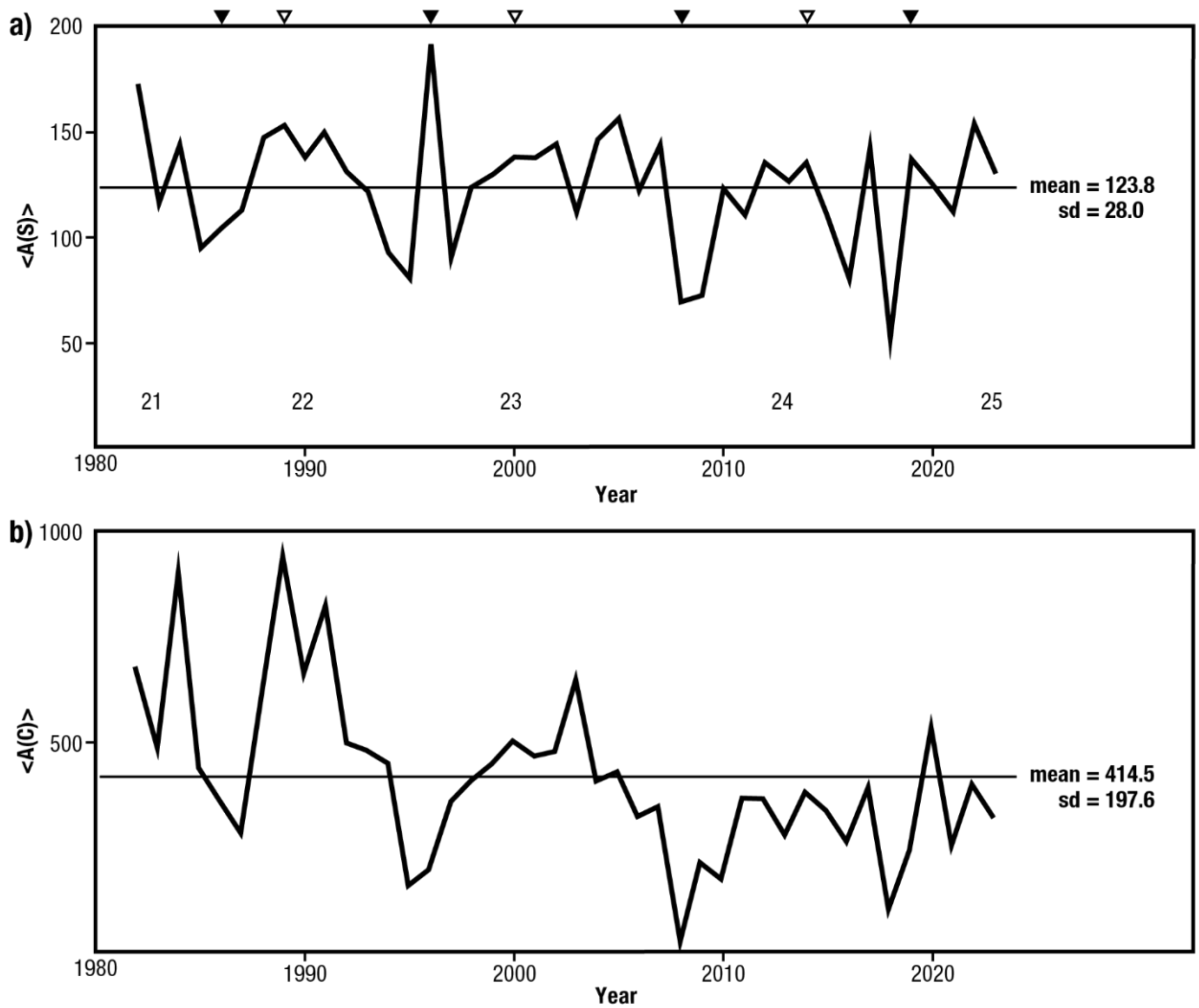

Figure 8. Yearly variation of (a) <A(S)> and (b) <A(C)>, 1982–2023.

Figure 9 shows the scatterplot of yearly N(S) vs. yearly SSN based on the MWC, 1982–2023. One finds a very strong correlation to exist between the two parameters, one having a coefficient of correlation $r = 0.9653$, a coefficient of determination $r^2 = 0.9317$ (meaning that about 93% of the variance in yearly N(S) can be explained by the inferred correlation, or vice versa), a standard error of estimate $S_{yx} = 334.1$, and a t statistic equal to 23.3650. Plainly, small (large) yearly SSN is associated with small (large) yearly N(S), and vice versa. Based on the observed 2x2 contingency table (determined by the vertical and horizontal lines), 20 of 21 small yearly N(S) are associated with small yearly SSN, and 20 of 21 large yearly N(S) are associated with large yearly SSN, yielding a probability $P \ll 0.001$ (i.e., the probability of obtaining the observed result, or one more suggestive of a departure from independence is $P \ll 0.001$). Because SC25 will have a yearly SSN maximum ≥125.3 (marked by the downward pointing arrow), its yearly N(S) will lie in the upper-right quadrant of Figure 9 (the value for the year 2023 is shown). Based on the regression equation, $y = 67.1 + 19.76x$, yearly N(S) at cycle maximum for SC25 will be ≥2,543 ± 334. Assuming a yearly SSN maximum equal to 148.5 for SC25 (Wilson 2023), its yearly N(S) based on MWC should measure about 3,000.

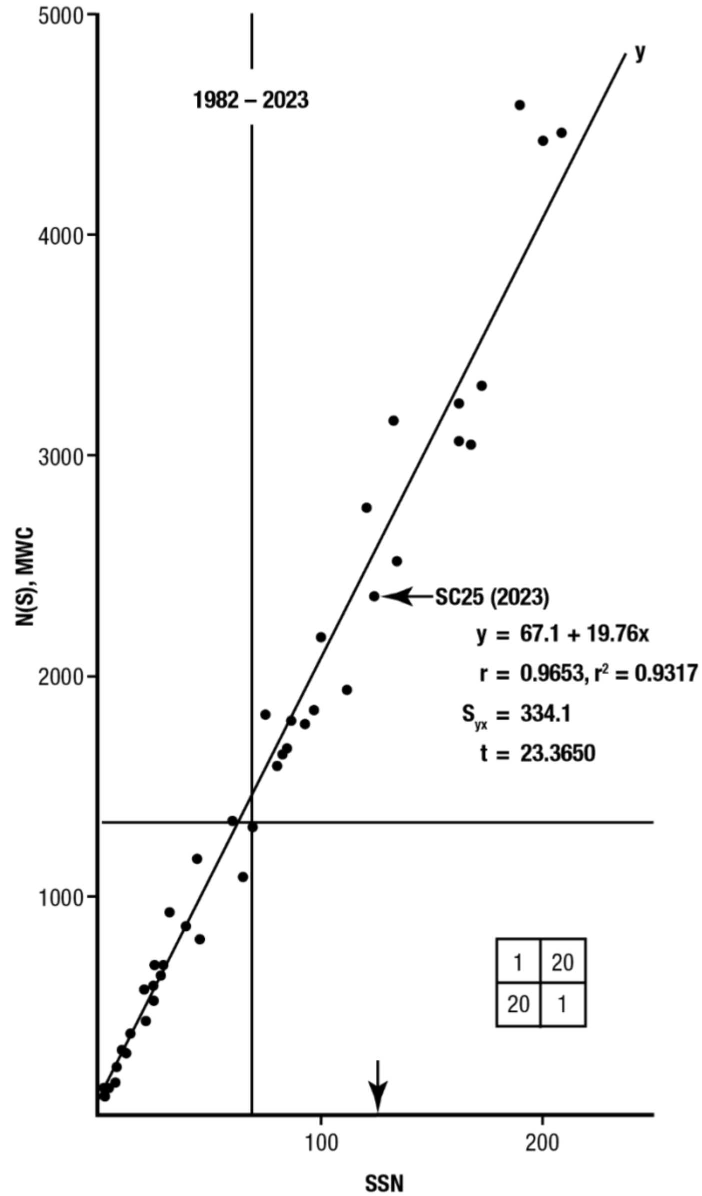

Figure 9. Scatterplot N(S), MWC vs. SSN, 1982–2023.

Similarly, Figure 10 depicts the scatterplot of yearly N(C) vs. yearly SSN based on the MWC, 1982–2023. The inferred linear regression is statistically important, having $r = 0.8052$, $r^2 = 0.6483$, $S_{yx} = 201.0$, and $t = 3.6451$. Again, small (large) yearly SSN is associated with small (large) yearly N(C), and vice versa. Based on the observed 2x2 contingency table, 19 of 21 small yearly N(S) are associated with small yearly SSN, and 19 of 21 large yearly N(S) are associated with large yearly SSN. Because SC25 will have a yearly SSN maximum ≥125.3 (marked by the downward pointing arrow), its yearly N(C) will lie in the upper-right quadrant of Figure 10 (the value for the year 2023 is likewise shown). Based on the regression equation, $y = 15.5 + 1.86x$, yearly N(C) at cycle maximum for SC25 will be ≥ 249 ± 201. Assuming yearly SSN maximum equal to 148.5 for SC25, its yearly N(C) based on MWC should measure about 292.

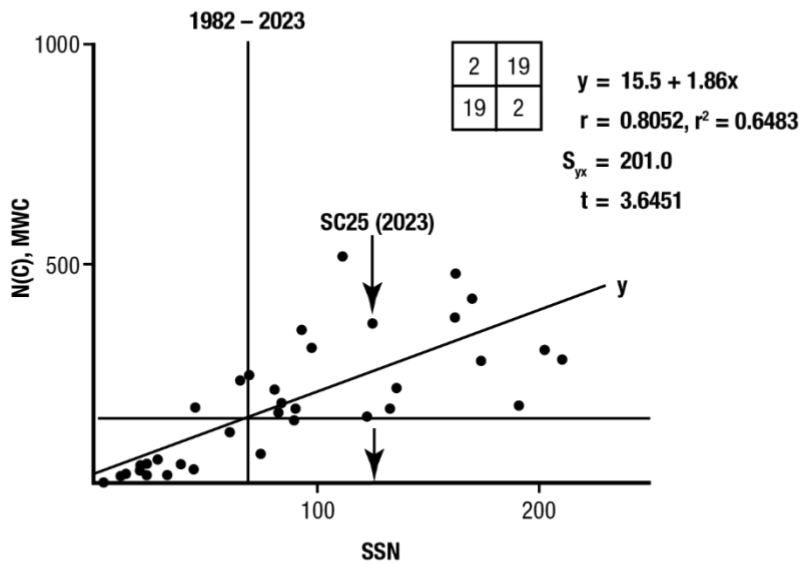

Figure 10. Scatterplot N(C), MWC vs. SSN, 1982–2023.

Figure 11 displays scatterplots of (a) yearly N(SS) vs. yearly SSN and (b) yearly N(D) vs. yearly SSN. Both inferred regressions are statistically important. For SC25, its yearly N(SS) at cycle maximum will be ≥ 603 ± 52, and its yearly N(D) will be ≥ 87 ± 31. (Yearly N(D) measured 129 in 2023.)

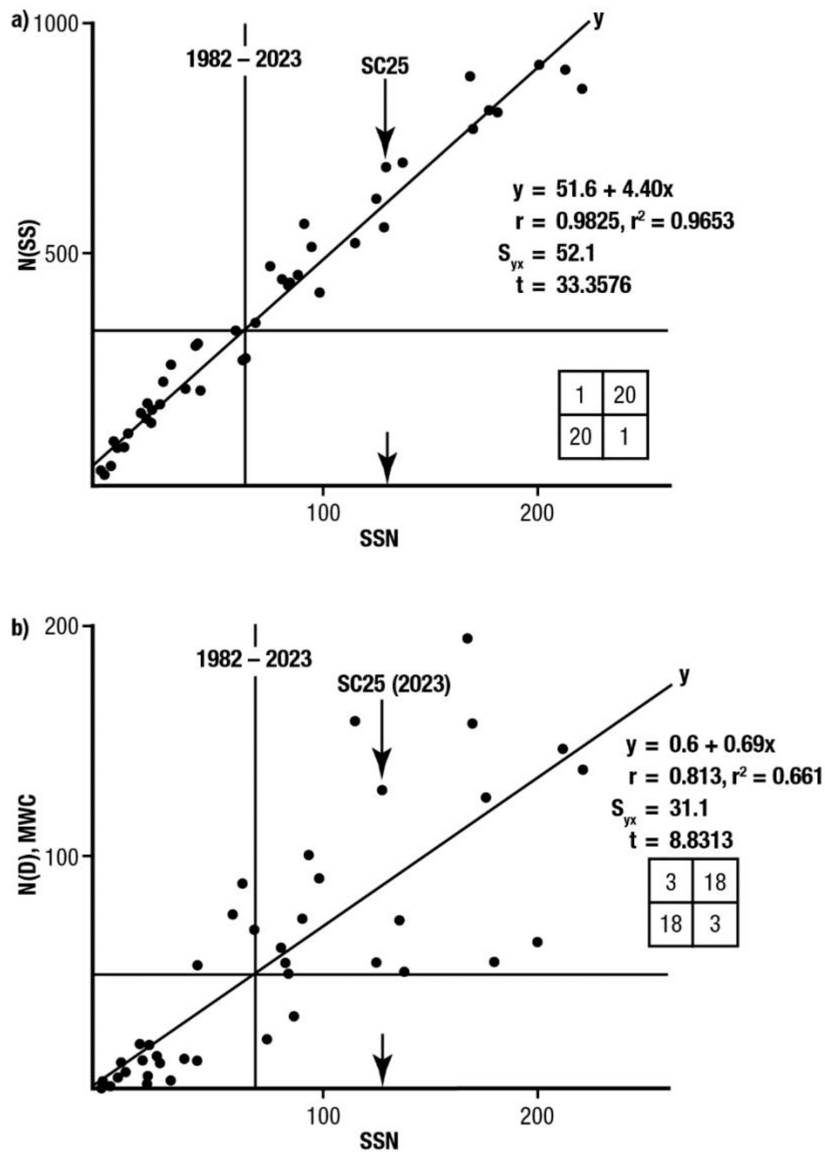

Figure 11. Scatterplots (a) N(SS) vs. SSN and (b) N(D) vs. SSN.

Figure 12 shows scatterplots of (a) yearly A(S) vs. yearly SSN, (b) yearly A(C) vs. yearly SSN, (c) yearly <A(S)> vs. yearly SSN and (d) yearly <(A(C)> vs. yearly SSN based on MWC. Of the four scatterplots, the weakest (although statistically significant at the 5% level of significance, or 95% level of confidence) is the one associating yearly <A(S)> vs. yearly SSN. All plots suggest that SC25 will have yearly values in the upper-right quadrant of the scatterplots. Interestingly, the yearly value of <A(C)> for 2023 is in the lower-right quadrant of its scatterplot. Presuming SC25 to have SSN maximum ≥125.3, one expects the A(S) maximum to be ≥ 985 ± 109 millionths of a solar hemisphere, A(C) maximum to be ≥363 ± 101 millionths of a solar hemisphere, <A(S)> maximum to be ≥134 ± 25 millionths of a solar hemisphere, and <A(C)> maximum to be ≥519 ± 145 millionths of a solar hemisphere. Assuming SSN maximum is equal to 148.5, A(S) maximum should be about 1,170 millionths of a solar hemisphere, A(C) maximum about 436 millionths of a solar hemisphere, <A(S)> maximum about 138 millionths of a solar hemisphere, and <A(C)> maximum about 569 millionths of a solar hemisphere.

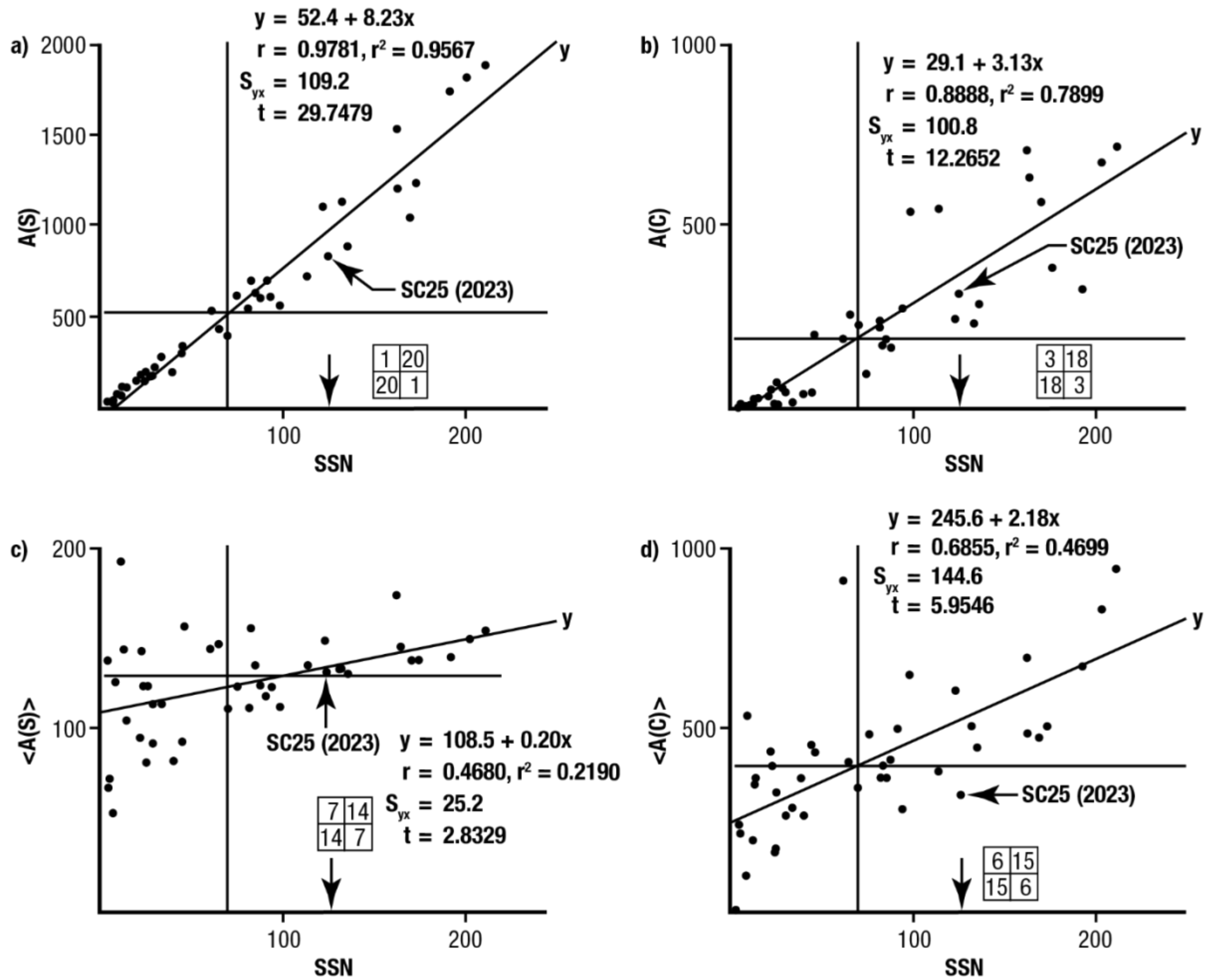

Figure 12. Scatterplots of (a) A(S) vs. SSN, (b) A(C) vs. SSN, (c) <A(S)> vs. SSN and (d) <A(C)> vs. SSN.

Table 9 provides a summary of the parametric maximum values for SC12–24 and their occurrence relative to SSN minimum occurrence. For the RGO-MMZ (and MWC) interval, N(S) and N(C) tend to occur on or after SSN maximum occurrence (i.e., during the declining phase of the solar cycle; only SC20 had N(S) maximum prior to its SSN maximum occurrence).

Table 9. Summary of parametric maximum values, SC12–24.

				RGO,MMZ				MWC				
SC	SSN	SSA	NARE	N(S)	N(C)	N(S)	N(C)	N(D)	A(S)	A(C)	<A(S)>	<A(C)>
12	106.1(5)	1148.9(5)	2039(6)	1524(6)	515(6)	-	-	-	-	-	-	-
13	142.0(4)	1460.6(4)	3071(4)	2030(4)	1041(4)	-	-	-	-	-	-	-

				RGO,MMZ				MWC				
SC	**SSN**	**SSA**	**NARE**	**N(S)**	**N(C)**	**N(S)**	**N(C)**	**N(D)**	**A(S)**	**A(C)**	**<A(S)>**	**<A(C)>**
14	105.5(4)	1195.9(4)	1959(6)	1222(6)	941(4)	-	-	-	-	-	-	-
15	173.6(4)	1533.9(4)	3510(4)	2233(4)	1277(4)	-	-	-	-	-	-	-
16	129.7(5)	1388.9(5)	2613(5)	1563(5)	1050(5)	-	-	-	-	-	-	-
17	190.6(4)	2072.8(4)	3705(4)	2368(5)	1450(4)	-	-	-	-	-	-	-
18	214.7(3)	2634.1(3)	4298(3)	2981(3)	1317(3)	-	-	-	-	-	-	-
19	269.3(3)	3048.5(3)	5016(4)	3468(3)	2027(4)	-	-	-	-	-	-	-
20	150.0(4)	1601.3(6)	3379(6)	2185(3)	1831(6)	-	-	-	-	-	-	-
21	220.1(4)	2220.1(6)	5439(4)	-	-	-	-	-	-	-	-	-
22	211.1(3)	2579.2(3)	4751(4)	3611(4)	1254(5)	4573(4)	297(5)	146(5)	1865.2(3)	714.0(3)	152.9(3)	930.8(3)
23	173.9(4)	1828.7(6)	3587(4)	2294(4)	1524(6)	3306(4)	475(6)	158(6)	1234.4(4)	625.4(6)	190.9(0)	645.8(7)
24	113.3(6)	1252.2(6)	2442(6)	1492(6)	950(6)	1920(6)	522(6)	158(6)	707.8(6)	544.4(6)	142.4(9)	392.0(9)

Note: The number in the parentheses is the elapsed time in years from SSN minimum year occurrence

In summary, this paper has presented the results of a study of the complexity of sunspot groups based on the solar areal dataset (http://solarcyclescience.com/activeregions.html). Sunspot groups can be simply divided into two groups—those with a simple visual or magnetic appearance and those with a more complicated visual or magnetic appearance. For the RGO/Zurich interval (1875–1976), simple spot groups (as defined in this study) accounted for about 64.5% of the daily observations, and complex spot groups accounted for about 35.5%. For the more recent MMZ interval (1982–2023), simple spots accounted for about 69.5% of the daily observations, and complex spot groups accounted for about 30.5%. Based on the MWC interval (1982–2023), simple spot groups accounted for about 90.8% of the daily observations, and complex spot groups accounted for only about 9.0% (0.2% of the observations during the interval had no MWC determinations). For the combined RGO/Zurich and MMZ intervals, simple spot groups accounted for about 66.1% of the combined daily observations, and complex spot groups accounted for 33.9%. (As stated earlier, the interval 1977–1981 has no MMZ or MWC spot group determinations of simplicity and complexity.)

For the most part, the current ongoing SC25 has tracked below mean values (SC12–24) of SSN, SSA, NARE, N(S), and N(C) for elapsed time t = 0–4 years. SC25 likely will attain maximum values in 2024 or 2025 (at t = 5 or 6 years). Based on MWC, N(D) appears to average about 3% of the daily observations (i.e., NARE) and has more often tended to peak in number during the declining phase of the solar cycle. For the interval 1982–2023, there were 6,600 complex spot groups based on MWC and 22,274 based on MMZ. 6,289 complex spot groups based on MMZ were also complex spot groups based on MWC (28.2%), but 95.3% of the complex spot groups as determined using MWC were also complex spot groups based on MMZ (i.e., types D, E, and F). Of the 6,600 complex spot groups, 34.1% were delta spots. Single spot groups accounted for about 64% of type A or type A+H spot groups and 22.6% of the daily entries. Simple spot group area accounted for about 73.3% of the SSA, while complex spot group area accounted for about 26.7%. During the 1982–2023 interval, simple spot groups averaged about 123.8 millionths of a solar hemisphere in size, while complex spot groups averaged about

414.5 millionths of a solar hemisphere. Interestingly, simply on the basis of N(S) or N(SS), one can predict SSN for an ongoing SC, or given the expected size of an ongoing SC, one can predict its N(S) or N(SS). As an example, Wilson (2023) predicted SC25 to have a maximum SSN of about 148.5 ± 21.1, based on the average of several techniques for predicting the size of an SC. Such a value predicts N(S) = 3,001 ± 334, N(C) = 292 ± 201, N(SS) = 705 ± 52, N(D) = 103 ± 31, A(S) = 1,170 ± 109 millionths of a solar hemisphere, A(C) = 436 ± 101 millionths of a solar hemisphere, <A(S)> = 138.2 ± 25.2 millionths of a solar hemisphere, and <A(C)> = 569.3 ± 144.6 millionths of a solar hemisphere (all predictions being +/– 1 sd prediction intervals).

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EVALUATING DISSOCIATIVE EXPERIENCES, ACEs, AND ACQUIRED CAPABILITY FOR SUICIDE IN COLLEGE STUDENTS

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ABSTRACT

The aim of this study was to examine the potential psychophysiological mechanisms: Adverse Childhood Experiences (ACEs), Psychache, Dissociation, Discomfort Intolerance, Pain Catastrophizing (PC), Positive Urgency and Negative Urgency, and their impact on the acquired capability for suicide (AC). Factor analysis of the study variables yielded a three-factor solution consisting of Dissociation, Distress, and Urgency, and Confirmatory analysis replicated the three factors. The Structural Equation Model indicated significant mediation effects between the variables. Psychache and PC significantly mediate the relationship between ACEs and AC. The key finding of our study is that PC was a significant mediator in the relationship between Dissociation and AC with or without the effect of ACEs. Psychache's indirect effect through PC on AC accounted for the most variance within our model. These results clarify the relationships between the variables being examined and their effect on AC, supporting the development theory of Dissociation.

Keywords: Dissociation, Adverse Childhood Experiences, Psychache, Self-Harm, Acquired Capability for Suicide, Discomfort Intolerance, Pain Catastrophizing, Rumination, Physical Pain Tolerance

Evaluating Dissociative Experiences, ACEs, and Acquired Capability for Suicide in College Students

According to the Centers for Disease Control and Prevention (CDC, 2021), suicide ranked as the ninth leading cause of death in the United States in 2020, reflecting a concerning upward trend. Between 2000 and 2020, the national suicide rate increased by 30% (Garnett et al., 2022). Although rates declined modestly from 14.2 per 100,000 in 2018 to 13.5 in 2020, the overall trajectory remains troubling. Research consistently demonstrates that suicidal ideation is a critical precursor to suicide attempts (Beck et al., 1979; Rossom et al., 2017; Wenzel et al., 2011), yet recent evidence challenges the predictive specificity of ideation alone (Ribeiro et al., 2016). While ideation correlates with later risk, the most robust predictors of future attempts include non-suicidal self-injury (NSSI) and prior suicide attempts.

Importantly, common psychiatric risk factors such as depression and impulsivity are shared by ideators and attempters alike, but these do not reliably distinguish those who will act (Klonsky & May, 2015). Psychological dissociation has been proposed as a facilitating factor in the transition from ideation to action. Dissociative symptoms—including depersonalization, derealization, and diminished bodily awareness—may reduce self-protective aversion to pain and facilitate suicidal behavior (Orbach, 1994; Calati et al., 2017). Elevated dissociative experiences have been observed more frequently among individuals with suicide attempts than among non-attempters (Ford & Gómez, 2015).

Dissociative states, especially absorption and emotional numbing, have also been associated with increased impulsivity and a diminished capacity for self-reflection (Butler, 2006; Dalenberg et al., 2012). Together, these patterns may foster a dissociative pathway toward acquired capability for suicide (AC), defined as a reduced fear of death and increased pain tolerance (Joiner, 2005). The present study aims to clarify the role of dissociation in modulating pain perception and suicide risk, with the broader goal of informing clinical interventions that target dissociative symptoms to reduce suicide attempts.

Dissociation

Suicidal behaviors often involve direct bodily harm, yet little is understood about how individuals with suicidal ideation perceive pain. Theoretical frameworks have posited that dissociation—characterized by disruptions in memory, identity, and bodily integrity—may explain the altered self-experience seen in suicidal individuals (Orbach et al., 1995). Dissociation may create psychological distance from the body, decreasing sensitivity to pain and lowering barriers to self-injury.

Developmental Theory of Dissociation

Dissociation is commonly conceptualized as a psychological defense against trauma, particularly childhood abuse and neglect (Baumeister, 1990; Orbach et al., 1995). Attachment theory offers a developmental lens: children exposed to disorganized or frightening caregiving may develop dissociative tendencies as a means of surviving overwhelming emotional conflict (Main & Hesse, 1990). Over time, these coping mechanisms can become maladaptive, persisting into adulthood and increasing vulnerability to psychopathology (Schauer & Elbert, 2010).

Measuring Childhood Traumatic Experiences

The present study employs the Adverse Childhood Experiences (ACEs) Questionnaire (Felitti et al., 1998) to assess early trauma. The ACEs index includes ten categories: five pertaining to personal abuse and neglect, and five assessing household dysfunction such as substance abuse, mental illness, incarceration, and domestic violence.

Dissociative Experiences

Dissociation can be parsed into psychoform (cognitive-affective) and somatoform (sensorimotor) experiences (Hart et al., 2004). Positive dissociative symptoms include intrusive memories and flashbacks, while negative symptoms involve amnesia and emotional numbing. These experiences can be disorienting and are often described as externally imposed or "forced" (Steinberg, 1995; Polskaya & Melnikova, 2020). The Dissociative Experiences Scale-II (DES-II) is a widely used self-report instrument assessing depersonalization, derealization, amnesia, and absorption (Carlson & Putnam, 1993). It captures both pathological and non-pathological dissociative phenomena.

Depersonalization/Derealization

Depersonalization involves a sense of detachment from the body or self, such as the inability to recognize oneself in a mirror. Derealization reflects a disconnection from external reality, often described as the world feeling "foggy," distant, or surreal (Steinberg, 1995).

Amnesia

Dissociative amnesia refers to the inability to recall significant personal information, typically related to trauma. Micro-amnesia—forgetting the content of a conversation moments after it occurs—is also common (Steinberg, 1995).

Absorption

Absorption is the deep immersion in internal or external stimuli, such as intense daydreaming or engrossment in media. This state, while common, may interfere with self-monitoring and impulse control (Butler, 2006). Despite debate over whether absorption qualifies as dissociation, it remains strongly associated with dissociative profiles (Soffer-Dudek et al., 2019).

The Link Between Dissociative Experiences and Self-Harm

Non-suicidal self-injury (NSSI) often co-occurs with dissociation and trauma exposure (Ford & Gómez, 2015; Polskaya & Melnikova, 2020). NSSI may function to either interrupt dissociative episodes (anti-dissociation) or induce dissociation to escape intolerable affect (induction-dissociation) (Edmondson et al., 2016). Both pathways reflect maladaptive coping mechanisms that can increase suicide risk.

Psychological Pain

Psychache, defined as unbearable psychological pain, has been proposed as a core cause of suicide (Shneidman, 1993). It encompasses guilt, shame, despair, and hopelessness. When psychache exceeds an individual's coping capacity, suicide may be perceived as the only escape. The Psychache Scale measures the frequency and intensity of psychological pain and distinguishes between tolerable and intolerable levels (Holden et al., 2001).

Pain Catastrophizing

Pain catastrophizing (PC) involves magnifying pain expectations and feelings of helplessness. Individuals high in PC struggle to divert attention from pain and may ruminate excessively, impairing their ability to cope (Sullivan et al., 1995). The Pain Catastrophizing Scale (PCS) assesses three dimensions: Rumination, Magnification, and Helplessness. High scores are associated with greater pain distress and reduced efficacy of coping strategies.

Trauma and Dissociative Experiences: Self-Harm Functions

Nock and Prinstein (2004) identified four functions of self-harm: automatic-negative reinforcement (relief from distress), automatic-positive reinforcement (induction of sensation), social-negative reinforcement (escape from social demands), and social-positive reinforcement (seeking attention). Dissociation may interact with these functions, both triggering and being modulated by NSSI. Empirical evidence supports dissociation as a mediator between trauma and self-harm (Franzke et al., 2015).

Suicide Frameworks

Ideation-to-action theories posit that suicidal ideation and attempts emerge through distinct processes. The Interpersonal Theory of Suicide (IPTS) emphasizes perceived burdensomeness, thwarted belongingness, and acquired capability (Joiner, 2005). Acquired capability is defined by pain tolerance and fearlessness about death. Exposure to pain and trauma can habituate individuals to aversive stimuli, increasing fearlessness and decreasing sensitivity to pain—thus facilitating suicidal behavior (Joiner, 2005; Franklin et al., 2011). Although genetic predispositions play a role, acquired capability often develops through repeated exposure to painful events, including NSSI and trauma. Individuals with high AC exhibit higher pain thresholds and a diminished fear of death (Orbach et al., 1996; Dodd et al., 2018). Perceived pain sensitivity is not always consistent with objective physiological measures. Subjective pain ratings are influenced by psychological factors such as mood, anxiety, and psychache (Edwards & Fillingim, 2007). The Discomfort Intolerance Scale (DIS) assesses individuals' perceived ability to tolerate unpleasant physical states (Schmidt et al., 2006). Low discomfort tolerance may lead to a paradoxical increase in suicide risk, as individuals become motivated to escape distress despite lacking prior pain exposure. This reinforces the role of psychological processes in building AC (Pennings & Anestis, 2013).

The Acquired Capability with Rehearsal for Suicide Scale (ACWRSS) measures fearlessness about death, pain tolerance, and mental rehearsal of suicide (George et al., 2016). Dissociation has been shown to mediate the relationship between trauma and suicidal behavior more strongly than depression or anxiety (Ford & Gómez, 2015). Elevated dissociation correlates with suicide attempts in both clinical and general populations (Maaranen et al., 2005).

THE CURRENT STUDY

This study investigates how dissociation contributes to acquired capability for suicide, particularly through its influence on pain perception and psychological distress. We examine several psychophysiological variables: ACEs, dissociation, psychache, discomfort intolerance, pain catastrophizing, and impulsivity. Previous research has found evidence that suggests high physical pain tolerance is linked with an increased likelihood of suicide attempts. Yet, the psychological correlates of higher tolerance must be extensively researched. Recently, dissociation has gained popularity and is recognized as a possible psychological indicator of increased pain tolerance. The current study aims to add evidence to the preexisting literature of possible underlying psychophysiological mechanisms that may explain the correlation between higher pain tolerance and increased AC. A narrative model of the hypotheses is presented below in Figure 1. There are four principal goals of the current study: (1) to examine the strength of the strength between study variables: The Adverse Childhood Experiences Questionnaire (ACEs); (Felitti et al., 1998), Dissociative Experiences Scale II (DES II); (Carlson & Putnam, 1993), Psychache Scale; (Holden et al., 2001), Impulsive Behavior Scale (UPPSP); (Lynam et al., 2007), Discomfort Intolerance Scale (DIS); (Schmidt et al., 2006), The Pain Catastrophizing Scale (PCS); (Sullivan et al., 1995) and The Acquired Capability with Rehearsal for Suicide Scale (ACWRSS); (George et al., 2016) (2) to determine the factor structure of the study variables; (3) to test the factor structure of the variables with moderate to good correlations; (4) to test the structural model of the study variables and latent constructs and to examine the potential mediating effects.

Using the CFA, we further aimed to evaluate whether variables hypothesized by the literature explain the mechanisms behind dissociation and AC. Given the significant correlations between suicide attempts, Dissociation, and physical pain tolerance, we expect individuals with increased Dissociation to have increased AC (Calati et al., 2017; Orbach, 1994; Orbach et al., 1996; Polskaya & Melnikova, 2020; Şar et al., 2004). The significant correlation may indicate the association eases an individual's decision to harm their body (Orbach, 1994). We expected that Dissociation would uniquely add to the variance in the predictive model. Additionally, we expected that Psychache would also uniquely impact the model. Further, authors, Demirkol et al. (2020) evaluated ACEs and the roles of Dissociation and Psychache in the Turkish population. Results indicated ACEs were significantly linked to previous suicide attempts, and Psychache, and Dissociation significantly mediated the relationship (Demirkol et al., 2020). The relationship between ACEs and suicide attempts may be explained through Psychache and Dissociation. Further, supporting our theory that Dissociation and Psychache mediate the relationship between ACEs and AC and uniquely account for a significant portion of the variance.

Based on findings that pain catastrophizers utilize several coping mechanisms to manage their pain without success, we anticipated PC (i.e., the tendency to hyperfocus on intensity, duration, and negative outcomes of physically painful stimuli), predictive model for AC (Sullivan et al., 1995). Finally, we expected positive and negative urgency would significantly add to the predictive model of AC. Positive Urgency is a type of impulsivity that results in risk taking behaviors that are more likely to lead to dangerous outcomes after experiencing intense positive emotions (Cyders et al., 2007). Negative Urgency is another type of impulsivity characterized by partaking in risky situations significantly likely to lead to bodily harm or dangerous outcomes (Jordan et al., 2019). Findings from a study by Anestis and Joiner, (2011) indicate individuals with low distress tolerance and increased Negative Urgency have increased suicidal ideation.

Hypotheses

1. Dissociation will correlate more strongly with pain catastrophizing than with discomfort intolerance.
2. Exploratory and confirmatory factor analyses will reveal a three-factor structure among dissociation, psychache, PC, impulsivity, and AC.
3. Indirect pathways from ACEs through dissociation and psychache will predict AC.
4. Psychache will mediate the relationship between ACEs, urgency traits, and AC.
5. PC will mediate the relationship between dissociation and AC.

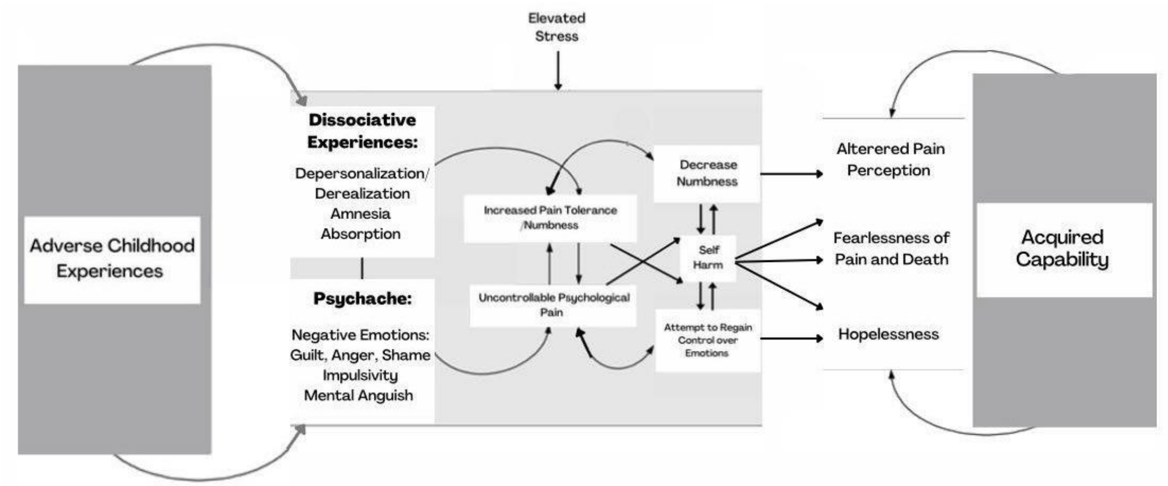

Figure 1. Narrative model of proposed developmental pathways of ACEs, Dissociation, Psychache, Pain Tolerance, and AC; including the behavioral function of self-harm.

Procedures

Participants

After data cleaning, 584 participants were included in the study. The majority the study's participants were female, 77.8%, while 22.4% were male. Ages ranged from 18 to 69, with 47% of participants stating they were 18 years old. Racial/ethnic composition consisted of 21% African American, 70% Caucasian, 4% Hispanic/Latino, 1% Native American, 6% Asian American, .2% Pacific Islander, 2% Multiracial, and 2% stating "other."

Materials

Demographic Questionnaire

Participants completed a brief demographic form including age, gender, race/ethnicity, military service, marital status, and education.

Adverse Childhood Experiences Questionnaire (ACEs)

The ACEs questionnaire (Felitti et al., 1998) assesses exposure to ten categories of childhood trauma, including five forms of personal maltreatment (e.g., physical, verbal, or sexual abuse, and physical/emotional neglect) and five indicators of household dysfunction (e.g., domestic violence, parental substance use, mental illness, incarceration, and separation/divorce; . Responses are scored dichotomously (“Yes”/“No”), yielding a total score from 0 to 7. Higher scores reflect greater cumulative exposure to early adversity. This scale has been widely used in research linking early trauma to adult health outcomes.

Dissociative Experiences Scale II (DES-II)

The DES-II (Carlson & Putnam, 1993) measures both normative (e.g., daydreaming) and pathological dissociation (e.g., derealization, amnesia, and absorption; . Respondents rate each item from 0% to 100% in 10% increments, indicating how frequently dissociative experiences occur. Subscale and total scores are computed by averaging item responses. Scores ≥30 suggest possible clinical dissociation. The DES-II demonstrates strong internal consistency (α = .95). Participants reporting zero on all items (denial of normative dissociation) will be excluded.

Psychache Scale

This 13-item scale assesses psychological pain as conceptualized by Shneidman (1993), using a 5-point Likert scale (1 = “Never,” 5 = “Always”; . Scores range from 13 to 65, with higher values indicating greater psychological distress. Internal reliability is high (α = .94; Holden et al., 2001).

Impulsive Behaviors Scale (UPPS-P)

The UPPS-P (Lynam et al., 2007) includes 59 items measuring five traits related to impulsivity: negative urgency, positive urgency, lack of premeditation, lack of perseverance, and sensation seeking . Items are rated on a 4-point Likert scale (1 = “Agree strongly,” 4 = “Disagree strongly”).
Each subscale demonstrates acceptable internal reliability: Premeditation (α = .83), Negative Urgency (α = .89), Positive Urgency (α = .94), Sensation Seeking (α = .85), and Perseverance (α = .82) (Cyders, 2013).

Discomfort Intolerance Scale (DIS)

The DIS (Schmidt et al., 2006) consists of seven items assessing physical discomfort intolerance and avoidance . Items are rated on a 7-point Likert scale (0 = “Not at all like me,” 6 = “Very much like me”). Subscales demonstrate good reliability: Tolerance (α = .91) and Avoidance (α = .72).

Pain Catastrophizing Scale (PCS)

The PCS (Sullivan et al., 1995) is a 13-item measure of cognitive and emotional responses to pain . Items are rated from 0 (“Not at all”) to 4 (“All the time”).

It includes three subscales: Rumination (α = .87), Magnification (α = .60), and Helplessness (α = .79). Total scores range from 0 to 52, with higher values indicating greater catastrophizing. Overall reliability is strong (α = .87).

Acquired Capability with Rehearsal for Suicide Scale (ACWRSS)

The ACWRSS (George et al., 2016) evaluates three aspects of acquired capability: fearlessness about death, pain tolerance, and suicide preparation . Items are rated from 0 (“Not at all”) to 8 (“Very strongly agree”).

The scale demonstrates acceptable psychometrics: Fearlessness (α = .70), Preparation (α = .85), and Pain Tolerance (α = .74). Items were adapted from prior measures and expanded to capture cognitive rehearsal of suicide.

Procedures

Survey data was collected between Fall 2022 and Spring 2023 from a population of The University of South Alabama undergraduate students through the Psychology Department's Subject Pool Database (SONA) Systems. Before participants complete the online questionnaires, informed consent will be obtained via a consent form . After completing the online questionnaires, participants in the study will receive two research course credits. Data collection ended on April 14th, 2023, with a total of 1361 participants. A data validation check was conducted with participants who completed less than 89% of the survey and finished faster than 391 seconds removed to ensure the data is valid and an acceptable effort is put forth. Participants were also excluded from the study if they scored a zero on the DES II.

RESULTS

Correlational Analysis

To evaluate the relationships among adverse childhood experiences, dissociation, pain-related cognitive appraisals, and suicide risk factors, a Pearson correlation matrix was computed for all primary variables (see Table 1). Several significant moderate-to-strong associations emerged. ACEs scores were significantly associated with all dissociation subscales (amnesia, derealization, absorption), psychache, pain catastrophizing components (rumination, magnification, helplessness), and both positive and negative urgency traits. Dissociation variables were in turn significantly related to pain catastrophizing dimensions and urgency measures. Psychache showed particularly strong correlations with both helplessness ($r = .509$, $p < .001$) and magnification ($r = .490$, $p < .001$), supporting its centrality to suicide-related distress. Finally, all PCS subcomponents (rumination, magnification, helplessness) were strongly intercorrelated, and each demonstrated moderate associations with acquired capability for suicide (ACWRSS), further underscoring their potential role in mediating suicidality pathways.

Table 1. Bivariate Correlations and Descriptive Statistics between Study Variables: ACEs, Dissociation, Psychache, Pain Catastrophizing, Urgency Traits, and Suicide Capability

	ACES	PSYCHACHE	DES_AMN	DES_DEREL	DES_ABS	PosUrg	NegUrg	PCS_R	PCS_M	PCS_H	ACWRSS
ACES	—	.378**	.226**	.282**	.263**	.069*	.202**	.210**	.246**	.250**	.222**
PSYCHACHE		—	.267**	.341**	.372**	.189**	.449**	.401**	.490**	.509**	.320**
DES_AMN			—	.852**	.668**	.393**	.291**	.186**	.294**	.305**	.117*
DES_DEREL				—	.670**	.379**	.328**	.207**	.306**	.319**	.152**
DES_ABS					—	.225**	.290**	.337**	.373**	.353**	.297**
PosUrg						—	.618**		.160**	.163**	
NegUrg							—	.212**	.299**	.308**	.218**
PCS_R								—	.763**	.789**	.297**
PCS_M									—	.794**	.330**
PCS_H										—	.298**
ACWRSS											—

Note. Values represent Pearson correlation coefficients between key psychological constructs relevant to the acquired capability for suicide. ACES = Adverse Childhood Experiences Scale (Felitti et al., 1998); PSYCHACHE = Psychache Scale measuring psychological pain (Holden et al., 2001); DES_AMN, DES_DEREL, DES_ABS = Amnesia, Derealization, and Absorption subscales of the Dissociative Experiences Scale II (Carlson & Putnam, 1993); PosUrg, NegUrg = Positive and Negative Urgency subscales from the UPPS-P Impulsivity Scale (Lynam et al., 2007); PCS_R, PCS_M, PCS_H = Rumination, Magnification, and Helplessness subscales of the Pain Catastrophizing Scale (Sullivan et al., 1995); ACWRSS = Acquired Capability with Rehearsal for Suicide Scale (George et al., 2016). *$p < .05$; ** $p < .001$.

Exploratory Factor Analysis

An exploratory factor analysis (EFA) was conducted on data from 584 participants to examine the latent structure underlying key study variables: ACEs, Psychache, Amnesia, Derealization, Absorption, Positive Urgency, Negative Urgency, Pain Catastrophizing (PC), and Acquired Capability (AC). Prior to analysis, data were screened for univariate and multivariate assumptions. All variables met criteria for interval measurement, displayed bivariate normality, and were judged to be independent. The sample size supported robust factor extraction. Sampling adequacy was confirmed via the Kaiser-Meyer-Olkin (KMO) test (KMO = .77), and Bartlett's test of sphericity was significant ($p < .001$), indicating sufficient intercorrelation among items. Principal component analysis with Promax rotation (Kappa = 4) revealed a three-factor solution with Eigenvalues exceeding 1, as visualized in the scree plot (Figure 3). No cross-loadings were observed. Although ACEs and AC demonstrated communalities below .30, both were retained for theoretical completeness.

Confirmatory Factor Analysis

Following the three-factor structure identified through exploratory factor analysis (EFA), a confirmatory factor analysis (CFA) was conducted using IBM AMOS 26 on the full sample (N = 584).

Model fit was evaluated using standard indices: the Comparative Fit Index (CFI = .930), the Standardized Root Mean Square Residual (SRMR = .075), and the Root Mean Square Error of Approximation (RMSEA = .113). These results suggest acceptable overall model fit, with CFI and SRMR values exceeding conventional thresholds (CFI > .90; SRMR < .08; Hooper et al., 2008). However, the RMSEA exceeded the acceptable cutoff of .10, indicating room for model refinement.

Modification indices suggested correlated residuals within the Distress factor, specifically among items for Psychache, PCS, and ACWRSS. These adjustments improved localized fit but did not substantially reduce RMSEA. Attempts to improve model fit by removing ACEs and AC from the Distress construct worsened overall fit (RMSEA = .140), supporting their conceptual relevance despite lower communalities. As illustrated in Figure 3, the CFA model includes three latent constructs: Dissociation: Indexed by DES-II subscales—Amnesia (.91), Derealization (.93), and Absorption (.73)—demonstrated strong convergent validity. Distress: Comprised of ACEs (.47), Psychache (.82), PCS (.59), and ACWRSS (.42), with moderate loadings indicating fair convergent validity. Urgency: Represented by Positive Urgency (.61) and Negative Urgency (1.01), showed moderate to strong convergence. Inter-factor correlations are reported in Table 2. Associations were moderate between Distress and both Dissociation (r = .47) and Urgency (r = .53), while the correlation between Dissociation and Urgency was lower (r = .34), suggesting some conceptual independence between factors.

Table 2. Correlations Among Latent Factors from Confirmatory Factor Analysis

	1. Dissociation	**2. Distress**	**3. Urgency**
1.	—	.47	.34
2.		—	.53
3.			—

Note. Factor loadings derived from standardized estimates using principal axis factoring with Promax rotation.

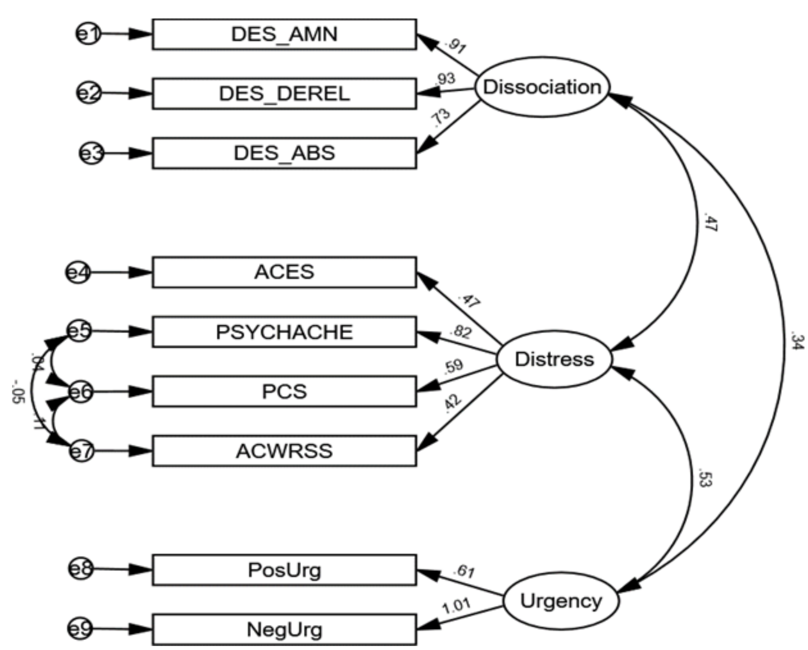

Figure 3. Confirmatory Factor Analysis.

Note. Coefficients are standardized. ACEs (ACES), Psychache (PSYCHACHE), Amnesia (DES_AMN), Derealization (DES_DEREL), Absorption (DES_ABS), Positive Urgency (PosUrg), Negative Urgency (NegUrg) PC (PCS), and AC (ACWRSS)

Structural Equation Modeling

Building upon the three-factor solution confirmed through confirmatory factor analysis (CFA), we developed a series of nine structural equation models (SEMs) to evaluate alternative theoretical configurations of the relationships among dissociation, distress, urgency, and acquired capability for suicide. All SEMs were conducted using IBM AMOS 26 on the full sample (N = 584). The models varied in whether they employed total scale scores or latent constructs composed of subscales—for example, the Dissociative Experiences Scale-II (DES-II) was alternately modeled as a single indicator versus a latent factor comprised of Amnesia, Derealization, and Absorption; similarly, pain catastrophizing was modeled either as a total PCS score or as a latent construct composed of Rumination, Magnification, and Helplessness.

Model specification followed theoretical guidance from the Interpersonal Theory of Suicide and prior empirical associations observed in the correlation matrix. Model fit was evaluated using standard criteria, including CMIN/DF, the Comparative Fit Index (CFI), the Standardized Root Mean Square Residual (SRMR), and the Root Mean Square Error of Approximation (RMSEA), with attention given to CFI values above .95 and SRMR values below .08 as benchmarks of excellent fit (Hooper et al., 2008). Modification indices were reviewed iteratively to improve local model fit, allowing residual covariances between closely related items within the same factor where theoretically justified.

Of the nine SEMs tested, Model 4 yielded the best overall fit. It retained the total DES-II score to represent dissociation and modeled pain catastrophizing as a latent construct using PCS subscales. This configuration demonstrated a CFI of .968, SRMR of .042, and a CMIN/DF of 4.76, all indicative of a well-fitting model. Although the RMSEA of .080 falls just above the ideal threshold for excellent fit, it remained within the acceptable range, and all retained paths were theoretically interpretable. The final model structure is displayed in Figure 4, with standardized coefficients. Pink lines indicate statistically significant paths, while dark blue and light blue paths represent the strongest and second-strongest effects, respectively.

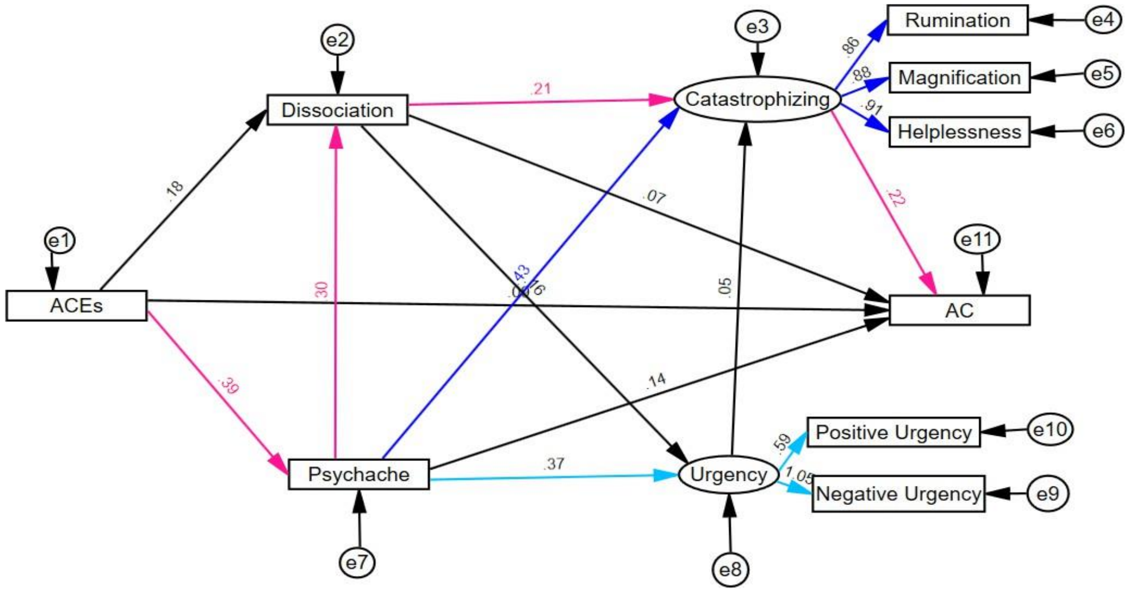

Figure 4. Structural Equation Model 4.

Note. Coefficients are standardized. Pink lines specify the key significant pathway; Dark blue lines represent the pathway accounting for the most variance within the model; Light blue lines represent the pathway accounting for the second most variance within the model.

Direct Effects

Standardized regression paths from Model 4 are reported in Table 4. Consistent with theory, Psychache emerged as the primary driver, predicting Dissociation (β = .30), Urgency (β = .37), Catastrophizing (β = .43), and AC (β = .14). ACEs retained modest direct effects on Psychache (β = .39) and Dissociation (β = .18), while Catastrophizing exerted a unique direct influence on AC (β = .22). The Urgency → Catastrophizing path was non-significant and was trimmed from follow-up mediation tests.

Table 4. Key Standardized Direct Paths (Model 4)

Predictor → Outcome	**β**	**p**
ACES → Psychache	.39	< .001
ACES → Dissociation	.18	< .001
ACES → AC	.09	.036
Psychache → Dissociation	.30	< .001
Psychache → Urgency	.37	< .001
Psychache→ Catastrophizing	.43	< .001
Psychache → AC	.14	.003
Dissociation → Urgency	.16	< .001
Dissociation→ Catastrophizing	.21	< .001
Catastrophizing → AC	.22	< .001

Note: Abbreviations: **ACES** = Adverse Childhood Experiences; **AC** = Acquired Capability (ACWRSS).

Mediation and Specific Indirect Effects

Bootstrapped (5 000 samples) indirect paths with bias-corrected 95 % CIs are summarized in Table 5. Psychache was the dominant mediator, fully or partially transmitting ACES effects to Dissociation and AC and cascading through Urgency and Catastrophizing to specific PCS sub-components.

Table 5. Significant Indirect Paths (Standardized Estimates)

Indirect Path	**β**	**p**	**Mediation Type**
ACES → Psychache → AC	.25	.005	Partial
ACES → Psychache → Dissociation	.87	< .001	Partial
Dissociation → Catastrophizing → AC	.03	.006	Full
Psychache → Catastrophizing → AC	.09	< .001	Partial
Psychache →Urgency → Positive Urgency	.22	< .001	Full
Psychache→Urgency→ Negative Urgency	.39	< .001	Full
Psychache→Catastrophizing→Helplessness	.40	< .001	Full
Psychache→Catastrophizing→Magnification	.38	< .001	Full
Psychache → Catastrophizing → Rumination	.37	< .001	Full

Interpretation

Model 4 clarifies a cascading risk sequence: early adversity (ACES) increases psychological pain (Psychache), which in turn heightens dissociative tendencies, urgency-based impulsivity, and catastrophic pain cognitions. Catastrophizing—especially the Helplessness facet—emerges as the final link to higher acquired capability for suicide. Direct ACE → AC effects persist but are modest once mediators are included, underscoring Psychache's central role in translating childhood adversity into lethal self-harm risk.

Together, these findings integrate the interpersonal theory's acquired capability construct with dissociative and pain-catastrophizing processes, suggesting that interventions targeting psychological pain and maladaptive pain cognitions may disrupt the pathway from early adversity to suicidal behavior.

DISCUSSION

The Interpersonal Theory of Suicide (IPTS) posits that an individual must possess both the desire and the acquired capability (AC)—defined as fearlessness about death and elevated pain tolerance—to engage in lethal self-harm (Joiner, 2005; Van Orden et al., 2010). This theory provides a framework for understanding the substantial gap between rates of suicidal ideation and suicide completion. While IPTS has received empirical support, relatively few studies have investigated the psychophysiological mechanisms that may underlie AC. The present study sought to address this gap by examining how adverse childhood experiences (ACEs), Psychache, Dissociation, Pain Catastrophizing (PC), and urgency traits contribute to AC. Our findings offer preliminary support for the hypothesized mediating pathways and highlight underlying psychological processes that may amplify risk.

The first goal was to examine associations between Dissociation and Discomfort Intolerance. Although we hypothesized strong correlations between subscales of the Dissociative Experiences Scale (DES-II) and the Discomfort Intolerance Scale (DIS), the data revealed only weak correlations ($r = .094$ to $r = .252$; see Table 1), failing to support Hypothesis 1. This suggests that Dissociation may not reduce intolerance for discomfort as theorized, or that the DIS may lack sensitivity to the constructs of interest.

Hypothesis 1a, however, was supported: Dissociation correlated more strongly with subscales of the Pain Catastrophizing Scale (PCS), with values ranging from $r = .186$ to $r = .337$ (see Tables 2 and 3). This implies that dissociative tendencies may relate more closely to maladaptive cognitive-emotional responses to pain than to physical discomfort per se. To clarify latent structure among constructs, we conducted exploratory and confirmatory factor analyses (EFA and CFA). Both analyses supported a three-factor model composed of Dissociation, Distress, and Urgency (see Figure 3 and Table 4). These factors replicate the classic three-component model of the DES-II—Absorption, Amnesia, and Derealization—as observed in prior research (e.g., Bernstein & Putnam, 1986; Carlson & Putnam, 1993).

The "Distress" factor emerged as particularly salient, comprising ACEs, Psychache, PC, and AC. This pattern is consistent with prior research showing that ACEs and Psychache predict suicidal behavior (Demirkol et al., 2020) and suggests that these constructs may load onto a common vulnerability domain. Furthermore, this aligns with literature linking early adversity to increased cognitive-emotional reactivity to pain, as indexed by PC (Tidmarsh et al., 2022; Zlotnick et al., 2022). The third factor, "Urgency," combined Positive and Negative Urgency and was consistent with conceptualizations of emotion-driven impulsivity leading to maladaptive behaviors under intense affect (Cyders et al., 2007; Anestis & Joiner, 2011).

Our fourth objective involved modeling structural relationships among these constructs to predict AC. Nine structural equation models were evaluated, and Model 4 (see Figure 4) demonstrated the best fit, with AC as the outcome variable. This model supported several key mediation pathways.

Hypothesis 3a proposed that the relationship between ACEs and AC would be mediated by both Psychache and Dissociation. While the indirect path through Psychache was significant ($B = 0.055$, $p = .007$), the path through Dissociation was not, offering only partial support for this hypothesis. However, Catastrophizing was found to fully mediate the relationship between Dissociation and AC, confirming Hypothesis 5. These findings suggest a serial mediation pathway in which ACEs increase Psychache, which in turn elevates Dissociation, ultimately leading to higher levels of PC and, consequently, AC.

These results partially replicate findings from Demirkol et al. (2020), who identified Psychache and Dissociation as mediators between ACEs and suicide attempts. Our extension of that model to include PC provides a more granular understanding of cognitive-affective amplification processes underlying AC. Hypothesis 3b, which proposed that Psychache would exert an indirect effect on AC through both

Dissociation and PC, was supported (B = 0.063, $p < .001$). This highlights the centrality of maladaptive pain-related cognitions in the pathway from emotional pain to suicidality.

In contrast, Hypothesis 3c was not supported: indirect effects of Psychache through Positive and Negative Urgency and PC were not significant in predicting AC. However, one pathway stood out—Psychache → Catastrophizing → AC (highlighted in dark blue in Figure 4)—and accounted for the largest share of variance in the model. This finding aligns with prior literature on pain catastrophizing, which suggests that individuals high in PC tend to ruminate on the aversive consequences of pain, thereby intensifying perceived suffering (Sullivan et al., 1995).

Hypothesis 4 was also supported. Psychache significantly mediated the relationship between ACEs and both Positive and Negative Urgency (B = 0.145, $p < .001$), with these paths accounting for the second-largest variance component in the model (see Figure 4, light blue). These findings indicate that trait-level urgency, particularly Negative Urgency, may serve as an amplifier of suicide risk, potentially by facilitating impulsive responses to Psychache. Previous research has similarly suggested that urgency is a stable personality trait associated with self-harming behaviors and suicidality (Whiteside & Lynam, 2001; Anestis & Joiner, 2011).

Finally, Hypothesis 5, concerning the mediating role of PC in the relationship between Dissociation and AC, was confirmed. These findings support the interpretation that individuals who experience dissociation may resort to maladaptive cognitive coping strategies such as catastrophizing, which in turn exacerbate their vulnerability to suicidality by intensifying Psychache (Sullivan et al., 1995).

CLINICAL IMPLICATIONS

These findings, while informative, should be interpreted with caution given the nonclinical, undergraduate sample. Future studies should test these relationships in clinical populations to better assess the translational relevance of the model. One key implication involves the pathway from ACEs through Psychache, Dissociation, and Pain Catastrophizing (PC) to Acquired Capability (AC). This suggests that individuals with dissociative tendencies may exhibit heightened internal self-focus and cognitive intrusions rooted in early trauma.

Clinically, this underscores the importance of assessing trauma histories and dissociative symptoms in individuals exhibiting suicidal ideation or behavior. The metacognitive model of Wells (2000) offers a promising intervention strategy, targeting maladaptive attentional control and ruminative thought patterns. Metacognitive Therapy may be especially useful in addressing the rumination and magnification dimensions of PC, thereby alleviating Psychache and reducing suicide risk (Ródenas-Perea et al., 2023). Interventions can focus either on the process of rumination—by increasing present-focused awareness and disengagement from repetitive thoughts—or on the cognitive content, using cognitive-behavioral techniques to reframe emotions such as anger, guilt, and shame.

Additionally, the strong associations observed between ACEs, Psychache, and Dissociation suggest a need for trauma-informed therapeutic approaches. Mindfulness-based therapies have demonstrated efficacy in reducing dissociative symptoms (Zerubavel & Messman-Moore, 2015). Empirically supported treatments such as Acceptance and Commitment Therapy (Baslet & Hill, 2011), Dialectical Behavior Therapy (Koons et al., 2001), and Sensorimotor Psychotherapy (Langmuir et al., 2012) may be particularly suited for individuals with trauma-related dissociation. Recognizing and targeting these interlocking constructs may help reduce suicide risk and inform tailored interventions for high-risk populations.

LIMITATIONS

The sample was demographically narrow—primarily Caucasian, female, and traditional-aged undergraduates from a single institution—limiting generalizability to clinical or more diverse populations. The study's cross-sectional design also precludes any inference of temporal or causal relationships. Conducting both the exploratory and confirmatory factor analyses on the same dataset may have artificially inflated model fit indices (Anderson & Gerbing, 1988), thereby limiting the reliability and replicability of the three-factor structure. Finally, reliance on self-report measures introduces common method biases. Participants may have misrepresented or struggled to accurately report sensitive experiences, particularly dissociative symptoms. Prior research suggests that self-reported dissociation is highly susceptible to mood state and psychological distress at the time of reporting (Marshall & Schell, 2002).

CONCLUSION

This study aimed to elucidate the psychophysiological mechanisms contributing to acquired capability for suicide. Contrary to our hypotheses, Dissociation alone did not significantly account for variance in AC. However, PC emerged as a critical mediator, particularly in the pathways connecting Dissociation and Psychache to AC. The most robust effects were observed in the indirect paths from Psychache through PC and Urgency, highlighting the role of maladaptive cognitive-emotional processes in suicide risk.

Although preliminary, these findings contribute to a nuanced understanding of how early trauma, emotional pain, and cognitive-affective dysregulation intersect to amplify suicide risk. Future research should adopt longitudinal and multi-method designs—including experimental and qualitative approaches—to clarify the dynamic interplay among ACEs, Psychache, Dissociation, and PC in the development of AC.

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BIODIVERSITY OF PLANTS ON CONSERVATION LAND IN NORTH ALABAMA: LESSONS LEARNED FROM A STUDY OF *POALES* AT BLOUCHER FORD NATURE PRESERVE, MADISON COUNTY

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ABSTRACT

Alabama is a hotspot for diversity in the United States, but very little land is under public protection with many conservation areas under management of local land trusts. This study provides the results of the first floristic inventory (focused on the Order *Poales*) on a land trust property in North Alabama before and after a change in habitat management regime that identifies over 70 species of grasses, sedges, and rushes with 29 new and updated contributions to vascular flora records. The results outlined in this study demonstrate the high species richness possible to find within a small nature preserve, the need for changes in management that may be necessary to complete identification and inventory of species, and the necessity for more local vascular plant studies to reduce gaps in local conservation organization knowledge as well as state and regional plant records that could lead to flawed analyses for studies or models that rely on that data.

Keywords: *Poales*; herbarium database; vascular flora records; conservation management; floristic inventory

1. Introduction

1.1 Biodiversity in Alabama

The conservation of biodiversity plays an important role in preservation of ecosystem function and the intrinsic and anthropogenic values of the ecosystem services provided by those functions [1,2]. Alabama has long been known as a biodiversity hotspot in the United States [3] with a variety of studies over the last few decades lending evidence to the state's importance in the conservation of biodiversity of a wide range of organisms including lichens, amphibians, fish, and vascular plants [e.g., 4-7]. Despite this high biodiversity, very little land in Alabama (~4.9%) is owned or managed by public agencies for conservation purposes [8]. Instead, like many other areas of the United States, conservation of land for public recreation, or ecosystem preservation is taken up by community-based non-profit entities known as land trusts [9,10].

1.2 Land Trusts' Role in the Conservation of Biodiversity

Land trust organizations directly purchase lands or pay for the placement of conservation easements on private property to protect properties from development and provide for some form of conservation [10,11]. Land trusts provide an avenue for targeted community and charitable funding of biodiversity conservation particularly for property acquisition [12] and since they are private entities, land trust organizations have more flexibility than public agencies in how they can reach their land management goals [13]. As community-based organizations that operate across a range of landscapes and political/social climates, the strategies used for land protection, the community funding potential, social capital available for mobilizing local volunteers and the efficiency of their operations vary widely across regions [14]. As community-based organizations that operate across a range of landscapes and political/social climates, the strategies used for land protection, the community funding potential, the social capital available for mobilizing local volunteers, and the efficiency of their operations vary widely across regions [10,14,15]. For example, in a survey of 626 land trusts across the United States, the Southeastern regions had the amount of lowest amount of land purchasing activity in the country relying on land easements instead, also had the most amount of urban land protected as well as the most likely to have urban areas within their service zone compared to other regions of the United States [10].

While land trusts are an important link in the preservation of biodiversity, there are also some shortcomings and gaps in the management of the conservation lands that are controlled by land trust organizations. These include gaps in the knowledge of land management, conservation biology, natural resource management, and biodiversity conservation [10,14,16]. There is also a lack of information and data on the effectiveness of land trusts in the conservation of biodiversity and the management decisions they make for their properties over time [14] including the presence of measurable goals that can define a level of ecological success over fundraising and land acquisition metrics [17]. There is also a reliance on volunteers for ecosystem evaluation and monitoring [18]; while this can increase community ownership and engagement in lant trust activities, there can be barriers to time and commitment. There are a wide variety of specific conservation objectives that would align with overall land trust aims and university research teams could assist in the creation, monitoring, and evaluation of these goals.

1.3 Herbariums, Inventories and Databases of Plant Records and their Importance

A vital part of the creation and monitoring of these conservation objectives would be an inventory of the population or subject of specific interest for each of the goals. Plant inventories, for example, provide the basis for estimating the local biodiversity and the lack of this information can reduce the accuracy of the mapping of plant communities needed for monitoring and evaluation [19]. These floristic studies are critical in understanding the threats to plant communities and the gaps in our understanding of the conservation status of certain plant populations [20,21], the relationships between plant populations and their environment [19], the changes in plant communities over time and due to differences in management or land use through monitoring [22], and introductions from invasive species [23]. Local inventories can span across a region or high spatial levels to illuminate larger scale trends and variations [24].

As floristic studies are completed, plant specimens are collected and stored in local and regional herbaria as a document of the plant's identity, morphology, and plant community as the species grew in specific climatic conditions in a particular time and place [25] with records validating each time that a plant species is found and identified with an area. These herbarium records offer a wealth of opportunities to explore how the phenology and biodiversity of a locality changes, and recent advances in DNA analysis and Big Data processing can unlock even more insights into the effects of events like climate change and the large-scale community shifts that can occur [26-28]. Digitizing and sharing local herbarium collections through state, regional, national and international databases offers a way to better understand spatial and temporal challenges to biotic communities that can lead to strategies to better conserve biodiversity [29-37]. Small local herbaria are especially important and are necessary to increase the total number of plant collections and inventories available to bridge temporal and spatial gaps found in larger collections [38,39].

A number of these biases can occur in the process of floristic inventories that can lead to gaps in plant records leading to the over- or under-sampling of plant communities or land-uses [39-42]. These biases can be geographic in nature with samples coming from areas easier to reach or land-uses that occur more frequently [41], sampling from plant communities that are more interesting or attractive [42], or difficulty in identification of species within a particular family or order (e.g., *Poales*) [43-45]. Bringing in collections from small herbaria that focus on local collections and have regional expertise can help alleviate these biases [39].

1.4 Purpose of this Study

This paper describes a research study conducted in collaboration with the Land Trust of North Alabama (LTNA), a 501(c)(3) conservation organization located in Huntsville, AL, established on June 24, 1987, as The Huntsville Land Trust, which was Alabama's first **l**and **t**rust. [46]. The overall objective of the study was to (1) document the diversity of vascular flora on LTNA properties and (2) provide LTNA management with the information necessary to make optimal decisions on the management of their plant community. For this paper, we will provide the results of the first floristic inventory (focused on the Order *Poales*) on a LTNA-owned property in North Alabama before and after a change in land management and then offer lessons learned about how the choice in vegetation management can affect the biodiversity of grasses, sedges, and rushes. We will also discuss new findings and updates to the records of vascular flora in the region including a selection of noteworthy flora found on the study site, and data gaps we have identified working with regional herbaria databases.

2. Materials and Methods

2.1 Study Area:

Bloucher Ford Nature Preserve is a 28.19-acre property managed by LTNA in New Market, AL (Madison County) in North Alabama in the Southeast Region of the United States (Figure 1).

2.1.1 Historic Land Use

The Bloucher Ford property is on the floodplain of the Flint River, an area whose anthropogenic use can be traced back to the Early Paleoindian, Late Archaic, and Middle Woodland periods [47] with Native American settlers occupying the land through the early 1800s. Modern settlers moved onto the property purchased from the United States government in 1809 and operated a grain mill from 1815 to 1959 marking the first settlement in what is now Madison County, AL [48]. In 1962, the property was effectively abandoned until the LTNA purchased the property in 2013 to develop the property as a recreational area and event venue.

2.1.2 Physical and Climatological Description

The study area is a floodplain consisting of wet meadows, riparian corridors, and bottomland hardwood forests at the confluence of Mountain Fork Creek with the Barren Fork of the Flint River which lies at the boundary of two physiographic regions: the Cumberland Plateau and the Tennessee Valley district of the Highland Rim. Most of the floodplain is covered in deep, well-drained soils of Humphreys silt loam (an Ultic Hapludalf). The lowest terraces along the stream are newer soils of the Lee-Lobellville complex soils that are poorly drained [47]. The soil along the waterways and in depressions on the floodplain are gravelly. Gravel bars and sand bars are abundant along the banks and in streambeds.

Bloucher Ford Nature Preserve has very little change in topography with the elevation of the site ranges from 206 m at the north and south ends with very shallow incline to 209 m in the middle of the property [49]. From 1991-2020, the average annual rainfall for the area is 54.29 inches ranging between an average of 5.87 inches in the rainiest month of December and 3.49 inches in the driest month of September. Mean high temperatures reaching 91.5F in July and mean low temperatures reaching 33.1F in January with an average annual temperature of 73.8F [50].

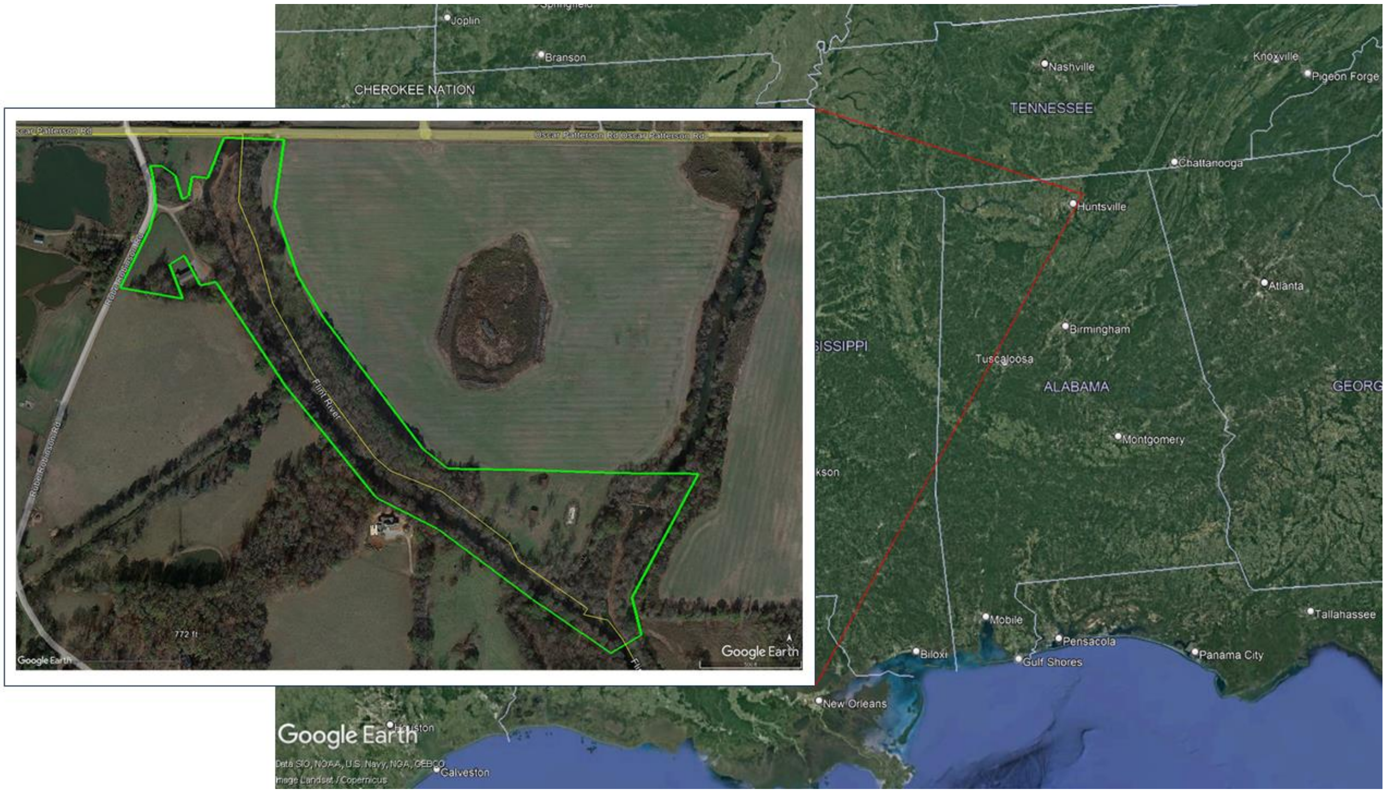

Figure 1. Map of Bloucher Ford Nature Preserve (outlined in green), Madison County, Alabama, in the Southeastern United States [51].

2.2 Vascular Plant Inventory

A vascular plant inventory was conducted across the entire property starting in early September 2020 and continuing through early October 2022. The project began with a series of multi-day rapid assessment floristic surveys with local and regional expert botanists; these "expert bio-blitzes" [52] formed the base of the dataset as further data was collected for the next two years. This study focused on identifying and documenting occurrences of the grasses, sedges and rushes in the Order *Poales* due to the effect on those species by the current management regime on the property.

Past literature has shown that for sampling wetland areas such wet meadows and bottomland forests, the sampling method with the most detection power is the timed meander search procedure as outlined by Goff et al. [53]. The technique has been demonstrated to more efficiently and thoroughly document species with less energy and time expended [54], particularly when the understory cover is heterogenous [55]. Modifying the methodology to include extra quality measures such as allowing extra time for searching below dominant species [54] can alleviate some concerns about missing species hidden from walking view [55].

A modified meandering sample of species was collected weekly during the growing season with the full site sampled every two to three weeks. All major plant communities and physically accessible habitats were sampled. Loosely divided into eight collection regions, habitats sampled included active channels of the Flint River and Mountain Fork Creek, a man-made dam, a millrace, bluffs, ditches, floodplain terraces, gravel bars, levees, roadsides, sand bars, seasonally swampy areas, springs, wet meadows, and tree lines of the Flint River and Mountain Fork Creek at its confluence with Flint River.

Every habitat on the property is subject to seasonal flooding, usually during the winter months with flood events also known to occur during the fall and spring of each year.

Specimens were collected in flower or fruit non-destructively (when possible); cleaned of all possible debris, pressed using standard field presses, dried, and subjected to freezer conditions before being accessioned into the Forestry Herbarium (AAMU) at Alabama A&M University, Normal, Alabama. The flora is then digitized and vouchered to the Alabama Plant Atlas upon approval from the Land Trust of North Alabama.

2.3 Change in Conservation Management

As of July 2023, the site is not open for use to the public, so the only direct human influence on the management of site flora is from the LTNA. Prior to this study, the LTNA managed the property through intense, regular mowing of the grasslands and wet meadows to create a lawn-like appearance. Literature has shown that tolerance to mowing differs between species of grasses, sedges, and rushes [56,57] with mowing can have a variety of differing effects on the diversity of plant communities depending on the regime and intensity either increasing or preserving current biodiversity or species richness [57-60] or suppressing/reducing species and deteriorating plant communities [61,62]. In addition, the timing of mowing is an important factor with mowing during the reproductive period reducing diversity of grasslands [63]. For this study, beginning at the end of June 2021, LTNA management ceased mowing several areas of grassland and wet meadow to allow for grasses to grow, flower and fruit for identification and documentation of species suppressed by the mowing management.

2.4 Identification and Herbarium Records

Online sources of vascular plant collections and county records from Madison County, AL were searched during the study period from within the Alabama Plant Atlas [64], Consortium of Midwest Herbaria [65], SEINet Portal Network [66], and SERNEC Data Portal [67]. In particular, the Vascular Flora of Madison County, AL [68] was used to verify and append county records currently not recorded by the Alabama Plant Atlas [64]. In addition, personal correspondence with other organizations and herbaria such as the Botanic Research Institute of Texas [69] was used to confirm and correct entries for various species such as *Juncus acuminatus* Michx. [68]. Specimen identifications were determined using Aquatic and Wetland Plants of Southeastern United States: Monocotyledons [70]; Common Grasses, Legumes and Forbs of the Eastern United States Identification and Adaptation [71]; Flora of North America Cyperaceae Volume 23, Juncaceae Volume 22, Poales Volume 24, and Poales Volume 25 [72]; the Manual of the Vascular Flora of the Carolinas [73]; Weeds of the South [74]; and the online Flora of the Southeastern States: Alabama [75].

Scientific nomenclature and species circumscriptions follow PLANTS Database [76]. The online Alabama Natural Heritage Program list of Rare, Threatened, and Endangered Plants & Animals of Alabama [77] and NatureServe [78] provided the information needed to identify rare, threatened, or endangered species in Madison County, AL.

3. Results and Discussion

3.1 Vascular Plant Inventory

Our floristic survey over the course of two years located and collected a total of 71 species of grasses, sedges, and rushes in the Order *Poales* alone (Figure 2). Among these, there were 29 species in 5 genera in the family Cyperaceae, 5 species in 2 genera in the family Juncaceae, and 37 species in 29 genera in the family Poaceae (Table 1, Figure 3). *Carex* was the largest genus representing 18 species followed by

Cyperus, with 8 species and both genera in the family Cyperaceae. Poaceae was the family with the most recorded species overall. The full annotated checklist for all collected specimens is found in Appendix A.

Figure 2. Georeferenced locations of plant specimens with Order *Poales* located and collected at Bloucher Ford Nature Preserve in North Alabama [51]

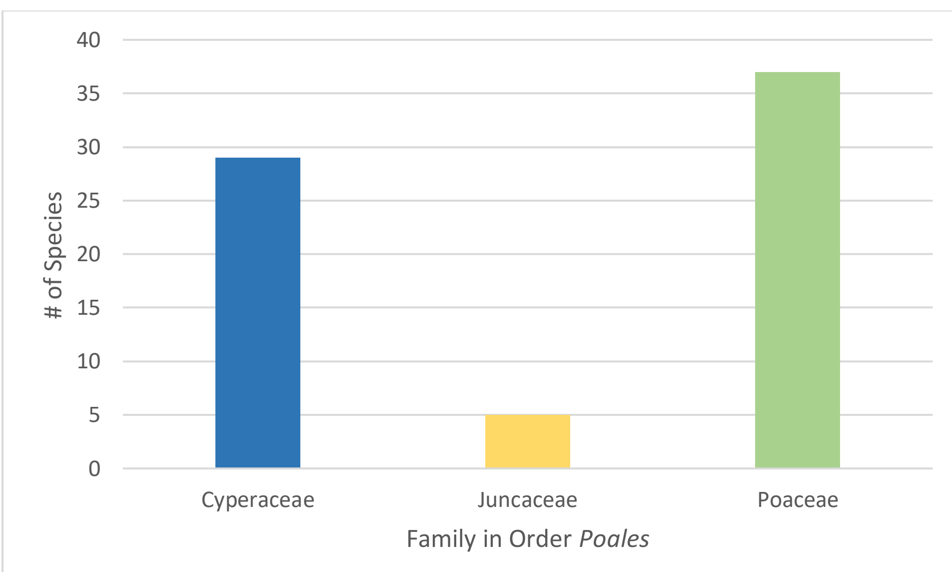

Figure 3. Number of species within each family in Order *Poales* identified at Bloucher Ford Nature Preserve in North Alabama

Table 1. Summary of *Poales* at Bloucher Ford Nature Preserve 2023.

Family	Genera	Species	Species of Concern – Rank *	Native Species	Non-native Species
Cyperaceae	5	29	1 - S1	27	2
	Carex	18	4-SNR/G4 1- S1/G4 1-*/G5 12-SNR/G5	18	0
	Cyperus	8	1-SNA/GNR Exotic 1-SNR/G5T5 6-SNR/G5	7	1
	Eleocharis	1	SNR/G5	1	0
	Kyllinga	1	SNA/GNR Exotic	0	1
	Scleria	1	SNR/G5	1	0
Juncaceae	2	5		5	0
	Luzula	1	1-SNR/G5	1	0
	Juncus	4	4-SNR/G5	4	0
Poaceae	29	37		23	14
	Andropogon	1	SNR/G5	1	0
	Arundinaria	1	SNR/G5	1	0
	Bromus	1	SNA/GNR Exotic	0	1
	Calamagrostis	1	SNR/G5	1	0
	Chasmanthium	1	SNR/G5	1	0
	Cinna	1	SNR/G5	1	0
	Cynodon	1	SNA/GNR	0	1
	Dactylis	1	SNA/GNR	0	1

			Exotic		
	Dichanthelium	1	SNR/G5	1	0
	Digitaria	1	SNR/G5	1	0
	Echinochloa	2	SNA/GNR Exotic SNR/G5T5	1	1
	Eleusine	1	SNA/GNR Exotic	0	1
	Elymus	2	1-*/GNR 1-SNR/G5	2	0
	Eragrostis	1	SNA/GNR Exotic	0	1
	Festuca	1	SNR/G5	1	0
	Hordeum	1	SNR/G5	1	0
	Leptochloa [Dinebra/ *Brachiaria*]	1	S1/G5	1	0
	Melica	1	SNR/G5	1	0
	Microstegium	1	SNA/GNR	0	1
	Muhlenbergia	1	SNR/G5	1	0
	Panicum	3	3-SNR/G5	3	0
	Paspalum	2	1-SNR/G5 1-SNA/GNR Exotic	1	1
	Poa	3	2-SNA/GNR Exotic 1-SNR/G5	1	2
	Schedonorus	1	SNA/GNR	0	1
	Setaria	2	2-SNA/GNR Exotic	0	2
	Sorghum	1	SNA/GNR Exotic	0	1

	Steinchisma	1	SNR/G5	1	0
	Tridens	1	SNR/G5	1	0
	Urochloa	1	S1**/G5	1	0
Total:	36	71		55	16

* Status ranks were acquired from NatureServe [78]; *C. corrugata* is not on the NatureServe map as being present in Alabama; *E. glabriflorus* is not yet rated or formally recognized by NatureServe and is not on the map as being present in Alabama. **The status of *Urochloa platyphylla* is conflicting between NatureServe [78] and Alabama Natural Heritage Program [77] tracking information.

The number of species found within just the *Poales* demonstrates the high species richness within the small nature preserve. Among the recorded 71 species, we would like to highlight a variety of noteworthy, endemic, and/or invasive/noxious species from the study (Table 2). Understanding species that are rare, in need of special management, or likely to create ecosystem problems is important for the preservation of the high diversity on the site. These species are listed in more detail with growth and habitat information in the following sections and a variety of these noteworthy species are documented in photographs in Appendix C.

3.1.1 Noteworthy, Rare, Threatened or Endangered Species (Table 2):

Carex socialis Mohlenbr. & Schwegm. Weninegar L.L.4427, 4450, 4460 was first recorded by Mollenbrock and Schwegman in 1969, currently in decline due to habitat loss [78], this species is endemic to the southeastern United States [75]. *C. socialis* is listed as S1 (critically imperiled) by Nature Serve [78], and S2 (imperiled) by the Alabama Natural Heritage Program [77].

The species was recorded in neighboring Jackson County, Alabama in 2019 [79]. Clear-cutting on floodplains and drainage of floodplains for agriculture, pastureland, or river channelization are likely the primary contributors to the species' decline and it has been suggested that floodplain protection is needed to prevent the further decline of the species and the invasion of its habitat by *Lonicera japonica* Thunb. (Japanese honeysuckle) and *Pueraria montana* (Lour.) Merr. (Kudzu). [78]

Small populations of *C. socialis* were observed in open, sunny, wet-mesic meadows of the Barren Fork region of the Flint River floodplain during this study. The area is subject to frequent flooding during the winter months, though flood conditions are not uncommon from late summer into early spring. Flowers appear in late April; fruit is fully mature in June of the year, at a time when mowing has traditionally occurred on the property. Though kudzu has not been documented on the property, Japanese honeysuckle is abundant on the floodplain. Prior to this study, *C.socialis* was known to exist in only 11 counties in Alabama [64].

No Federal or State of Alabama rare, threatened, or endangered grass or rush species were collected on the property [77]. Though NatureServe [78] lists *Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster (broadleaf signalgrass), identified as *Brachiaria platyphylla* in the NatureServe database, as critically imperiled (S1) in Alabama, it currently is not tracked by the Alabama Natural Heritage Program [77]. Weakley [75] lists broadleaf signalgrass as an exotic species in the interior low plateau and an uncommon exotic in the Alabama mountains, while NatureServe lists it as a native species. An agricultural weed with very small seeds allows it to be easily transported with crop seeds to farm sites where the seeds germinate and become a pest species in corn, soybeans, and other economically important crops, particularly in open sandy fields [80] potentially causing economic and environmental detriment to areas it exploits.

Eragrostis minor Host (little lovegrass*), Leptochloa panicea* (Retz.) Ohwi ssp. *brachiata* (Steud.) N. Snow (mucronate or red sprangletop), and *Melica mutica* Walter (twoflower melicgrass), are of minor importance on the Preserve; all three are vouchered in the Alabama Plant Atlas [64]. *E. minor* was vouchered during the initial bio-blitz surveys of October 2020 and is a county record from the Bloucher Ford Nature Preserve in New Market, AL. *E. minor* is an introduced grass from Europe [75]. The species has become naturalized across the United States [81].

Leptochloa. panicea ssp. *brachiata* is a native grass, first collected by R. David Whetstone 6977 with A.E. Radford on 15 October 1975 [64]. Its presence on Bloucher Ford Nature Preserve is the only other documented occurrence in Madison County, AL; also housed at UWAL was collected by J. Kevin England 11296, 04 October 2020 and vouchered as *Dinebra panacea (*Retz.) P.M. Peterson & N. Snow. Red sprangletop is often found in agricultural settings on disturbed, mesic soils. The U.S. Department of Agriculture considers it a noxious weed [82] but it is not on a more recent Federal Noxious Weed List [83]. The habitats of *E. minor* and *L. panicea* ssp. *brachiata* will be monitored to ascertain associated vegetation and the extent of their occurrence on the floodplain.

Two vouchered accounts of *Melica mutica* have been reported to the Alabama Plant Atlas [64] for Madison County, AL. Russell A. Meigs 349 collected it on 04 May 1980; two specimens were vouchered by Brian R. Keener 6956 on 27 March 2012. Twoflower melicgrass grows in well-drained soil under shade at Bloucher Ford Nature Preserve and is rare on the property. The species is a relatively small plant and can be easily overlooked amongst other more robust species in a study area.

3.1.2 Endemic Species Observed

Carex cherokeensis, *C. corrugata*, and *C. socialis* are endemic to the Southeastern United States. While *C. cherokeensis* and *C. corrugata* are well documented in the Southeast, in Alabama, *Carex conjuncta* and *C. normalis* occur very near their southernmost limit in the state [79] and are facultative wet (FACW) species; *C. socialis*, is currently not rated [84] but is found on moist to wet, well-drained floodplains, in calcareous soils. *Cyperus lancastriensis* is an endemic species [75] of frequent occurrence at Bloucher Ford Nature Preserve. It can be found in full sun near the edges of water and in open meadows.

3.1.3 Importance of Native Species at Bloucher Ford

Over 70% of the Poales species observed at Bloucher Ford Nature Preserve are native. Some of these plants have been historically important for food and cover for wildlife, floodplain stability, and for limiting the spread of non-native/exotic species. The preserve is currently being impacted by local recreation enthusiasts via kayaking and canoeing, fishing, swimming, and other outdoor activities (including unauthorized off-road vehicles). Urban land cover is also increasing in the region [85] and could impact the integrity of the floodplain as native trees, shrubs, and grasses are removed for development which can open gaps for non-native horticultural species of grasses, sedges, and rushes as well as ornamental cultivars of landscape plants not native to the area.

Table 2. Noteworthy species of Bloucher Ford Nature Preserve, Madison County, AL.

Family	Scientific Name	State Rank*	Global Rank*	Wetland Code**	Significance
Cyperaceae	*Carex abscondita* Mack.	SNR	G4	FAC	Though common in Alabama [75], it is a rare native species in the Preserve; possibly under-collected on floodplains due to its small size and hidden culms
	Carex albolutescens Schwein.	SNR	G5	FACW	Rare in the Preserve, wet meadows in acid soil along floodplain tree lines; this native species usually inhabits acidic, calcium-poor soils [79]; common in the interior low plateau and AL mountains [75]
	Carex amphibola Steud.	SNR	G5	FAC	Rare in the Preserve, native; a habitat generalist [78], often along riparian zones of streams, slopes above streams, and uplands [72]; it is often cultivated and sold in the nursery industry [86]
	Carex blanda Dewey	SNR	G5	FAC	Common in the Preserve, often weedy, along mesic well-drained banks of floodplain in partial shade near disturbed areas. A native that is common in the AL mountains and interior low plateau [75]

	Carex caroliniana Schwein.	SNR	G5	FACW	Rare in the Preserve, in part-sun to shady sites. A common native in the AL mountains and interior low plateau [75].
	Carex conjuncta Fernald	SNR	G4	FACW	Infrequent in the Preserve, A native; near the southern range for the species [79]; rare in the AL interior low plateau and mountains [75]
	Carex leavenworthii Dewey	SNR	G5	NR	Infrequent in the Preserve, in wet meadows along the east bank of Flint River. A native common to the interior low plateau and AL mountains [75]
	Carex longii Mack.	SNR	G5	OBL	Rare in the Preserve; a native and a Madison County, AL record; uncommon in AL mountains [75]
	Carex normalis Mack.	SNR	G5	FACW	Infrequent in the Preserve, a native; near the southern range for the species [79]; rare in AL mountains [75]
	Carex socialis Mohlenbr. & Schwegm.	S1	G4	NR	Infrequent in the Preserve. Rarity possibly due to frequent mowing within riparian zones/habitat during active growth/reproductive stage. SE endemic; rare to the interior

					plateau and AL mountains [75]
	Cyperus esculentus L.	SNR	G5	FACW	Grows with Cyperus strigosus and C. lancastriensis on the property. Native to interior low plateau and AL mountains [75]
	Cyperus iria L.	SNR/ Exotic	SNR	FACW	Common in the Preserve. Considered one of the world's worst weeds [64, 87]. Common in the AL mountains and interior low plateau [75]
	Cyperus lancastriensis Porter in A. Gray	SNR	G5	FAC	Common in full sun near water in the Preserve. Uncommon to lower interior plateau and AL mountains, endemic to Southeastern US [75]
	Kyllinga gracillima Miq. = *Cyperus brevifolioides* Thieret & Delahoussaye	SNR/ Exotic	SNR	FACU	Infrequent in the Preserve; Madison County, AL record; from eastern Asia; rare exotic in AL mountains. [75].
Poaceae	*Calamagrostis coarctata* Eaton	SNR	G5	OBL	A rare native species in Alabama [75] Madison County, AL Record; rare in the Preserve. It was known to only five counties in AL until this study [64].
	Cinna arundinacea L.	SNR	G5	FACW	An uncommon species in the Preserve. Madison County, AL Record

					[67]. A common native in AL mountains and interior low plateau [75]
	Cynodon dactylon (L.) Pers.	SNA/ Exotic	SNR	FACU	Madison County, AL Record [67]. A common exotic from Eurasia [75], noxious weed, first collected in 1897 along the Tennessee River in Madison County [67]; allelopathic [88]
	Dactylis glomerata L.	SNA/ Exotic	GNR	FACU	Madison County, AL Record [67]. Common in the Preserve. Grows in full sun in large wet meadows with various sedges, rushes, and other grasses. Exotic from Europe [75]
	Digitaria ciliaris (Retz.) Koeler	SNR	G5	FAC	Common weed in the Preserve; Madison County, AL Record. A common native to the interior low plateau and AL mountains [75].
	Microstegium vimineum (Trin.) A. Camus	SNR/ Exotic	SNR	FAC	Alabama - Class C noxious weed [83,84]; nonnative invasive; invaders forested floodplains [89]
	Muhlenbergia schreberi J.F. Gmel.	SNR	G5	FAC	Some success with use in the control of *Microstegium vimineum* [90]
	Setaria faberi Herrm.	SNA/ Exotic	SNR	UPL	Noxious weed [91]

	Sorghum halepense (L.) Pers.	SNR/ Exotic	SNR	FACU	Noxious weed introduced into the United States in the early 1800s [92] and is now naturalized; heavy presence in AL [93]
	Urochloa platyphylla (Munro ex C. Wright) R.D. Webster	S1	G5	FAC	A rare weedy species but is infrequent on the study site; its origin is also in question [75]. The last status review was in 1988 [78]

* Nature Serve [78] **Eastern Mountains and Piedmont, Plants.gov [84]

3.1.4 Selected Noxious Weed Species

Leptochloa panicea (Retz.) Ohwi ssp. *brachiata* (Steud.) N. Snow (red sprangletop) is an uncommon native in the lower interior plateau of Alabama [75]. It is a weedy species occupying moist to wet soils along the riparian zone, but not in abundance at Bloucher Ford Nature Preserve. United States Department of Agriculture has in the past labeled the species a noxious weed [82], but it is not on a more recent Federal Noxious Weed List [83].

Microstegium vimineum (Trin.) A. Camus (Nepalese browntop) is on the Alabama Noxious Weed List [94] as a Class C species capable of causing significant harm to agricultural industries. The state of Alabama considers the species a public nuisance. Since its introduction into the United States in 1919, it is now a frequent inhabitant of riparian zones of wooded floodplains, grows well in full sun, is extremely shade tolerant, and rapid vegetative reproduction is possible. The seeds are distributed via water, and animals [95]. This nonnative species is one of the most damaging in the United States to native ecosystems with seeds viable for up to five years. The grass is avoided by deer and livestock allowing it to grow without being browsed allowing its spread. The species is an early invader after prescribed burns and displaces native species, particularly if it is present in the burn area prior to the burn [96].

Setaria faberi Herrm. (Japanese bristlegrass) a native of SE Asia, is a troublesome weed in cultivated fields; the long awns of the mature fruit are injurious to grazing animals [97]. It was introduced in 1925 as a contaminant in grain and quickly became a major agricultural weed by the 1950s in corn and soybean crops [98]. The species is now common in the Northeastern Alabama counties [93] but is only now reported for Madison County, AL [64].

Most *Poales* species found at Bloucher Ford Nature Preserve are native (71%) (Figure 4); the remaining species (29%) are non-native introductions from Central and South America, Eurasia, Africa, the Pacific Islands, China, Japan, Korea, Taiwan, and the Middle East. Interestingly, all of the non-native invasive species were grasses in the Poaceae family.

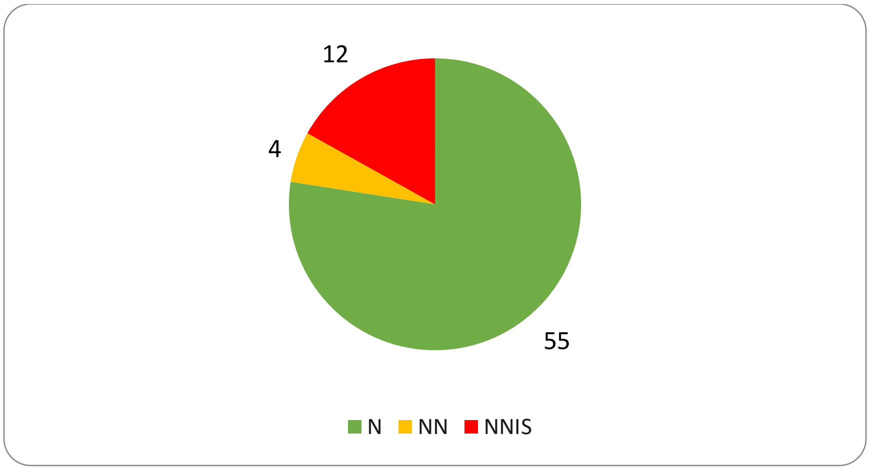

Figure 4. Number of native (N), non-native (NN) and non-native invasive species (NNIS) in Order *Poales* recorded at Bloucher Ford Nature Preserve, Madison County, Alabama

3.2 Change of Conservation Management

Floristic records documented after LTNA ceased mowing in late June 2021 show an increase in discovered species in the Fall of 2021 and the following Summer and Fall of 2022, particularly in additions to the Poaceae (grasses) family (Figure 5) that would have been most affected by activity. As with Kozub et al. [61], the diversity after mowing ended increased and while not every species discovery after Fall 2021 can be directly attributed to changes in mowing frequency and intensity, the change in management did have a dramatic effect on the ability to identify and collect species from the wet meadows and grasslands as well as better observe species density particularly for non-native invasive species.

There were 32 species documented after mowing ended with 15 being Poaceae including 1 county record and 14 Cyperaceae including 3 county records (Figure 5, 6) amounting to 45% of all species identified during the study. The lack of mowing did allow us to identify several species of non-native invasive species on the property that had been hidden or suppressed by the mowing with 2 non-native, non-invasive and 6 non-native, invasive species identified in the entirety of the following year (Figure 7). Of the 32 new species identified from Fall 2021 through Fall 2022, 75% were native, 6.25% were non-native but not invasive, and 18.75% were non-native, invasive species (Figure 7).

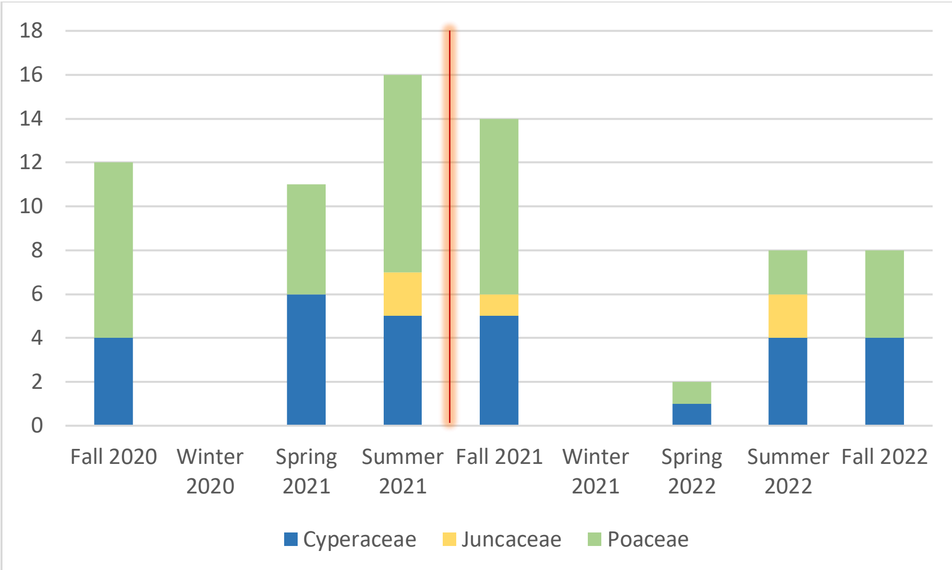

Figure 5. Number of species per family in Order *Poales* recorded by season and year in Bloucher Ford Nature Preserve, Madison County, Alabama. Red vertical line indicates the period of management change.

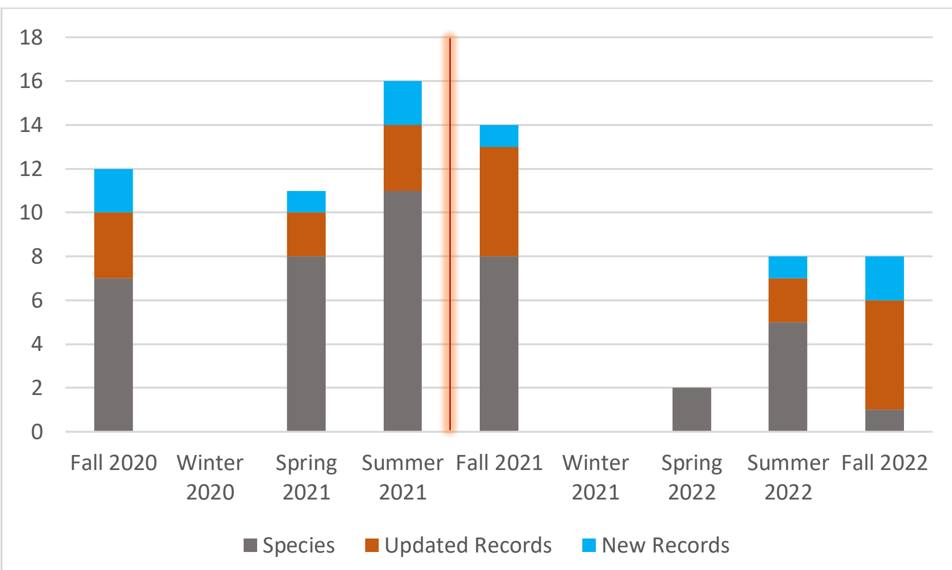

Figure 6. Number of identified species, updated county records and new county records recorded by season and year in Bloucher Ford Nature Preserve, Madison County, Alabama. Red vertical line indicates the period of management change.

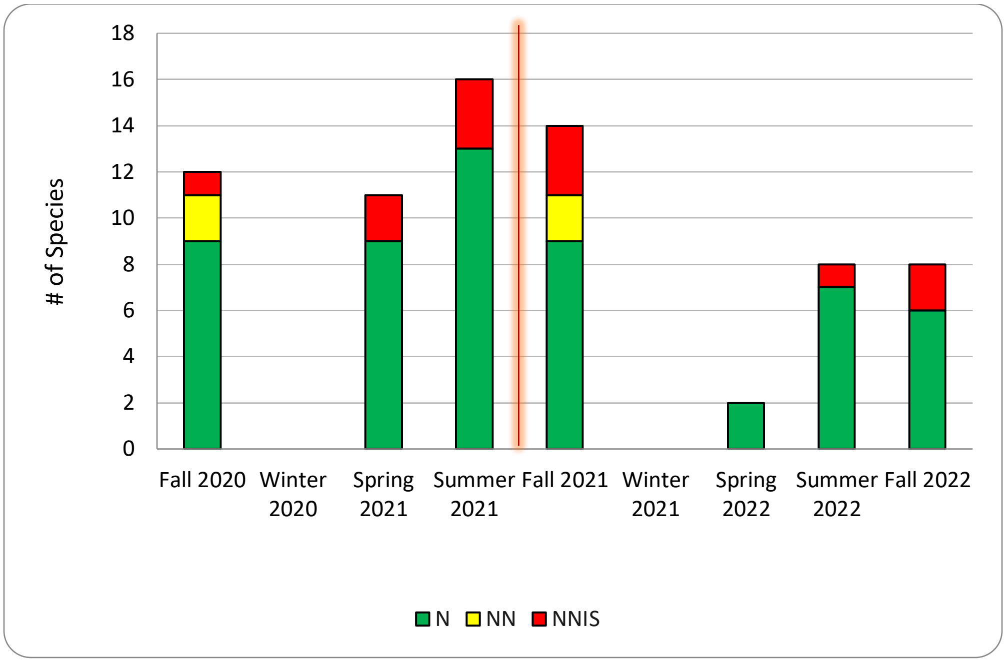

Figure 7. Number of total native (N), non-native (NN), and non-native invasive species (NNIS) recorded by season and year in Bloucher Ford Nature Preserve, Madison County, Alabama. Red vertical line indicates the period of management change.

3.3 Herbarium Records

This Bloucher Ford Nature Preserve floristic study and an extensive, time-consuming online data portal search revealed 29 new, missing, or incorrect first records for Madison County, Alabama within Order *Poales*, including species within the families: Cyperaceae (12), Juncaceae (1), and Poaceae (16). For a floristic study within such a small area, this study provides a strikingly large contribution to updating current local and regional botanical records. In comparison, a floristic study of *Carex* by Naczi et al. [79] of nearby Jackson County, Alabama, recorded an updated 23 species bringing the county-wide total to 90 vouchered species in the Alabama Plant Atlas [64].

Of the 29 contributions to records added or updated, 9 of them are newly reported species in Madison County, Alabama including 4 in Cyperaceae (*Carex (2)*, *Cyperus Kyllinga*), 0 in Juncaceae, and 5 in Poaceae: (*Calamagrostis, Echinochloa, Elymus, Eragrostis, Urochloa)*.

The remaining are 20 updated or missing reports of Madison County vouchered records that are already housed in various herbaria across the country with 6 species already collected by Steven J. Threlkeld for his thesis, Vascular Flora of Madison County, AL [68] that are stored in the JSU Herbarium in Jacksonville, AL (Table **3**). Many of these records are from decades past with many from the 1970s through 1980s with the oldest from 1897. This highlights the necessity of small-scale studies and additions to local herbaria collections, such as demonstrated in this paper, in reducing data deficiencies and removing gaps in state-wide and regional herbarium databases. Without these updates, floristic studies or models relying on regional and state databases to track data such as plant migration, climate change or phenological changes in plants over time would be using outdated and incorrect information.

Table 3. Madison County, AL records documented October 2020 - October 2022.

Family	Scientific Name*	Collector/ Specimen Number	Collection Date	Alabama Plant Atlas Specimens	Herbarium**
Cyperaceae	*Carex abscondita* Mack.	Charles T. Bryson 554	02 May 1974	5	MISSA
	Carex albolutescens Schwein.	Charles T. Bryson 3541, 25885	23 May 1983, 05 May 2021	1, 1	GA; UWAL/APA
	Carex laevivaginata (Kük.) Mack.	Loretta L. Weninegar 4472, & 5032 w/Charles T. Bryson	23 Apr 2021, 25 Aug 2022	0	AAMU
	Carex longii Mack.	Loretta L. Weninegar 4986	01 Jun 2022	0	AAMU
	Carex normalis Mack.	Steven J. Threlkeld 273	05 May 1996	0	JSU
	Cyperus croceus Vahl	Loretta L. Weninegar 5023, Charles T. Bryson 27817	25 Aug 2022	0	AAMU (Weninegar) MMNS (Bryson)
	Cyperus echinatus (L.) Alph. Wood	Charles T. Bryson 13972	14 Jul 1994	0	VSC
	Cyperus esculentus L. var. *leptostachyus* Boeckeler	Charles T. Bryson 4947	26 Aug 1986	0	VSC
	Cyperus iria L.	R. Kral 74169	12 Aug 1987	1	VDB/BRIT

	Cyperus lancastriensis Porter ex A. Gray	Charles T. Bryson 3107	08 Aug 1980	0	IBE
	Kyllinga gracillima Miq. =*Cyperus brevifolioides* Thieret & Delahoussaye	Loretta L. Weninegar 4732 w/G.S. Bushey	28 Aug 2021	0	AAMU
	Scleria oligantha Michx.	R. Kral 70195	17 Jun 1983	2	VDB/BRIT
Juncaceae	*Juncus effusus* L.	Harold D. Green 081	20 Sep 1995	0	VDB/ BRIT
Poaceae	*Andropogon virginicus* L.	D. Giannasi, et al. 147	30 Sep 2001	1	GA
	Arundinaria gigantea (Walter) Muhlenberg	Ross C. Clark 18344	17 Aug 1967	2	NCU
	Bromus catharticus Vahl	Steven J. Threlkeld 285	05 May 1996	0	JSU
	Calamagrostis coarctata Eaton	Loretta L. Weninegar 5030 w/ C.T.Bryson	25 Aug 2022	0	AAMU
	Cinna arundinacea L.	Loretta L. Weninegar 4812 w/Anna M. Bright	17 Sep 2021	0	AAMU
	Cynodon dactylon (L.) Pers.	Heinrich K.D. Eggert s.n.	02 Jul 1897	1	MO
	Dactylis glomerata L.	Glen N. Montz 6117	12 Apr 1993	0	SELU

	Digitaria ciliaris (Retz.) Koeler	Steven J. Threlkeld 1092	04 Aug 1997	1	JSU
	Echinochloa colona (L.) Link	England, J. Kevin 11351	04 Oct 2020	2	UWAL
	Eleusine indica (L.) Gaertn.	Steven J. Threlkeld 1067	04 Aug 1997	2	**JSU**/UWAL
	Elymus glabriflorus (Vasey ex L.H. Dewey) Scribn. & C.R. Bell	Loretta L. Weninegar 4549 w/James E. Jackson, Jr.	08 Jun 2021	0	AAMU
	Eragrostis minor Host	J. Kevin England 11412	17 Oct 2020	1	UWAL
	Setaria faberi Herrm.	Charles T. Bryson 13948	11 Jul 1994	0	VSC
	Setaria pumila (Poir.) Roem. & Schult.	Stephen J. Threlkeld 462	05 May 1996	1	JSU/UWAL
	Sorghum halepense (L.) Pers.	Stephen J. Threlkeld 1 093	04 Aug 1997	1	JSU/UWAL
	Urochloa platyphylla (Munro ex C. Wright) R.D. Webster	Loretta L. Weninegar 4656 w/ Benjamin J. & Tiberius R. Hoksbergen; 4879 w/Jerry D. Green	23 Jul 2021, 24 Oct 2021	0	AAMU

* Species names follow USDA Plants online database [76]. **Thiers, B. M. Index Herbariorum [99], updated continuously (Table 4).

Table 4. Herbaria codes of the herbaria searched in the study [99]

AAMU	Alabama A&M Forestry Herbarium. U.S.A. Alabama. Normal.
BRIT	Botanical Research Institute of Texas. U.S.A. Texas. Fort Worth.
GA	University of Georgia. U.S.A. Georgia. Athens.
IBE	Institute of Botanical Exploration. U.S.A. Mississippi. University.
JSU	Jacksonville State University Herbarium. U.S.A. Alabama. Jacksonville.
MO	Missouri Botanical Garden Herbarium. U.S.A. Missouri. Saint Louis.
MISSA	Mississippi State University. U.S.A. Mississippi. Mississippi.
NCU	University of North Carolina at Chapel Hill Herbarium. U.S.A. North Carolina. Chapel Hill.
SELU	Southeastern Louisiana University. U.S.A. Louisiana. Hammond.
UWAL	University of West Alabama Herbarium. U.S.A. Alabama. Livingston.
VDB	Vanderbilt University Herbarium (now at BRIT). U.S.A. Texas. Fort Worth.
VSC	Valdosta State, U.S.A. Georgia. Valdosta.

4. Conclusions and Lessons Learned

This study reports on a vascular plant study conducted in North Alabama in collaboration with the Land Trust of North Alabama and added 29 new and updated contributions to regional *Poales* species records despite the small study area highlighting the high species richness of the order on the property and demonstrating the need for management that considers the effects of management activities on grasses, sedges, and rushes if that biodiversity is to be conserved.

4.1 Changes in Conservation Management

The reduction in mowing after June 2021 was an important change that allowed us to catalog additional species including several new county records throughout the second year. Even the discovery of new invasive species that were being suppressed by the mowing is important as it provides more detailed information to allow for better targeting of chemical or physical treatments for managing specific species. The willingness of LTNA management to change scheduled management activities and pause organizational goals for the property to gather more and better data is a valuable trait that demonstrates a desire to move toward ecological goals that are property specific and measurable such as those mentioned by Alexander and Hess [17]. Providing a clear time-bound pathway to collect this data and a commitment to finish the data collection were important to the LTNA for acceptance of our request to change their management regime.

Giving the preponderance of the literature on the effects of mowing on species richness and abundance in grasslands and meadows and the maintenance required to limit the invasion of undesired species (e.g., invasive, or woody species) [57-60], there will most likely need to be a return in the future of a less intense and better-timed mowing regime. Armed with the data from this study, we can assess and monitor how the changes in mowing affect the appearance (or disappearance) of species within the grasslands and wet meadows on the property.

4.2 State Plant Records and Data Availability

Vascular plant studies are not particularly rare state-wide in Alabama with spatial scales reaching from park to county-size and objectives ranging from building plant inventories to updating state and county checklists [100-104]. Most of these studies, however, have been conducted across the central and southern regions of the state leading to a blind spot in available botanical records for an area, such as North Alabama, that is rapidly urbanizing. Between 2010 and 2020, Huntsville grew at a population growth rate of over 19% while Madison County's growth rate topped 32% [105]. With urban growth model predictions [85] estimating a rapid 1% growth rate in urban land cover for Madison and Limestone Counties, it becomes even more imperative that conservation land management decisions be made with the best available data to make the best choices regarding biodiversity conservation as habitat is replaced by urban infrastructure. Land conservation organizations such as LTNA, cannot act to conserve or manage habitat for species they do not know exist on the properties under their management. Likewise, up-to-date county plant records can provide data for estimating what plants are likely to occur on a property assisting conservation organizations in deciding what sites to invest money in protecting.

Without local studies, such as this one, and the subsequent time-consuming efforts in searching, examining, adding, and updating state and regional botanical databases and herbaria records, gaps in spatial and temporal information can be formed [39] that can lead to flawed analyses for studies that use the data to assess changes in population, phenology, and community structure over time. Difficulty in finding plant record data is increased when searching for local records held in out-of-state or regional herbaria which can contain, as this study shows, important contributions to records kept in databases that then need to be manually updated (Table 3). With digitalization and sharing through regional databases, the difficulty of gathering data can be reduced. However, even with online resources, there are vast areas of the United States that lack in floristic herbaria records [106]. This lack of data hinders our ability to make the best decisions for the conservation of biodiversity and will only be solved by the completion, documentation, and publication of vascular flora studies from those regions.

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APPENDIX A

Annotated Checklist of Vascular Flora of Bloucher Ford Nature Preserve

All species are within the division Magnoliophyta and the order Poales. Species are further divided into the families Cyperaceae, Juncaceae, and Poaceae. Family names are arranged alphabetically and within each family, the species are alphabetized. A few symbols are used in the list of species in Appendix 1. A star (★) denotes a species not considered to be native to Madison County, Alabama. A triangle (▲) denotes a non-native invasive species. A dagger (†) after the species name indicates a species photographed by the author but not collected due to oversight; a specimen will be collected and vouchered as soon as feasible. Species the author collected are followed by the author's collection number(s) in *italics*. Madison County, Alabama records collected by the author are denoted by a closed circle (●) A few vouchers collected by Dr. Charles T. Bryson while on the property with the author are listed with the last name of the collector, collector's specimen number, and herbarium code where they are deposited in bold and italics. A plus (+) identifies the species as one having an earlier Madison County, AL record that was located through a data portal but not currently documented by the Alabama Plant Atlas. Loretta Lynne R. Weninegar collected and compiled this flora from late September 2020 through early October 2022. Many field assistants and volunteers participated in field collections; the last name of anyone present when the specimen was collected will follow the author's collection number. The few specimens not vouchered by the author are housed in the herbarium at the University of West Alabama (UWAL) in Livingston, AL.; a diamond (◆) follows the scientific name, the last name of the collector, collector's specimen number, and herbarium code in bold and italics. All specimens collected by the author are housed at Alabama A&M University, Normal, AL, and will be accessioned into the Alabama A&M Forestry Herbarium (AAMU). Specimens highlighted in green have pictures included as figures in this publication in Appendix C.

Cyperaceae
Carex
Carex abscondita Mack. + *5024* w/Bryson
Carex albolutescens Schwein + *4968* w/ Mousel
Carex amphibola Steudel *4425* w/Bright
Carex blanda Dewey *4435* w/Bright*, 4959b* w/Mousel
Carex caroliniana Schwein.*4998*
Carex cherokeensis Schwein.*4416* w/Bowman*, 4613* w/Jackson
Carex conjuncta Boott *4513* w/Young*, 4532* w/Hoksbergen
Carex corrugata Fernald *4945* w/Czech*, 4959a* w/Mousel*, 4973* w/Czech & Troby*, 4980* w/Czech & Troby*, 4992, 5001*
Carex frankii Kunth *4556* w/Jackson*, 4576* w/Jackson & Lacy, *4972* w/Czech & Troby
Carex grayi Carey *4409* w/Bowman, *4419* w/ Bright, *4502* w/Young, *4557* w/Jackson *Bryson 27818 MMNS w/Weninegar*
Carex laevivaginata (Kük.) Mack. ● *4472*, *5032* w/Bryson
Carex leavenworthii Dewey *4424* w/Bright*, 4479* w/Young
Carex longii Mack. ● *4986*
Carex lupulina Muhl. ex Willd. *4171* w/Bowman, Czech, & England*, 4555* w/Jackson, 4583 w/Jackson & Lacy, *5029* w/Bryson
Carex normalis Mack. *4547* w/Jackson
Carex socialis Mohlenbr. & Schwegm. *4427* w/Bright, *4450, 4460*, *4991*
Carex tribuloides Wahlenb. *4977* w/Czech & Troby
Carex vulpinoidea Michx. *4571* w/Jackson & Lacy

Cyperus
Cyperus croceus Vahl● *5023* w/*Bryson 27817 MMNS*
Cyperus echinatus (L.) Alph. Wood *5005, 5019* w/Bryson
Cyperus erythrorhizos Muhl. *4210* w/Bowman, Czech, & Finzel
Cyperus esculentus L. ▲ 5026 w/Bryson
Cyperus iria L.★ + *4686*
Cyperus lancastriensis Porter ex A. Gray *4218* w/Bowman, Czech, & Finzel, *4602* w/Jackson & Lacy, *4691*, *4731* w/Bushey, *5021* w/Bryson *27816 MMNS*, *5028* w/Bryson
Cyperus odoratus L. *4186* w/Bowman, Czech, & England
Cyperus strigosus L. *4682; 4764* & *4765* w/Bushey, *5020* w/Bryson
Eleocharis
Eleocharis obtusa Willd. *4688*
Kyllinga
Kyllinga gracillima Miq. ★● (*Cyperus brevifolioides* Thieret & Delahouss.) *4732* w/Bushey, *5022* w/Bryson
Scleria
Scleria cf oligantha Michx. + *4876* w/Green

Juncaceae
Juncus
Juncus acuminatus Michx. *4975 & 4981* w/Czech & Troby, *5000*
Juncus dichotomus Elliott *4575* w/Jackson & Lacy
Juncus effusus L. *4577* w/Jackson & Lacy, *4976* w/Czech & Troby
Juncus tenuis Willd. *4480*, *4683*, *4897* w/Green
Luzula
Luzula bulbosa (Alph. Wood) Smyth & Smyth 4957 w/Mousel

Poaceae
Andropogon
Andropogon virginicus L. + *4180, 4181*
Arundinaria
Arundinaria gigantea (Walter) Muhlenberg + *4437* w/Bright, *4623* w/Jackson
Bromus
Bromus catharticus Vahl ★▲ *4459, 4589* w/Jackson & Lacy, *4756* w/Bushey
Calamagrostis
Calamagrostis coarctata Eaton ●*5030* w/Bryson
Chasmanthium
Chasmanthium latifolium (Michx.) Yates 4620 & 4719 w/Jackson
Cinna
Cinna arundinacea L.● *4812* w/Bright
Cynodon
Cynodon dactylon (L.) Pers.★▲ + *4676, 5017*
Dactylis
Dactylis glomerata L.★▲ *4995*
Dichanthelium
Dichanthelium commutatum (Schult.) Gould *4640* w/Jackson & Lacy, *4795*
Digitaria

Digitaria ciliaris (Retz.) Koeler + *4834*, *4837*
Echinochloa
Echinochloa colona (L.) Link★*4191* w/Bowman, Czech, & England, *4690*, *4706* w/Jackson
Echinochloa muricata (P. Beauv.) Fernald *4658* w/Hoksbergen & Hoksbergen, *4774* w/Bushey
Eleusine
Eleusine indica (L.) Gaertn.★▲ + *4211* w/Bowman, Czech, & Finzel, *4839*
Elymus
Elymus glabriflorus (Vasey ex L.H. Dewey) Scribn. & C.R. Bell● 4549 w/Jackson
Elymus virginicus L. *4173* w/Bowman, Czech, & England
Eragrostis
Eragrostis minor Host ★◆ *E*ngland 11412 UWAL w/Bowman, Czech, & Weninegar
Festuca
Festuca subverticillata (Pers.) Alexeev *4431* w/Bright, *4956* & *4974* w/Czech & Troby
Hordeum
Hordeum pusillum Nutt.*4967* w/Mousel
Leptochloa
Leptochloa panicea (Retz.) Ohwi ssp. *Brachiate* (Steud.) N. Snow ◆
Dinebra panicea (Retz.) P.M. Peterson & N. Snow ssp. *brachiata* (Steud.) P.M. Peterson & N. Snow *England 11296 UWAL*
Melica
Melica mutica Walter *4447*
Microstegium
Microstegium vimineum (Trin.) A. Camus ★▲ *4880* w/Green
Muhlenbergia
Muhlenbergia schreberi J.F. Gmel. *4175* w/Bowman, Czech, & England, *4816* w/Bright
Panicum
Panicum dichotomiflorum Michx.★◆ *England 11308 UWAL*
Panicum rigidulum Bosc ex Nees *4757* w/Bushey
Panicum virgatum L. *4818* & *4826* w/Bright
Paspalum
Paspalum dilatatum Poir. ★▲ *4680*
Paspalum pubiflorum Rupr. ex Fourn. *5031* w/Bryson
Poa
Poa annua L.★▲ *4432* w/Bright, *4907* w/Czech, Z.M. Green, & Knight
Poa compressa L.★▲ *4573* w/Jackson & Lacy
Poa sylvestris A. Gray 4952 & *4955* w/Czech
Schedonorus
Schedonorus arundinaceus (Schreb.) Dumort., nom. cons.★▲ *4550* w/Jackson, *4574* w/Jackson & Lacy, *4994*, *4999*
Setaria
Setaria faberi Herrm.★▲† *5027* w/Bryson
Setaria pumila (Poir.) Roem. & Schult. ★▲+ *4653* & *4662 w*/Hoksbergen & Hoksbergen, *4681, 4724* w/Jakson, *4744* w/Bushey, *4809* w/Bright
Sorghum
Sorghum halepense (L.) Pers.★ ▲† + England *11331 UWAL*
Steinchisma
Steinchisma hians (Elliott) Nash *4631* w/Jackson, *4685*
Tridens
Tridens flavus (L.) Hitchc. *4824* w/Bright

Urochloa
Urochloa platyphylla (Munro ex C. Wright) R.D. Webster ● *4656* w/Hoksbergen & Hoksbergen, *4879* w/Green

APPENDIX B

Madison County AL Plant County Record Status in Alabama Plant Atlas [64]

Madison County, AL records with vouchers collected earlier than Alabama Plant Atlas records [64] (11):

Cyperaceae (4)
Carex abscondita Mack. (Bryson 1974)
Carex albolutescens Schwein (Bryson 1983)
Cyperus iria L. (Kral 1987)
Scleria oligantha Michx. *(*Kral 1983)

Poaceae (7)
Andropogon virginicus L. (Giannasi et al. 2001) *
Arundinaria gigantea (Walter) Muhl. (Clark 1967)
Cynodon dactylon (L.) Pers. (Eggert 1897) *
Digitaria ciliaris (Retz.) Koeler (Threlkeld 1997) *
Eleusine indica (L.) Gaertn. (Threlkeld 1997) *
Setaria pumila (Poir.) Roem. & Schult. (Threlkeld 1996) *
Sorghum halepense (L.) Pers. (Threlkeld 1997)*

County Records not recorded in the Alabama Plant Atlas [64] prior to the Bloucher Ford Nature Preserve study (18):

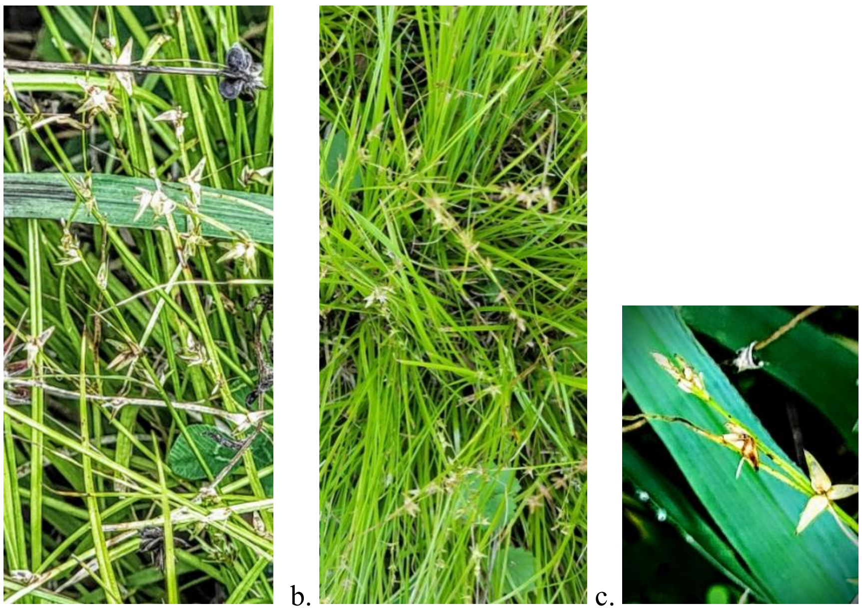
Cyperaceae (8)
Carex laevivaginata (Kük.) Mack. (Weninegar 2021; Weninegar & Bryson 2022)
Carex longii Mack. (Weninegar 2022)
Carex normalis Mack. (Threlkeld 1996)
Cyperus croceus Vahl (Weninegar & Bryson 2022)
Cyperus echinatus (L.) Alph. Wood (Bryson 1994)
Cyperus esculentus L. var. *leptostachyus* Boeckeler (Bryson 1986)
Cyperus lancastriensis Porter ex A. Gray (Bryson 1980)
Kyllinga gracillima Miq. [*Cyperus brevifolioides* Thieret & Delahoussaye] (Weninegar & Bushey 2021)
Juncaceae (1)
Juncus effusus L. (Green 1995)
Poaceae (9)
Bromus catharticus Vahl (Threlkeld 1996)
Calamagrostis coarctata Eaton (Weninegar & Bryson 2022)
Cinna arundinacea L. (Weninegar & Bright 2021)
Dactylis glomerata L. (Montz 1993)
Echinochloa colona (L.) Link (England 2020)
Elymus glabriflorus (Vasey ex L.H. Dewey) Scribn. & C.R. Bell (Weninegar & Jackson, Jr. 2021)
Eragrostis minor Host (England 2020) *
Setaria faberi Herrm. (Bryson 1994) †
Urochloa platyphylla (Munro ex C. Wright) R.D. Webster (Weninegar, Hoksbergen & Hoksbergen 2021)

* The only voucher in Alabama Plant Atlas [64] for Madison County is a Bloucher Ford Nature Preserve specimen from this study.

† A photo voucher was taken 22 August 2022; at Bloucher Ford; a specimen was collected on 28 July 2023 by Weninegar.

APPENDIX C

Photographs of noteworthy Poales species identified at Bloucher Ford Nature Preserve in Madison County, Alabama with description and location data (Latitude and Longitude).



b. c.

Figure 17. *Carex socialis* Mohlenbr. & Schwegm., 01 June 2022, (34.875293, -86.475966), a. culms, b. culms & leaves, c. mature fruit.


Figure 18. *Cyperus croceus* Vahl, 25 August 2022, (34.878986, -86.481269)

Figure 19. *Cyperus esculentus* var. l*eptostachyus* Boeckeler*,* 25 August 2022, (34.879817, -86.48128)

Figure 20. *Kyllinga gracillima* Miq., 25 August 2022, (34.878868, -86.481901)

Figure 21. *Calamagrostis coarctata* Eaton, 25 August 2022, (34.878254, -86.47965)

Figure 22. *Cinna arundinacea* L., 17 September 2021, (34.880277, -86.480364)

Figure 23. *Elymus glabriflorus* (Vasey ex L.H. Dewey) Scribn. & C.R. Bell
08 June 2021, (34.880177, -86.481831)

Figure 24. *Microstegium vimineum* (Trin.) A. Camus
11 September 2021, (34.875941, -86.474059)

Figure 25. *Muhlenbergia schreberi* J.F. Gmel., 11 September 2021,
(34.875955, -86.474077)

Figure 26. Schedonorus arundinaceus (Schreb.) Dumort., nom. Cons., 14 June 2021. (34.87549, -86.475561)

Figure 27. *Setaria faberi* Herrm. †, 25 August 2022, (34.875871, -86.474831)

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MINUTES OF THE
ALABAMA ACADEMY OF SCIENCE
Executive Committee Meeting
Held via Zoom and at Samford University 10/5/2024 9:00 AM CST

Meeting was called to order by Jack Shelley-Tremblay

Those in attendance were
John Shelley-Tremblay
Summary
Jack Shelley-Tremblay led a meeting discussing the upcoming spring conference, including the layout of the Montgomery campus, event arrangements, and potential partnerships. The meeting also covered updates on various programs, such as the Alabama STEM Science Trail, the Science and Engineering Fair, and the 3-minute thesis competition. The importance of attendance and participation in the upcoming annual business meeting was emphasized, with John encouraging everyone to invite their friends and colleagues.

Fall Executive Committee Meeting Preparation
John welcomed everyone and discussed the recording of the meeting for those who couldn't attend. He introduced the distinguished faculty present, including Dr. hkabir, Dr. Lee, Dr. Golapali, Dr. Matthew Edwards, Karen, Cindy von Allelefeld, and Jean-Pierre. John also mentioned the local arrangements update from Dr. Ken Robley, who is the chair of mathematics at Troy and the local arrangements host for the year. The meeting also included a discussion on the approval of the minutes from the spring 2024 Executive Committee meeting. The primary purpose of the Fall Executive Committee meeting was to ensure readiness for the upcoming spring conference.

Montgomery Campus Layout and Event Arrangements
John discussed the layout of the Montgomery campus, highlighting key locations such as the main parking lot, Whitley Hall, and the Davis Theater. He mentioned that an alternative parking deck is available behind Whitley Hall and that the preferred hotel, Staybridge Suites Montgomery, is within a 2 to 3 block radius. John also detailed the arrangements for an upcoming event, including the use of Whitley Hall for registration and poster sessions, several classrooms for paper sessions, and the Trojan statue for event pictures. Box lunches will be provided in the gold room.

Upcoming Event Planning and Logistics Discussion
John discussed the upcoming event, suggesting a practical training or parent session, and proposed having a grad student or staff member present. He also mentioned that Dr. Jackie Jones from Troy University had agreed to be interviewed by Troy public radio to promote the event. John's local arrangements committee is working on a Troy website and food arrangements, with a target cost of $25-$28 per person for meals. He requested a final cost by the 14th of October to open registration. John also expressed interest in reaching out to STEM coordinators or curriculum chairs for the Auburn schools.

Banquet Ticket Pricing, Membership, and Newsletter

John proposed adopting last year's pricing for banquet tickets and conference registrations, which was approved by the attendees. Bettina suggested including the membership fee on the registration page, which John agreed to consider. John also shared a page on the Alabama Academy of Science website, discussed the process of becoming a member, and mentioned the potential move of the Journal of the Alabama Academy of Science to the South Alabama Digital Commons platform. He also introduced the Material Science Symposium and expressed interest in launching a newsletter. Lastly, he emphasized the importance of adding the official email domain to safe lists and highlighted the Science Trail Patch System for scouts and children's groups.

Alabama STEM Science Trail and Passport Program
John discussed the Alabama STEM Science Trail, a color-coded trail broken up by geographic region, co-sponsored by the Alabama Tourism Commission. He encouraged participants to add their university or campus science sites or local business sites to the trail. John also mentioned that Scouts, Girl Scouts of America, and 4H are participating in the passport program, with a patch sent to the parent upon completion of 10 sites and a feedback form. John expressed interest in strengthening the trail and suggested a potential partnership with the STEM Collaborative to enhance data collection. He also invited participants to share their own STEM education sites and offered to reformat any existing spreadsheets for compatibility.

Discussing Outreach and Awards for STEM Education
Karen emphasized the importance of reaching out to Girl Scouts of North Central Alabama and Girl Scouts of Southern Alabama to inform them about the patch. John clarified that the organization is different from Boy Scouts, and he suggested that more connections could be made. John also encouraged everyone to nominate their colleagues for the Mason Science Teaching Fellowship, which provides up to two $1,000 awards for teacher trainees. Matthew and John discussed the Right Gardner Award, the Fellow Award, and the Dr. Adrian Johnson Award, with the due date for nominations set for January 10th. John highlighted the importance of recognizing unsung heroes in STEM education and mentoring.

Science and Engineering Fair Update and Programs
Jessica Gilpin, Assistant Director of the College of Science and Math Outreach Center at Auburn University, provided an update on the center's programming. She highlighted the growth of the Science and Engineering Fair, which saw 220 participants in 2024, and the distribution of over $13,000 in prizes. Jessica also mentioned the upcoming International Science and Engineering Fair in Columbus, Ohio in 2025. She emphasized the need for professional development for teachers and the importance of volunteers and mentors in the programs. Jessica also mentioned the Science Olympiad program, which is an academic track meet with various STEM events, and the need for experts to write exams at regional and state levels.

South Tournament and Mobile Care Network Updates
John discussed the upcoming South Tournament for Science Olympiad, which will be held at Enterprise High School and will include both middle and high school levels. He also mentioned the need for an elementary tournament in the southern region. John's office is planning to continue development in the Mobile Care network and is running a summer camp called Summer Science Institute for high achieving students. He also introduced the Anatomy program, a

nationwide competition about anatomy and physiology, which will have an online local competition in January. Ravi requested the information about the Anatomy program to be shared with the team.

3-Minute Thesis Competition and 2025 Meeting Planning

Jean-Pierre discussed the 3-minute thesis competition, mentioning that he had emailed the presidents of the CSGs and the Southern Conference but was still awaiting their response. John suggested that they could meet with the individual they were waiting for to expedite their decision. Jean-Pierre was asked to consider potential prizes for the competition, and John proposed repurposing research awards to cover prize costs. The possibility of advertising the competition to Florida and Georgia was also discussed, with John suggesting they could reach out to Auburn University. A plan was made to meet next week with Cindy to further discuss and advertise the competition. John and Jean-Pierre discussed the possibility of organizing a 3-minute thesis competition for graduate students. John suggested that the competition could be held in two hours with 20 participants and could be followed by an award ceremony. Jean-Pierre agreed and mentioned that the competition would require at least three to four judges. John also mentioned that the competition is an excellent preparation for young scientists and could be a good training for those who want to give Ted Talks. Jean-Pierre then shared that he had received feedback from several reviewers who had agreed to review papers he had sent them, and he hoped to get their feedback by the next week. John expressed satisfaction with the progress made and encouraged everyone to focus on making the 2025 meeting a success. He emphasized the importance of attendance, suggesting that participants should plan to stay at least one night in Montgomery. He also suggested that sections could include mini keynotes or hands-on experiences. Dr. Edwards was asked to make a motion to adjourn the meeting, which was seconded by Dr. Mark Calkins and passed. The meeting was adjourned. John emphasized the importance of personal attendance at the upcoming annual business meeting on the 26th of February at the Troy, Montgomery campus. He encouraged everyone to invite their friends and colleagues, highlighting that the success of the academy lies in the presence of its members. The following day, the 27th of February, is scheduled for the Aas meeting.

Next Steps

1. Ken Robley to provide banquet and lunch cost estimates to John by October 14th. 2. John to open conference registration after receiving final cost information from Ken Robley. 3. Ken Robley to coordinate with local committee to schedule a Thursday lunchtime speaker. 4. John to update the Alabama Science Trail website with current year information. 5. Jessica Gilpin to send digital versions of Science Fair and Science Olympiad flyers to John for distribution. 6. Jean-Pierre Arditi, Cindy, and John to meet next week to finalize 3 Minute Thesis competition details. 7. All Executive Committee members are to encourage colleagues to attend and stay overnight at the 2025 meeting in Montgomery. 8. Section chairs to consider incorporating mini keynotes or didactic experiences into their section programs.

Alabama Academy of Science Journal

Scope of the Journal:

The Alabama Academy of Science publishes significant, innovative research of interest to a wide audience of scientists in all areas. Papers should have a broad appeal, and particularly welcome will be studies that break new ground or advance our scientific understanding.

Information for the Authors:

- Manuscript layout should follow the specific guidelines of the journal.
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- At least one author must be a member of the *Alabama Academy of Science* (except for Special Papers).
- The author(s) should provide the names and addresses of at least two potential reviewers.
- Assemble the manuscript in the following order: Title Page, Abstract Page, Text, Brief acknowledgments (if needed), Literature Cited, Figure Legends, Tables, Figures.

Review Procedure and Policy:

Manuscripts will be reviewed by experts in the research area. Manuscripts receiving favorable reviews will be tentatively accepted. Copies of the reviewers' comments (and reviewer-annotated files of the manuscript, if any) will be returned to the correspondent author for any necessary revisions. The final revision and electronic copy are then submitted to the *Alabama Academy of Science Journal* Editor. The author is required to pay $100 for partial coverage of printing costs of the article.