2021

Biodiversity Of The Indian River Lagoon System: A Cautionary Tale From The Birds

Richard L. Turner

Proceedings of Indian River Lagoon Symposium 2020

Biodiversity of the Indian River Lagoon System: a cautionary tale from the birds

Richard L. Turner

Department of Ocean Engineering and Marine Sciences, Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901-6975

Abstract Prevailing dogma on comparative biodiversity of the Indian River Lagoon (IRL) stems mainly from one claim about ichthyofauna and two about avifauna. The extensive network of bird-watchers, clarity of bird taxonomy, long history of the Christmas Bird Count (CBC), and burgeoning database on ebird.org make birds excellent for geographic comparison. The 1985 claim that Merritt Island CBCs are often the "most speciose count" in the U.S. is unfounded. CBCs there in 1970–1985 never had the highest count, even compared to the nearby Cocoa site. For the 114th CBC (2013), it ranked 11th in Florida and 44th nationally. The 1989 claim that IRL has "the most diverse avifauna in the United States" also is unfounded. Of 543 hotspots (>250 species) in coastal continental states on ebird.org in December 2019, Merritt Island National Wildlife Refuge had 300 species; but 110 other sites listed more species of bird. Because government agencies, legislators, media, and the public rely on scientists for information, scientific statements must rely on evidence. Scientists should abandon the current dogma about the high relative biodiversity of the IRL. Studies should focus on increasing our knowledge of diversity of all taxa; and geographic comparisons should be attempted with great caution.

Key words Aves, Christmas Bird Count, eBird, National Audubon Society

> "To a new truth there is nothing more hurtful than an old error"—Johann Wolfgang von Goethe (Maxim 549; Saunders 1892)

Introduction

The Indian River Lagoon System (IRL) is a major physiographic feature on the Atlantic coast of Florida, spanning more than one-third (250 km) of the peninsula, exclusive of the Florida Keys. The system comprises three lagoons (and associated uplands, creeks, and wetlands), formed by barrier islands during the Holocene reduction in the rate of sea-level rise. The Atlantic coast was transformed from an ocean beach east of the Atlantic Coastal Ridge to a complex of habitats, which are claimed to be partly responsible for a presently high biotic diversity of the region.

Levels of biodiversity for the IRL reported in peer-reviewed and popular literature, in agency reports, in news media, on websites on the Internet, and in other sources range from ~4,000 species to ~4,300 species. The estimates seem to have their origin in the Governor's Nomination Package (Panico et al. 1989) to have the lagoon system designated an Estuary of National Significance and to

Corresponding author: Richard L. Turner, rturner@fit.edu

become part of the National Estuary Program. The number (4,315 species) given in that document was presented without support of citations or tabulation and was much higher than a well-documented list that appeared later (Swain et al. 1994; 2,493 species). Swain et al. (1994) pointed out that claims of high biodiversity in the IRL lacked support, and they developed a list as a baseline for future additions. Oversight of their list was assumed by the Smithsonian Marine Station at Fort Pierce (Smithsonian Institution 2014). As of September 2014, the list contained only 3,191 species, although the front page of the website claimed more than 3,500 species as of May 2014, when the website was most recently updated. Hargraves (2002) noted that the known biodiversity of the lagoon system does not include many groups that have remained poorly surveyed.

More frequent than claims about the level of biodiversity are claims that biodiversity in the IRL is the highest or among the highest of all estuaries in the [continental] United States (e.g., Gilmore 1985, Littler et al. 2008, Indian River Lagoon National Estuary Program, 2020), North America (e.g., Reed 1985, Yates 2008, Lapointe et al. 2020), and the world (Pulver 2013). Day (1995) argued that the claim of high comparative biodiversity was partly responsible for the success of the Governor's Nomination Package (Panico et al. 1989) in achieving recognition to the lagoon system. Indeed, the claims have largely been the basis for much of the attention given to the region in scientific symposia, special designations, the establishment of numerous IRL-focused organizations, and the issuance of a State of Florida specialty automotive tag. Day (1995) attributed the original claim to Gilmore (1985), a source often cited in literature about lagoonal biodiversity; but Gilmore (1985) provided no comparative data or citations. Only two sources (Mikkelsen et al. 1995, Winston 1995) have given limited comparisons of IRL biodiversity to other estuaries for animal phyla (mollusks in five other estuaries and bryozoans in one other estuary, respectively). Johnston et al. (2015) reported 586 species of fish from Sydney Harbor, Australia, and compared fish biodiversity there with data from FishBase (http://www.fishbase.org) for Chesapeake Bay (207 species) and Puget Sound (155 species) in the United States; the authors did not give comparative data from FishBase for the IRL (397 species; Gilmore 1995). No comparisons exist for plants, macroalgae, or microbes (but see Leray and Knowlton 2015 and Sweat 2016).

Two claims of comparative biodiversity in the literature that were unsupported but quite testable dealt with birds. Gilmore (1985) wrote, "Christmas bird counts on Merritt Island often represent the most speciose count in the United States". No citation or data were given. Panico et al. (1989) wrote that the region has "the most diverse avifauna in the United States (Kale 1988)." Unfortunately, Kale (1988) was never published, and it contained no such statement or comparative data. The purpose of this paper is to evaluate these statements on the comparative diversity of birds in the IRL and other parts of the United States.

Materials and Methods

Two resources are easily accessible to extract comparative data on avian diversity: the Christmas Bird Counts (CBCs) of the National Audubon Society (NAS); eBird, an Internet database maintained by the

Cornell Lab of Ornithology and NAS. Both resources rely on an extensive network of professional and amateur bird watchers, and both are heavily edited databases. Birds are a well-known group in North America. Names are standardized by the American Ornithological Union and American Birding Association. Bird watchers have strong support for their activities by local chapters of NAS, a plethora of field guides, and growing Internet resources.

CBCs began in 1900 with 25 locations in North America and 27 participants. The 118th (2017) CBC covered 2,585 locations worldwide, of which 1,957 were in the United States with 58,719 participants. Each location comprises a circle 15 miles in diameter that is surveyed by volunteer bird watchers on one day in late December through early January. The data are edited and are available at http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx. Summaries of the CBCs by state are available at www.audubon.org. CBCs were held at Merritt Island National Wildlife Refuge (MINWR) in 1937–1941 and in almost all years from 1970 to present. Data were harvested for CBCs at MINWR and several other locations since 1970, with a focus on the period 1970–1985. For a more recent comparison, selected data through the 118th CBC were used from those states that reported high counts in their state summaries. At present, not all state summaries are finalized and available for the 119th (2018) and 120th (2019) CBCs, and not all states included reports of locations with high counts.

The Internet database eBird (https://ebird.org) was launched in 2002. It included more than 730 million observations by November 2019. Data for the present study were harvested from sites with 250 or more species (called "hotspots" herein) recorded in coastal states from Maine to Alaska. (Note that eBird calls all birding locations on its website "hotspots", not as the term is used here.) The first harvest took place in December 2014, and the second in November 2019. Only fully identified species were used.

Results

Early CBCs (1937–1941) at the MINWR circle were low, ranging from 94 to 117 species (Figure 1). When counts resumed in 1970, counts were much higher, ranging from 148 to 174 species in the period through 1985. During the same period (1970–1985), counts in the nearby Cocoa CBC circles were higher (175–225 species). Some other CBC circles known for high counts had fewer or comparable numbers of bird species in this period (Figure 2): Cape May, NJ; Salton Sea south, CA. Others, however, had much higher counts than the MINWR circle: Freeport and Corpus Christi, TX; San Diego and Santa Barbara, CA.

Only since 1985 have the counts in the MINWR and Cocoa circles been similar (Figure 1). In the state summary for the 118th CBC (2017) in Florida—the most recent for which the state summary is available—six circles had counts of 150 species or greater: Jacksonville, St. Marks National Wildlife Refuge, west Pasco County, Sarasota, Gainesville, and north Pinellas County. The national report for the 118th CBC added St. Petersburg and Alafia Banks circles but excluded west Pasco County. In addition, the national report listed 83 circles in the United States with counts of 150 or more in 2017, Matagorda Island, TX leading with 220 species. On the other hand, 130 species were recorded at MINWR circle in 2017, and the number dropped to 125 species in 2018 (119th CBC). In the 114th (2013) CBC, MINWR had 151 species, placing it 11th in Florida and 44th in the United States.

In December 2014, eBird mapped 241 hotspots, locations with 250 species or more, in coastal states of the continental United States (Table 1). MINWR had 295 species recorded, placing it 62nd in rank. Plum Island, MA was first with 368 species. Twelve hotspots were in Florida, and MINWR was fourth highest in rank in the state. No other locations in the IRL region were hotspots in the December

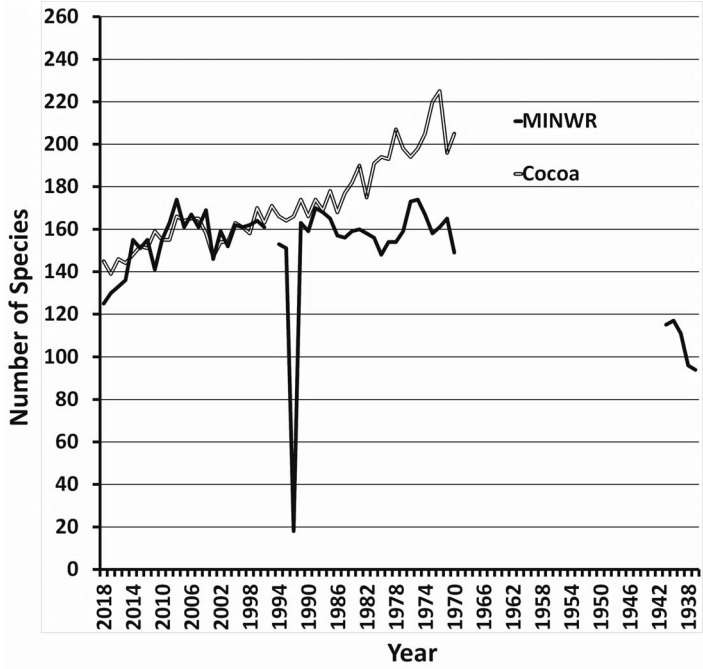

Figure 1. Results of Christmas Bird Counts for the Merritt Island (MINWR, 1937–2018) and Cocoa (1970–2018) circles. Data were harvested from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

2014 survey. In November 2019, there were 543 hotspots (Table 1). MINWR, with 300 species, shared the rank of 111th with four other locations. One site on Farrallon Island, CA ranked first with 428 species. MINWR was fifth highest among the 25 hotspots in Florida. Only two other sites in the IRL region were hotspots in the November 2019 survey: Merritt Island National Wildlife Refuge–Black Point Wildlife Drive, 257 species; "Viera" Ritch Grissom Memorial Wetlands, 255 species. Locations in some landlocked states—most notably Arizona and New Mexico—had counts that exceeded 300 bird species.

Discussion

Claims about the comparative biodiversity of the IRL over the last three to four decades are replete with misinformation and lack of evidence. One of the earliest claims was made by Jones et al. (1975) with regard to the fish fauna of the IRL, but no comparative geographic data were provided. Fernald et al. (1982) cited Jones et al. (1975, on fish), Gore et al. (1976, on crustaceans), and Gilmore et al. (1981, on fish) as evidence that the biota of the IRL is "one of the richest in the United States." Neither of the latter two sources provided comparative data on their respective taxonomic groups let alone on biota of the IRL in general; and neither included statements on comparative diversity. Gilmore's (1985) report of more than

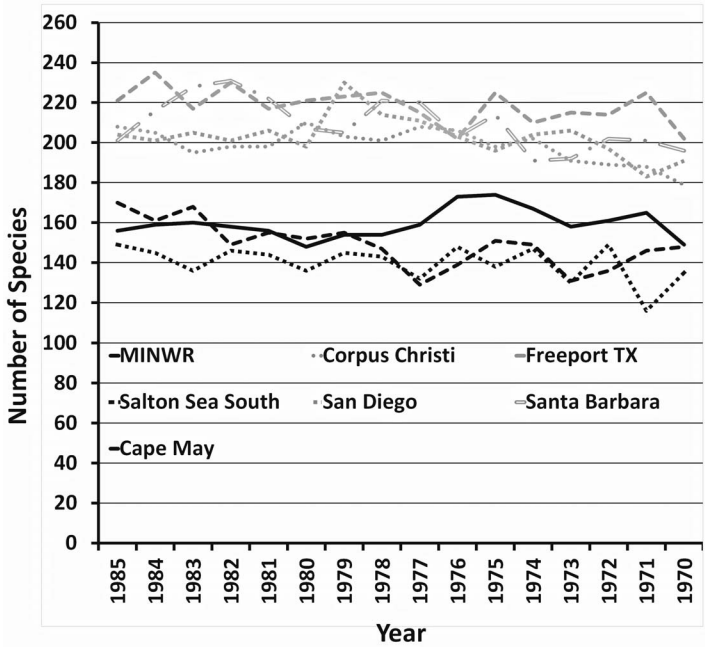

Figure 2. Results of Christmas Bird Counts for Merritt Island (MINWR) circle and several other circles in the United States, 1970–1985: Salton Sea South, San Diego, and Santa Barbara, CA; Corpus Christi and Freeport, TX; Cape May, NJ. Data harvested as for Figure 1.

400 species of fish in the IRL, although not accompanied by a list, was supported by lists published earlier and later (Gilmore 1977, Gilmore et al. 1981); but no comparative data on fish diversity has supported his claim that the IRL contains "the most speciose estuarine fish fauna in North America." His second claim about Christmas Bird Counts at Merritt Island National Wildlife Refuge is refuted by data given in the present paper. There also is no body of literature before 1985 that supports his bald statement that "it has now been proven by a wide variety of researchers and institutions that the Indian River lagoon and associated aquatic systems contains one of the richest and productive aquatics faunas within the continental United States. No other estuary has revealed such a large variety of plants and animals and greater concentration of rare and endangered organisms." In the same volume of proceedings, Reed (1985) stated that the IRL "hosts the highest diversity of species of any estuary in North America." No evidence or citations accompanied Reed's statement. Panico et al. (1989) cited Gilmore (1985) but broadened his statement about fish diversity in North America to plant and animal biodiversity of the IRL. They cited Fernald et al. (1982) in support of a statement that the IRL has more species of rare and endangered biota; although Fernald et al. (1982) claimed that Florida (not the IRL) has more rare and endangered species than other states; and no comparative data were provided. Panico et al. (1989) also claimed that there are 4,315 species of biota (2,965 animal species, 1,350 plant

Table 1. Rank order of birding hotspots (recorded species ≥250) in coastal states of the continental United States from eBird.org. Locations listed as "N/A" were not hotspots in 2014, were not located in 2019, or had changed status or name since 2014. Location names are given as in eBird.org to aid future searches.

	December 2014		November 2019	
Location	No. species	Rank	No. species	Rank
MA Plum Island	368	1	363	6
NJ Cape Island (Cape May Co., south of Cape May canal)	367	2	359	9
TX Aransas NWR (CTC 037) (Aransas Co.)	363	3	367	2
NJ Cape Island—CMP (Cape May Point)	361	4	367	2
MA Parker River NWR	354	5	362	7
NJ Sandy Hook	348	6	360	8
TX Laguna Atascosa NWR (LTC 024)	348	6	359	9
CA Southeast Farallon Island	344	8	428	1
TX South Padre Island-WBC/Conv. Center/Laguna Madre Trail (LTC 035)	343	9	356	11
CA Salton Sea-south end	342	10	341	25
TX Bentsen-Rio Grande Val. State Park WBC (Mission) (LTC 069)	336	11	348	17
TX Mitchell Lake Audubon Center (HOTE 103)	334	12	341	25
CA Andrew Molera SP–Big Sur River mouth	332	13	350	15
TX Santa Ana NWR (LTC 059)	332	13	345	21
TX Hornsby Bend (HOTE 037)	331	15	348	17
TX Estero Llano Grande State Park WBC (LTC 054)	330	16	346	19
TX Goose Island State Park (CTC-048)	330	16	349	16
CA Arcata Marsh and Wildlife Sanctuary	329	18	336	33
FL Fort De Soto Park	329	18	343	23
VA Chincoteague NWR	327	20	341	25
TX Corpus Christi–Hazel Bazemore Park (CTC-078)	325	21	338	30
TX Quintana Neotropical Bird Sanctuary (UTC 121)	325	21	331	39
TX Corpus Christi	324	23	333	35
TX Sabal Palm Sanctuary (LTC 042)	322	24	338	30
TX Anahuac NWR (UTC 049)	321	25	331	39
TX High Island (UTC 051)	319	26	332	36
FL St. Marks NWR	317	27	328	42
TX Choke Canyon State Park–Calliham Unit (McMullen Co.) (CTC 082)	317	27	327	43
TX Port Aransas-Leonabelle Turnbull Birding Ctr. (CTC 057)	317	27	324	52
CA Death Valley NP–Furnace Creek	316	30	336	33
TX Hagerman NWR	316	30	340	28
AL Dauphin Island	315	32	326	46
DE Bombay Hook National Wildlife Refuge	315	32	323	54
NC Pea Island NWR	315	32	322	56
SC Huntington Beach SP	314	35	332	36
NJ Cape Island–Higbee Beach WMA	313	36	332	36
NJ Edwin B. Forsythe NWR (Brigantine Unit)	312	37	323	54
TX San Bernard NWR (UTC 125)	312	37	322	56
PA Presque Isle SP (IBA)	309	39	316	66
NJ Edwin B. Forsythe NWR–Wildlife Drive	308	40	316	66
TX Brazoria NWR (UTC 108)	307	41	316	66
TX Corpus Christi–Pollywog Pond (CTC 077)	307	41	327	43

Table 1. Continued.

Location	December 2014		November 2019	
	No. species	Rank	No. species	Rank
TX Galveston–Lafitte's Cove (UTC 068)	307	41	326	46
TX Granger Lake Area (HOTE 031)	307	41	321	58
TX Sabine Woods (UTC 026)	307	41	325	50
TX Lake Tawakoni–Rains Co. beach & CR1480	306	46	305	97
TX Bolivar Flats Shorebird Sanctuary (UTC 058)	303	47	315	71
CA Point Reyes–Outer Point	302	48	352	13
AL Fort Morgan State Historic Site	300	49	325	50
FL Honeymoon Island SP	300	49	296	123
GA Jekyll Island	300	49	303	103
CA Huntington Central Park	299	52	318	62
TX King Ranch–Norias Division (Kenedy Co.)	299	52	327	43
CA San Joaquin Wildlife Sanctuary	298	54	326	46
LA Peveto Woods-Baton Rouge Audubon Society Sanctuary	297	55	310	83
NY Jamaica Bay Wildlife Refuge	297	55	313	76
TX Lake Tawakoni Dam (Van Zandt Co.) (incl. Sabine R. bottomland)	297	55	305	97
CA Galileo Hill–Silver Saddle Ranch and Club	296	58	324	52
CA San Clemente Island	296	58	N/A	N/A
LA Grand Isle	296	58	314	73
NY Jones Beach SP	296	58	312	77
FL MINWR	**295**	**62**	**300**	**111**
NJ Cape Island–Cape May Point SP (CMPSP)	N/A	N/A	365	4
CA Hayward Regional Shoreline	N/A	N/A	365	4
FL Lake Apopka North Shore Restoration Area (Orange Co.)	N/A	N/A	353	12
TX South Padre Island (LTC 034)	N/A	N/A	351	14
NJ Cape Island–South Cape May Meadows (SCMM)	N/A	N/A	346	19
TX South Padre Is.–Birding and Nature Center	N/A	N/A	345	21
NJ Cape Island–CMPSP–Hawkwatch Platform	N/A	N/A	342	24
TX High Island–Boy Scout Woods (UTC 055)	N/A	N/A	339	29
CA Pt. Pinos–general (sea & shore Coral to Jewell, Crespi Pond, cypresses etc)	N/A	N/A	337	32
TX High Island–Smith Oaks Sanctuary (UTC 052)	N/A	N/A	331	39
TX Packery Channel Park (CTC 064)	292	66	326	46
VA Back Bay NWR	282	95	321	58
TX Laguna Atascosa NWR–HQ and Kiskadee Trail	283	93	321	58
NJ Edwin B. Forsythe NWR	N/A	N/A	319	61
NJ Cape Island–CMP–Coral Ave. dune crossing	N/A	N/A	318	62
CT Milford Pt. (CT Audubon)	284	88	317	64
CA Bodega Bay–harbor and immediate vicinity	N/A	N/A	317	64
TX Port O'Connor	289	72	316	66
TX Big Bend NP–Rio Grande Village (FWTX 44)	294	63	316	66
TX Galveston Island SP (UTC 070)	294	63	315	71
VA Chesapeake Bay Bridge-Tunnel (Northampton Co.)	N/A	N/A	314	73
CA Pt. Mugu Naval Air Station	264	159	314	73
CT Hammonasset Beach SP	281	101	312	77
ME Monhegan Island	N/A	N/A	311	79
CT Sherwood Island State Park	270	140	311	79
NY Jones Beach SP–West End	278	117	311	79

Table 1. Continued.

Location	December 2014		November 2019	
	No. species	Rank	No. species	Rank
CA San Jacinto Wildlife Area	289	72	311	79
TX Port Aransas–Holt Paradise Pond	N/A	N/A	310	83
CA Malibu Lagoon	293	65	310	83
OR Malheur NWR–Headquarters	288	75	310	83
MA Manomet Inc. [formerly Manomet Center for Conservation Studies]	273	129	309	87
NY Robert Moses SP	260	178	309	87
FL Gulf Islands National Seashore–Fort Pickens	292	66	309	87
TX Salineño Wildlife Preserve (LTC 080)	277	120	309	87
NJ Island Beach SP	276	121	308	91
AK St. Paul Island (Pribilof Islands-Bering Sea)	N/A	N/A	308	91
CT Greenwich Point Park	N/A	N/A	307	93
TX Laguna Atascosa NWR–Bayside Drive	N/A	N/A	307	93
TX Aransas NWR–Wildlife Dr.	257	195	306	95
TX Village Creek Drying Beds (PPW-W 083)	292	66	306	95
TX Mad Island WMA- Crab Lake area	N/A	N/A	305	97
TX Balmorhea Lake [formerly Lake Balmorhea (FWTX 20)]	279	110	305	97
TX Big Bend NP	292	66	304	101
CA Rodeo Lagoon	269	144	304	101
MA Wellfleet Bay Wildlife Sanctuary (Mass Audubon)	292	66	303	103
TX Sea Rim SP (UTC 027)	280	107	303	103
TX Smith Point–Candy Abshier WMA (UTC 048)(GCBO Hawk Watch loc.)	289	72	303	103
TX San Jacinto Battleground (UTC 041)	288	75	302	107
TX Mad Island Marsh Preserve/WMA (CTC 007)	285	82	302	107
TX King Ranch–Santa Gertrudis Unit (CTC 087)	271	136	302	107
TX Resaca de la Palma SP WBC (Brownsville) (LTC 048)	290	71	301	110
NH coast	273	129	300	111
RI Block Island	284	88	300	111
SC Savannah Spoil Site	N/A	N/A	300	111
TX Anzalduas Park (LTC 068)	285	82	300	111

species) in the IRL region, attributing these numbers to Fernald et al. (1982), which reported quite different numbers and only for the region of the barrier island from Sebastian Inlet to Fort Pierce Inlet. Finally, Panico et al. (1989) attributed to Kale (1988) the claim that the IRL has "the most diverse avifauna in the United States" (an attribution also stated by Swain et al. 1995 as "Kale (unpubl.)"). The currently available draft of Kale's (1988) manuscript stated only that the IRL is "well known for its richness in avian species and number of birds." Although data from the eBird website post-date these publications, it is clear that areas in the IRL highest in avian diversity are high compared to many locations in coastal states, but they are not by far currently "the most diverse".

Swain et al. (1994) challenged the claim by Panico et al. (1989) about the comparative biodiversity of the IRL: "this general statement is not supported by

any comprehensive species list." The lists of plants, animals, and microbes in Swain et al. (1994) were drawn from published literature, museum records, and taxonomic specialists who worked on local biota. Their total of 2,493 documented species was much lower than the 4,315 species given without documentation by Panico et al. (1989). The document prepared by Swain et al. (1994) became the foundation for the current Indian River Lagoon Species Inventory Project of the Smithsonian Marine Station at Fort Pierce, FL (Smithsonian Institution 2014). After about two additional decades of documentation, the inventory, front page last updated in 2014, claims to hold more than "3,500 species that live in one of the most biologically diverse estuaries in the continental United States."

Papers from a symposium on biodiversity of the IRL appeared in a 1995 issue of *Bulletin of Marine Science*. Day (1995) suggested that statements in Panico et al. (1989) quoting Gilmore (1985) might have strongly influenced the eventual designation of the IRL as an estuary of national significance. De Freese (1995) stated, "Virnstein (1990) documented and discussed the extreme biological diversity of the IRL." But Virnstein (1990) provided no such documentation, although he did address how species diversity in some higher taxa varies within the IRL and how densities of organisms vary on small and large scales of time and space. Garland's (1995) title was a bit misleading, the contribution offering no discussion of the potential extent of bacterial diversity. Despite the more conservative treatment by Swain et al. (1994) about claims of IRL biodiversity, Swain et al. (1995) embraced Gilmore's (1985) general statement, and their paper continues to be cited as an authority (Lapointe et al. 2020).

There are a few comparisons of taxonomic biodiversity between the IRL and other estuaries for lower-level taxa. Mikkelsen et al. (1995) listed 428 species of mollusk from the IRL. After paring the list to 388 species to allow fair comparison with other surveys, they cited literature that gave values for Biscayne Bay, FL (364 species), Tampa Bay, FL (265), Florida Bay, FL (193), Nichupté Lagoon, Mexico (160), and Chesapeake Bay (131). Winston (1995) compared bryozoan biodiversity (36 species) with that of Chesapeake Bay (24 species), but the latter data were from a study done a half century earlier. Leray and Knowlton (2015), using genetic techniques, found 1,391 operational taxonomic units (OTUs) at the microbial level in the IRL and 1,204 OTUs from the Eastern Shore of Virginia. Microbial diversity in the IRL might, however, be two orders of magnitude higher (Sweat 2016) and represent a huge realm of yet-unknown diversity (Locey and Lennon 2016).

Legitimate geographic comparisons of IRL biodiversity above all require a good understanding of the level of biodiversity in the IRL. Considering the dilution effect of unknown microbial diversity, it does not make sense to compare overall biodiversity. Even at lower taxonomic levels, we must have good data on those groups. For example, comparison of "animal" biodiversity is not possible when whole phyla such as Nematoda are omitted. On the other hand, mollusks (Mikkelsen et al. 1995) and submerged aquatic vegetation (Littler et al. 2008) are well documented. One's choice of taxa could be critical. Also, we must define the boundaries of the IRL system included in a comparison and be certain that the

boundaries used for other geographic sites are comparable. Should uplands within the watershed be included (Fernald et al. 1982) or excluded (Swain et al. 1994)? Moreover, can biodiversity of bar-built estuaries and their drainage systems be compared with that of drowned river valleys, coastal plain estuaries, and tectonic estuaries?

There are potentially significant consequences when unsupported claims are made and perpetuated by scientists and when this misinformation is subsequently used by local and state agencies, legislators, environmental managers, news media, and the public. Those users must be able to trust their sources. In matters of biodiversity as well as other areas of scientific study, it is imperative that scientists seek to fill gaps in our knowledge of biodiversity, to correct error, and to keep those sources trustworthy (Coleman 2015, Lepore 2017, Saunders 2019, Scheufele and Krause 2019).

Acknowledgments The purpose of this study would have been difficult to accomplish without the extensive accumulated data on bird diversity provided by the Christmas Bird Count and by the eBird website. CBC data were provided by National Audubon Society and through the generous efforts of Bird Studies Canada and countless volunteers across the Western Hemisphere. The Cornell Lab of Ornithology, Ithaca, NY, gave permission for use of eBird data. I thank both sources for making their data available for scholarly use. I also thank the many students who took my field course "Natural History of the Indian River Lagoon" from 1989 to 2015 and kept me immersed in the diversity of habitats and life in the waters, shores, and uplands of this region.

References

Coleman CO. 2015. Taxonomy in times of the taxonomic impediment—examples from the community of experts on amphipod crustaceans. Journal of Crustacean Biology 35:729–740.

Day R. 1995. The IRLNEP and biodiversity in the Indian River Lagoon. Bulletin of Marine Science 57:8–9.

De Freese DE. 1995. Land acquisition: a tool for biological diversity protection in the Indian River Lagoon, Florida. Bulletin of Marine Science 57:14–27.

Fernald RT, Barnett BS, Goetzfried A, Lau SR. 1982. The Sebastian Inlet-Ft. Pierce Inlet barrier island: a profile of natural communities, development trends, and resource management guidelines. Florida Game and Fresh Water Fish Commission, Office of Environmental Services, Vero Beach.

Garland JL. 1995. Potential extent of bacterial biodiversity in the Indian River Lagoon. Bulletin of Marine Science 57:79–83.

Gilmore RG. 1977. Fishes of the Indian River Lagoon and adjacent waters, Florida. Bulletin of the Florida State Museum, Biological Sciences 22:101–147.

Gilmore RG. [1985]. The productive web of life in the estuary. Pp. 27–32 *in* Barile DD, ed. The Indian River Lagoon, Proceedings of the Indian River Resources Symposium. Sea Grant Project No. IR 84-28, Florida Sea Grant, Gainesville.

Gilmore RG. 1995. Environmental and biogeographic factors influencing ichthyofaunal diversity: Indian River Lagoon. Bulletin of Marine Science 57:153–170.

Gilmore RG Jr, Donohoe CJ, Cooke DW, Herrema DJ. 1981. Fishes of the Indian River Lagoon and adjacent waters, Florida. Harbor Branch Foundation Technical Report No. 41, Fort Pierce.

Gore RH, Becker LJ, Blum N, Scotto LE. 1976. Studies of decapod Crustacea in the Indian River region of Florida. Pp. 148–161 *in* Young DK, ed. Indian River Coastal Zone Study, Third Annual Report: a Report on Research Progress October 1975–October 1976, Volume 1. Harbor Branch Consortium, Fort Pierce.

Indian River Lagoon National Estuary Program. 2020. Position statement on restoration of the Indian River Lagoon. http://www.irlcouncil.com/5-year-program-evaluation.html. Accessed: January 3, 2020.

Hargraves PE. 2002. Diatoms of the Indian River Lagoon, Florida: an annotated account. Florida Scientist 65:225–244.

Johnston EL, Mayer-Pinto M, Hutchings MPA, Marzinelli EM, Ahyong ST, Birch G, Booth DJ, Creese RG, Doblin MA, Figueira W, Gribben PE, Pritchard T, Roughan M, Steinberg PD, Hedge LH. 2015. Sydney Harbour: what we do and do not know about a highly diverse estuary. Marine and Freshwater Research 66:1073–1087.

Jones RS, Gilmore RG Jr, Kulczycki GR, Magley WC, Gaunke B. 1975. Studies of the fishes of the Indian River coastal zone. Pp. 57–88 *in* Young DK, ed. Indian River Coastal Zone Study, Second Annual Report: a Report on Research and Progress October 1974–October 1975, Volume 1. Harbor Branch Consortium, Fort Pierce.

Kale HW II. 1988. Biology: birds. Pp. 1–51 (and Fig. 1–11 unpaginated) *in* Barile D, ed. Indian River Lagoon Estuarine Monograph, Volume 3. Marine Resources Council, Florida Institute of Technology, Melbourne. [unpublished]

Lapointe BE, Herren LW, Brewton RA, Alderman PK. 2020. Nutrient over-enrichment and light limitation of seagrass communities in the Indian River Lagoon, an urbanized subtropical estuary. Science of the Total Environment 699(134068):1–15.

Lepore J. 2017. Inquietude. The New Yorker 93(31):17–18.

Leray M., Knowlton N. 2015. DNA barcoding and metabarcoding of standardized samples reveal patterns of marine benthic diversity. Proceedings of the National Academy of Sciences 112:2076–2081.

Littler DS, Littler MM, Hanisak MD. 2008. Submersed Plants of the Indian River Lagoon: a Floristic Inventory and Field Guide. Offshore Graphics, Inc., Washington.

Locey KJ, Lennon JT. 2016. Scaling laws predict global microbial diversity. Proceedings of the National Academy of Sciences 113:5970–5975.

Mikkelsen PM, Mikkelsen PS, Karlen DJ. 1995. Molluscan biodiversity in the Indian River Lagoon, Florida. Bulletin of Marine Science 57:94–127.

[Panico C, Moore E, De Freese D.] 1989. The Indian River Lagoon, Florida: National Estuary Program nomination; a governor's nomination report submitted to the U.S. Environmental Protection Agency. Florida Department of Environmental Protection, Tallahassee.

Pulver DV. 2013. Troubled water: the Indian River Lagoon in peril. Special report. Daytona Beach News-Journal, 18 December. http://creative.news-journalonline.com/troubledwater/. Accessed: January 3, 2020.

Reed NP. 1985. [Letter to Governor Bob Graham, 19 January.] Pp. 120–121 *in* Barile DD, ed. The Indian River Lagoon, Proceedings of the Indian River Resources Symposium. Sea Grant Project No. IR 84-28, Florida Sea Grant, Gainesville.

Saunders ME. 2019. No simple answers for insect conservation. American Scientist 107:148–151.

Saunders TB. 1892. The Maxims and Reflections of Goethe. Macmillan, New York.

Scheufele DA, Krause NM. 2019. Science audiences, misinformation, and fake news. Proceedings of the National Academy of Science 116:7662–7669.

Smithsonian Institution. 2014. Indian River Lagoon species inventory. https://naturalhistory2.si.edu/smsfp/irlspec/index.htm. Accessed January 7, 2020.

Swain HM, Hopkins SE, Thornton CL. 1994. A preliminary species list for the Indian River Lagoon, Florida. National Estuary Program, Melbourne.

Swain HM, Breininger DR, Busby DS, Clark KB, Cook SB, Day RA, De Freese DE, Gilmore RG, Hart AW, Hinkle CR, McArdle DA, Mikkelsen PM, Nelson WG, Zahorcak AJ. 1995. Introduction. Bulletin of Marine Science 57:1–7.

Sweat LH. 2016. Exploring the role of biofilms in the transport and establishment of invasive marine macrofoulers. PhD dissertation. Florida Institute of Technology. Melbourne.

Virnstein RW. 1990. The large spatial and temporal biological variability of Indian River lagoon. Florida Scientist 53:249–256.

Winston JE. 1995. Ectoproct diversity of the Indian River coastal lagoon. Bulletin of Marine Science 57:84–93.
Yates CS. 2008 Treasured Waters: the Indian River Lagoon. Pioneer River Press, Fort Pierce.

Submitted: May 17, 2020
Accepted: November 28, 2020