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Indices of abundance for Gulf Gag (*Mycteroperca microlepis*) from stereo-baited underwater video surveys

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Background

In the Gulf of America (Gulf), several fishery-independent surveys targeting reef fishes operate with the specific objective of providing more reliable indices of abundance compared with those estimated from fishery-dependent sources. Of these, surveys using stereo baited underwater video gear (SBRUV) have proven the most tractable for Gulf-wide, multi-species monitoring through several decades-worth of work by three survey programs. The first of which was the SEAMAP reef fish video survey (SRFV) run by the NMFS Mississippi Laboratory in Pascagoula and sampled shelf-edge features across the Gulf beginning in 1992. This was followed by the NMFS Panama City trap and video survey (PC), which started in 2005 and sampled shallower reef habitat on the Panhandle and Big Bend regions of the West Florida Shelf (WFS). A third video survey, run by FWC's Fish and Wildlife Research Institute, started in 2010 sampling the central region of the WFS before expanding south towards the Florida Keys and north through the Florida Panhandle. These three historic video surveys were superseded in 2020 by the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER), a multi-agency collaboration initiated by the researcher leads of the SRFV, PC, and FWRI surveys. Combining these efforts will ultimately resolve limitations and analytical challenges associated with the integration of data from multiple surveys as data from G-FISHER constitutes an ever-growing portion of the collective, video time series. In the interim, a pseudo, design-based approach was developed that integrates data from all four surveys into relative index of abundance (Thompson et al 2022) and determined to be suitable and recommended by multiple SEDAR index working groups (see data workshop reports for SEDAR 94 and SEDAR 98).

Gag (*Mycteroperca microlepis*) is one of a few managed species whose ecology challenges an implicit assumption of the combined index approach which is that survey observations across years are representative of the same underlying population. With Gag there are two primary challenges. First, they exhibit strong ontogenetic patterns in habitat use, where subadults primarily occupy shallow reef habitats prior to moving further offshore as they approach maturity. Because of this, there is a clear change in size composition from the time period when only deeper, shelf edge sites are sampled (large individuals; 1993–2005) to later periods when shallow shelf habitats were also sampled (large and small individuals; 2006 onward). The second challenge is that both the frequency of occurrence as well as site-specific abundance of Gag is much higher in the Panhandle and Big Bend regions of the WFS compared with those to the south, potentially confounding the estimated contribution of the FWRI survey prior to 2016 when coverage spanned the entire WFS. Options for mitigating these issues were discussed extensively among SEDAR 72 Index Working Group (IWG) participants during and in the weeks following the Data Workshop. However, a consensus was not reached with respect to alternatives to the status quo. Thus, the recommendation to provide separate SRFV and PC indices remained unchanged. For SEDAR 105, a truncated combined video index (e.g., Lewis et al 2025) was considered as a potential alternative for incorporating the recent data from G-FISHER based primarily on discussions by and final recommendation of the IWG at the SEDAR 94 Hogfish Data Workshop in August 2025. However, after input from the co-lead assessment analysts, it was decided that priority should be given to approaches that maximize the duration of the time series even if this requires the use of multiple video index data sets. Ultimately two sets of video indices spanning all suitable survey years from 1993–2024 were requested. The first set (Set 1) includes an offshore SRFV index (1993–2015), inshore PC index (2006–2015), and shelf-wide FWRI-GF index (2016–2024). The second set (Set 2) includes an offshore SRFV-GF index (1993–2024) and inshore PC-GF index (2006–2024).

Methods

Historic survey designs:

The SRFV survey primarily targeted high-relief topographic features along the continental shelf from south Texas to south Florida. Site selection followed a stratified random design with strata determined by region and total proportion of reef area in a sampling block of 10 minute latitude X 10 minute longitude in size. Sites were selected at random from known reef areas identified through habitat mapping either with multi-beam or side-scan sonar (Campbell et al 2017).

The PC survey targeted the inner shelf (5–60 m), of the northeast Gulf (NMFS statistical zones 6–10). Survey design has changed over time, but since 2010 a two-stage unequal probability design has been used. The survey area was divided into eastern and western sub-regions by Cape San Blas in the Florida Panhandle and further gridded into sampling blocks, which were 5 minutes x 5 minutes in size. Sites were randomly selected and proportionally allocated by region and depth with site characteristics were described using side-scan sonar prior to video deployments (Gardner et al. 2017).

The FWRI survey initially focused on the regions offshore of Tampa Bay and Charlotte Harbor, FL (i.e., NMFS statistical zones 4 and 5) that were partitioned into inshore or offshore depth strata (depth ranges of 10–36 m and 37–110 m respectively). In 2014, the survey was expanded to include NMFS statistical zones 9 and 10, the outer depth limit of the offshore strata increased to 180 m. This was followed by another spatial expansion in 2016 to cover the entirety of the West Florida Shelf (i.e., NMFS statistical zones 2–10) from 10 to 180 m. For natural reefs, sites were randomly selected and mapped using side scan sonar over a 2.1 km^2 area (Switzer et al. 2020; Keenan et al. 2022). Video deployment sites were then randomly assigned proportionally across region and depth zones (Thompson et al. 2017).

G-FISHER survey design:

Beginning in 2020, Gulf-wide video survey efforts were integrated under a single, novel survey design under the G-FISHER program (Switzer et al. 2023). A stratified-random design structure was adopted that included both spatial and habitat stratification since this approach has proven useful for subdivide the survey domain into homogeneous strata and partition population variance of reef fish species (Smith et al. 2011). To do so, a retrospective analysis of data on reef fish assemblages and their habitats was conducted to (1) delineate biologically relevant spatial and habitat strata, and (2) define optimal allocation of sampling effort based on a combination of habitat availability and managed species richness. Spatially, the Gulf survey domain was subdivided into three depth strata (10–25 m, > 25–50 m, > 50–180 m) and six regional strata (Texas, west Louisiana, east Louisiana, north-central Gulf, Big Bend, and southwest Florida). For both natural and artificial reefs, habitat strata were delineated based on relative relief (low, medium, high) and size of the individual reef feature, although delineation of reef scale differed markedly between natural (< 100 m^2, 100–1000 m^2, > 1000 m^2) and artificial habitat strata (< 25 m^2, 25–100 m^2, > 100 m^2). Under the new G-FISHER design, approximately 2,000 reef fish stations are sampled annually with SBRUV camera arrays designed to characterize benthic habitats and provide data on abundance and size composition of reef fishes observed.

Video processing:

All surveys use paired stereo-imaging cameras at each site. All videos are read to identify the maximum number of individuals of each species viewed in a single frame within a 20-minute time frame, often referred to as MaxN or MinCount. Habitat characteristics on video are also noted with the percentage or presence/absence of abiotic and biotic habitat types that may contribute to fish biomass (e.g. sponge, algae, and corals). While some categories were not historically recorded by all three labs (Campbell et al. 2017; Gardner et al. 2017; Thompson et al. 2017), the habitat annotation procedures adopted by G-FISHER are more comprehensive and include most habitat variables recorded during any of the three prior surveys.

Length measurements:

The methods employed to gather fish length data video records have also evolved over time. Length measurements from the SRFV and PC surveys were initially estimated using parallel lasers attached to the camera system (Campbell et al. 2017; Gardner et al. 2017). However, the fixed mounted lasers resulted in very few usable laser contacts needed to obtain individual length measurement while also mitigating repeated measurements of the same individual. Therefore, both surveys adopted stereo-video methods (2008 and 2010 for SRFV and PC surveys, respectively). From the onset, the FWRI survey used stereo-video methods to obtain length measurements. Length estimates from all three historic surveys were obtained from Vision

Measurement System (VMS, Geometrics Inc.) through 2014. From 2015 to present, all length measurements are obtained from the SeaGIS software (SeaGIS Pty. Ltd.).

Data processing:

All data collected on artificial reefs were excluded from subsequent analyses. For all surveys, video reads were excluded if they were unreadable due to turbidity or deployment errors. Of the remaining sites, only those east of NMFS statistical zone 10 were retained because of the low annual frequency of occurrence of Gag in the western Gulf (Table 1; Figure 1). Data from the SRFV survey collected in 1992 were excluded from index calculations because of differences in counting methods in this first year, and no survey data are available for years 1998-2001 and 2003. A further 16 sites from 1993, 1994, 1997, and 2005 were excluded because these early events occurred within inshore sampling blocks that were eventually excluded from the selectable universe. Panama City survey data from 2005 was excluded because of an incomplete survey.

Three data sets were used for the indices in Set 1. The first two were simply truncated versions of the SRFV and PC time series (i.e., SRFV 1993–2015 and PC 2006–2015). The third data set was comprised of FWRI (2016–2019) and G-FISHER (2020–2024), providing shelf-wide coverage of juvenile through adult life stages (Figure 2). The indices that comprise Set 2 represent updated versions of the SRFV and PC video indices used in SEDAR 72, which required the extension of each time series beyond the period each survey operated. This was accomplished by first defining the spatial extent of the historic survey domains, then partitioning G-FISHER sites within each survey domain between each data set and finally repartitioning those G-FISHER sites within the overlapping survey domains proportionally into one data set or the other (Figure 3). The result is an SRFV-GF data set spanning the period of 1993–2024 and a PC-GF data set spanning the period of 2006–2024.

SRFV data discrepancy:

Preliminary comparisons of the annual survey effort, occurrence rate, and nominal catch rate identified a large discrepancy between the SRFV data used in SEDAR 72 compared with what are reported here (Figure 4). This was the results of an additional data processing step for SEDAR 72 to resolve convergence issues with the delta-lognormal model because of the low occurrence rate. Sites with relief values < 0.15 m were removed to resolve this issue. However, a negative binomial error distribution was ultimately determined to be more appropriate in SEDAR 72 and, in the current application, the retention of these sites did not lead to issues with convergence.

Index models:

Data for all indices contained with Set 1 and Set 2 were modeled using generalized linear models (GLMs) in R version 4.5.2 (R Core Team 2025) using standard selection procedures to identify the appropriate suite of explanatory variables and error distribution. Both Poisson and negative binomial distributions were considered. However, only results from negative binomial models are presented because they consistently outperformed the Poisson models. For the SRFV and PC indices in Set 1, the same potential explanatory variables from SEDAR 72 were used (Table 2). For the FWRI-GF index, Year, latitude, longitude, depth, substrate max relief, and percent cover of rock, hard coral, soft coral and sponge were all included as potential explanatory variables. The variables for SRFV-GF and PC-GF models in Set 2 required minor adjustments to accommodate the integration of G-FISHER sites. First, the threshold values of the logical expression used to generate the SRFV reef variable (i.e., a binary value to identify whether the camera pod landed on reef habitat) needed to be increased from 5% to 10% for G-FISHER because of changes in video annotation procedures. Second, month was removed from the list of potential explanatory variables for PC-GF because of issues with model convergence. From these initial sets of explanatory variables, bidirectional stepwise model selection was performed using MASS::stepAIC (Venables and Ripley 2002) to identify the final set of explanatory variables. Model fits were then evaluated using the DHARMa package (Hartig 2024) to identify any problematic deviations from the expected distribution, under/overdispersion, and outliers.

Results and Discussion

Video lengths:

There was a noticeable difference in the size of Gag observed between surveys, specifically SRFV and PC (Figure 5). Importantly for the indices in Set 1, the size distribution of Gag measured by FWRI-GF from shelf-wide sampling spans the full range of sizes observed by PC and SRFV (Figure 5 top panel). Moreover, the distribution of lengths from G-FISHER sites within Set 2 data sets closely correspond to the distributions from historic sites (Figure 5 bottom panel).

Abundance indices:

The full set of explanatory variables were retained for all index models except the FWRI-GF model in Set 1 of which hard coral percent cover was excluded (Table 2). Similarly, diagnostics plots revealed issues with one index model. In this case, the PC model from Set 1 showed significant quantile deviations but ultimately resolved by including a quadratic term for depth (Supplemental Figure 1). The diagnostics plots for the remaining index models are provided in (Supplemental Figures 2 and 3).

Despite differences between the present SRFV data set and the one used in SEDAR 72, the scaled indices and associated CVs were reasonably similar (Figure 6). The same was also true for the PC video index but not the CVs (Figure 7). However, the difference in CV values is most likely because of difference between the assumed error structure (i.e., delta-lognormal vs. negative binomial).

The final indices within Set 1 are provided in Tables 3–5 and the top panel of Figure 8, while those of Set 2 are in Tables 6–7 and the bottom panel of Figure 8. The SRFV and PC indices differ little between Set 1 and Set 2 through 2015. The main difference is that the average index value for the PC in Set 1 is approximately twice as high as it is for Set 2 (0.85 vs. 0.43) but nearly the same for SRFV (~ 0.05). This is driven by the drop in Gag catch rates when the time series transitions from PC and G-FISHER and leads to a scaled index that peaks at a value which is double the average value. This apparent scaling artifact is not evident in the Set 1 indices since there was essentially no blending of independent survey data sets. Moreover, the inclusion of a shelf-wide index from 2016-2024 makes the best use of the available data and certainly more representative of population trends when compared with Set 2. For these reasons, the indices of Set 1 are recommended over those provided in Set 2.

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Table 1. Summary of Gulf-wide video survey effort and Gag frequency of occurrence (FO) on natural reefs.

	Western Gulf		Eastern Gulf	
Year	Effort	FO	Effort	FO
1993	45	0	115	6
1994	51	0	91	1
1995	46	0	61	3
1996	165	1	133	10
1997	127	2	162	11
2001	43	0	32	1
2002	109	0	152	28
2003	0	0	62	9
2004	50	3	149	28
2005	136	1	313	38
2006	139	0	367	55
2007	171	6	373	51
2008	131	3	290	30
2009	167	4	367	63
2010	106	0	409	66
2011	103	2	706	88
2012	200	3	646	53
2013	136	2	435	28
2014	113	3	747	46
2015	57	2	699	33
2016	168	3	1110	76
2017	194	3	991	70
2018	194	5	1000	50
2019	263	0	1293	95
2020	0	0	764	33
2021	286	7	1001	84
2022	311	6	945	88
2023	284	5	942	70
2024	257	3	1018	71

Table 2. Explanatory variable considered and selected in final index models for each survey. Note that although the SRFV and PC indices in Set 2 included data from G-FISHER the variables retained in the final index model did not change.

Survey	Variable	Retained
SRFV	Year	Yes
	Latitude	Yes
	Longitude	Yes
	Depth	Yes
	Combo max relief	Yes
	Reef*	Yes
PC	Year	Yes
	Region (PC)	Yes
	Depth	Yes
FWRI-GF	Year	Yes
	Latitude	Yes
	Longitude	Yes
	Depth	Yes
	Substrate max relief	Yes
	Rock	Yes
	Hard coral	No
	Soft coral	Yes
	Sponge	Yes

*Logical variable historically derived and used as predictor variable in SRFV index models. The conditions of this expression were revised for G-FISHER sites because of differences in video annotation procedures. See methods section for more details.

Table 3. Nominal effort, rate of occurrence, CPUE and final index for SRFV in Set 1. Lower (LCL) and upper (UCL) confidence limits reported as Index ±2SE.

Year	Effort	Occurrence rate	Nominal CPUE	Index	SE	CV	LCL	UCL	Index (scaled)	LCL (scaled)	UCL (scaled)
1993	109	0.0550	0.0642	0.0173	0.0081	0.4700	0.0010	0.0335	0.3182	0.0191	0.6172
1994	83	0.0120	0.0120	0.0030	0.0033	1.0783	-0.0035	0.0096	0.0562	-0.0650	0.1774
1995	50	0.0600	0.1800	0.1431	0.0638	0.4457	0.0156	0.2706	2.6380	0.2867	4.9892
1996	133	0.0752	0.0902	0.0268	0.0100	0.3729	0.0068	0.0467	0.4933	0.1254	0.8613
1997	161	0.0683	0.0745	0.0269	0.0098	0.3656	0.0072	0.0465	0.4951	0.1331	0.8571
2002	152	0.1842	0.2895	0.0572	0.0162	0.2837	0.0248	0.0897	1.0553	0.4565	1.6541
2004	149	0.1879	0.2819	0.0917	0.0233	0.2544	0.0450	0.1383	1.6895	0.8301	2.5490
2005	274	0.1095	0.2080	0.0737	0.0162	0.2197	0.0413	0.1061	1.3595	0.7622	1.9567
2006	277	0.0686	0.1011	0.0578	0.0149	0.2571	0.0281	0.0875	1.0651	0.5173	1.6129
2007	319	0.0909	0.1317	0.0558	0.0132	0.2358	0.0295	0.0822	1.0295	0.5439	1.5151
2008	206	0.0194	0.0243	0.0146	0.0072	0.4972	0.0001	0.0290	0.2684	0.0015	0.5352
2009	262	0.0573	0.1031	0.0413	0.0111	0.2680	0.0192	0.0634	0.7611	0.3532	1.1690
2010	221	0.0860	0.1176	0.0569	0.0158	0.2782	0.0252	0.0885	1.0484	0.4651	1.6318
2011	337	0.1009	0.1721	0.0757	0.0158	0.2092	0.0440	0.1073	1.3947	0.8112	1.9782
2012	281	0.0890	0.1815	0.0755	0.0175	0.2314	0.0406	0.1104	1.3916	0.7476	2.0357
2013	163	0.0859	0.1656	0.0690	0.0193	0.2788	0.0305	0.1075	1.2728	0.5630	1.9826
2014	230	0.0478	0.0739	0.0355	0.0111	0.3119	0.0133	0.0576	0.6539	0.2461	1.0618
2015	152	0.0789	0.1184	0.0548	0.0175	0.3202	0.0197	0.0898	1.0095	0.3630	1.6560

Table 4. Nominal effort, rate of occurrence, CPUE and final index for PC in Set 1. Lower (LCL) and upper (UCL) confidence limits reported as Index ±2SE.

Year	Effort	Occurrence rate	Nominal CPUE	Index	SE	CV	LCL	UCL	Index (scaled)	LCL (scaled)	UCL (scaled)
2006	87	0.3908	1.8161	1.8458	0.4117	0.2230	1.0224	2.6691	2.1637	1.1986	3.1288
2007	44	0.4318	1.0000	1.0733	0.3421	0.3188	0.3890	1.7575	1.2582	0.4560	2.0603
2008	83	0.3012	0.6506	0.7364	0.1893	0.2571	0.3578	1.1150	0.8633	0.4194	1.3071
2009	104	0.4519	1.0769	1.3070	0.2775	0.2123	0.7521	1.8620	1.5322	0.8816	2.1827
2010	138	0.3333	0.7029	0.9947	0.1925	0.1935	0.6097	1.3797	1.1660	0.7147	1.6174
2011	150	0.2800	0.6667	0.8954	0.1653	0.1846	0.5649	1.2260	1.0497	0.6622	1.4371
2012	148	0.1081	0.1757	0.2316	0.0585	0.2527	0.1146	0.3487	0.2715	0.1343	0.4087
2013	86	0.1279	0.5349	0.8742	0.2393	0.2737	0.3956	1.3529	1.0248	0.4638	1.5859
2014	169	0.1361	0.1775	0.2923	0.0734	0.2510	0.1455	0.4390	0.3426	0.1706	0.5146
2015	155	0.0581	0.1871	0.2798	0.0707	0.2528	0.1384	0.4213	0.3280	0.1622	0.4939

Table 5. Nominal effort, rate of occurrence, CPUE and final index for FWRI-GF in Set 1. Lower (LCL) and upper (UCL) confidence limits reported as Index ±2SE.

Year	Effort	Occurrence rate	Nominal CPUE	Index	SE	CV	LCL	UCL	Index (scaled)	LCL (scaled)	UCL (scaled)
2016	719	0.0751	0.1238	0.0992	0.0156	0.1570	0.0681	0.1304	1.5891	1.0902	2.0880
2017	622	0.0643	0.0820	0.0520	0.0100	0.1927	0.0320	0.0720	0.8327	0.5118	1.1537
2018	694	0.0418	0.0793	0.0494	0.0091	0.1843	0.0312	0.0677	0.7917	0.4999	1.0836
2019	899	0.0623	0.1012	0.0624	0.0095	0.1528	0.0433	0.0814	0.9987	0.6935	1.3039
2020	764	0.0432	0.0510	0.0341	0.0069	0.2033	0.0202	0.0479	0.5458	0.3239	0.7678
2021	998	0.0842	0.1192	0.0689	0.0095	0.1381	0.0498	0.0879	1.1029	0.7983	1.4075
2022	936	0.0929	0.1314	0.0737	0.0102	0.1391	0.0532	0.0941	1.1797	0.8516	1.5078
2023	939	0.0735	0.1203	0.0606	0.0087	0.1436	0.0432	0.0780	0.9706	0.6918	1.2494
2024	1017	0.0698	0.1131	0.0617	0.0086	0.1386	0.0446	0.0788	0.9887	0.7147	1.2628

Table 6. Nominal effort, rate of occurrence, CPUE and final index for SRFV in Set 2. Lower (LCL) and upper (UCL) confidence limits reported as Index ±2SE.

Year	Effort	Occurrence rate	Nominal CPUE	Index	SE	CV	LCL	UCL	Index (scaled)	LCL (scaled)	UCL (scaled)
1993	109	0.0550	0.0642	0.0149	0.0071	0.4796	0.0006	0.0291	0.3030	0.0124	0.5937
1994	83	0.0120	0.0120	0.0026	0.0028	1.0906	-0.0030	0.0082	0.0524	-0.0618	0.1665
1995	50	0.0600	0.1800	0.1312	0.0602	0.4591	0.0107	0.2516	2.6768	0.2188	5.1347
1996	133	0.0752	0.0902	0.0247	0.0094	0.3795	0.0060	0.0434	0.5039	0.1215	0.8864
1997	161	0.0683	0.0745	0.0246	0.0091	0.3693	0.0064	0.0427	0.5013	0.1310	0.8715
2002	152	0.1842	0.2895	0.0542	0.0155	0.2857	0.0232	0.0851	1.1051	0.4736	1.7366
2004	149	0.1879	0.2819	0.0924	0.0237	0.2569	0.0449	0.1399	1.8854	0.9166	2.8543
2005	274	0.1095	0.2080	0.0704	0.0155	0.2197	0.0395	0.1013	1.4360	0.8050	2.0670
2006	277	0.0686	0.1011	0.0551	0.0141	0.2565	0.0268	0.0833	1.1239	0.5473	1.7006
2007	319	0.0909	0.1317	0.0546	0.0128	0.2341	0.0291	0.0802	1.1149	0.5928	1.6370
2008	206	0.0194	0.0243	0.0142	0.0071	0.4984	0.0000	0.0283	0.2890	0.0009	0.5771
2009	262	0.0573	0.1031	0.0392	0.0105	0.2685	0.0181	0.0602	0.7997	0.3703	1.2292
2010	221	0.0860	0.1176	0.0558	0.0157	0.2807	0.0245	0.0871	1.1385	0.4994	1.7775
2011	337	0.1009	0.1721	0.0749	0.0155	0.2071	0.0439	0.1059	1.5281	0.8952	2.1610
2012	281	0.0890	0.1815	0.0712	0.0165	0.2323	0.0381	0.1043	1.4532	0.7781	2.1284
2013	163	0.0859	0.1656	0.0678	0.0191	0.2816	0.0296	0.1059	1.3825	0.6039	2.1610
2014	230	0.0478	0.0739	0.0337	0.0105	0.3127	0.0126	0.0548	0.6878	0.2576	1.1181
2015	152	0.0789	0.1184	0.0551	0.0174	0.3164	0.0203	0.0900	1.1252	0.4133	1.8372
2016	205	0.0293	0.0293	0.0193	0.0089	0.4611	0.0015	0.0372	0.3948	0.0307	0.7590
2017	221	0.0407	0.0407	0.0364	0.0140	0.3840	0.0084	0.0644	0.7432	0.1724	1.3139
2018	213	0.0329	0.0423	0.0344	0.0130	0.3791	0.0083	0.0604	0.7014	0.1696	1.2332
2019	285	0.0386	0.0737	0.0462	0.0128	0.2765	0.0206	0.0717	0.9425	0.4212	1.4638
2020	174	0.0287	0.0287	0.0150	0.0076	0.5060	-0.0002	0.0302	0.3065	-0.0037	0.6167
2021	229	0.0786	0.1135	0.0478	0.0129	0.2700	0.0220	0.0736	0.9749	0.4485	1.5012
2022	238	0.1513	0.2017	0.0813	0.0182	0.2240	0.0449	0.1178	1.6598	0.9163	2.4034
2023	258	0.0814	0.1705	0.0692	0.0157	0.2265	0.0379	0.1006	1.4123	0.7725	2.0520
2024	268	0.0597	0.0970	0.0371	0.0097	0.2600	0.0178	0.0565	0.7578	0.3638	1.1519

Table 7. Nominal effort, rate of occurrence, CPUE and final index for PC in Set 2. Lower (LCL) and upper (UCL) confidence limits reported as Index ±2SE.

Year	Effort	Occurrence rate	Nominal CPUE	Index	SE	CV	LCL	UCL	Index (scaled)	LCL (scaled)	UCL (scaled)
2006	87	0.3908	1.8161	1.4009	0.3465	0.2474	0.7078	2.0939	3.2765	1.6554	4.8976
2007	44	0.4318	1.0000	0.7692	0.2767	0.3597	0.2158	1.3225	1.7991	0.5049	3.0933
2008	83	0.3012	0.6506	0.5088	0.1404	0.2759	0.2280	0.7896	1.1901	0.5333	1.8468
2009	104	0.4519	1.0769	0.9044	0.2104	0.2326	0.4836	1.3252	2.1154	1.1312	3.0995
2010	138	0.3333	0.7029	0.6602	0.1384	0.2096	0.3835	0.9370	1.5442	0.8969	2.1916
2011	150	0.2800	0.6667	0.6428	0.1298	0.2019	0.3832	0.9025	1.5035	0.8963	2.1108
2012	148	0.1081	0.1757	0.1705	0.0452	0.2650	0.0802	0.2609	0.3989	0.1875	0.6103
2013	86	0.1279	0.5349	0.4586	0.1275	0.2781	0.2035	0.7137	1.0727	0.4761	1.6694
2014	169	0.1361	0.1775	0.1742	0.0435	0.2495	0.0873	0.2611	0.4074	0.2041	0.6107
2015	155	0.0581	0.1871	0.1846	0.0472	0.2556	0.0902	0.2791	0.4319	0.2111	0.6527
2016	158	0.1013	0.2089	0.1942	0.0479	0.2470	0.0983	0.2900	0.4541	0.2298	0.6784
2017	147	0.1429	0.3878	0.3433	0.0768	0.2236	0.1898	0.4968	0.8030	0.4440	1.1620
2018	76	0.1316	0.1842	0.1570	0.0578	0.3679	0.0415	0.2725	0.3671	0.0970	0.6373
2019	94	0.2660	0.8085	0.7624	0.1902	0.2494	0.3821	1.1427	1.7832	0.8936	2.6728
2020	135	0.0593	0.0667	0.0664	0.0254	0.3831	0.0155	0.1173	0.1553	0.0363	0.2744
2021	263	0.1369	0.1901	0.1906	0.0373	0.1956	0.1160	0.2651	0.4457	0.2713	0.6201
2022	280	0.1214	0.1821	0.1849	0.0356	0.1927	0.1137	0.2562	0.4326	0.2658	0.5993
2023	286	0.1154	0.1818	0.1820	0.0346	0.1900	0.1129	0.2512	0.4258	0.2640	0.5876
2024	284	0.0880	0.1655	0.1681	0.0330	0.1965	0.1021	0.2342	0.3932	0.2387	0.5478

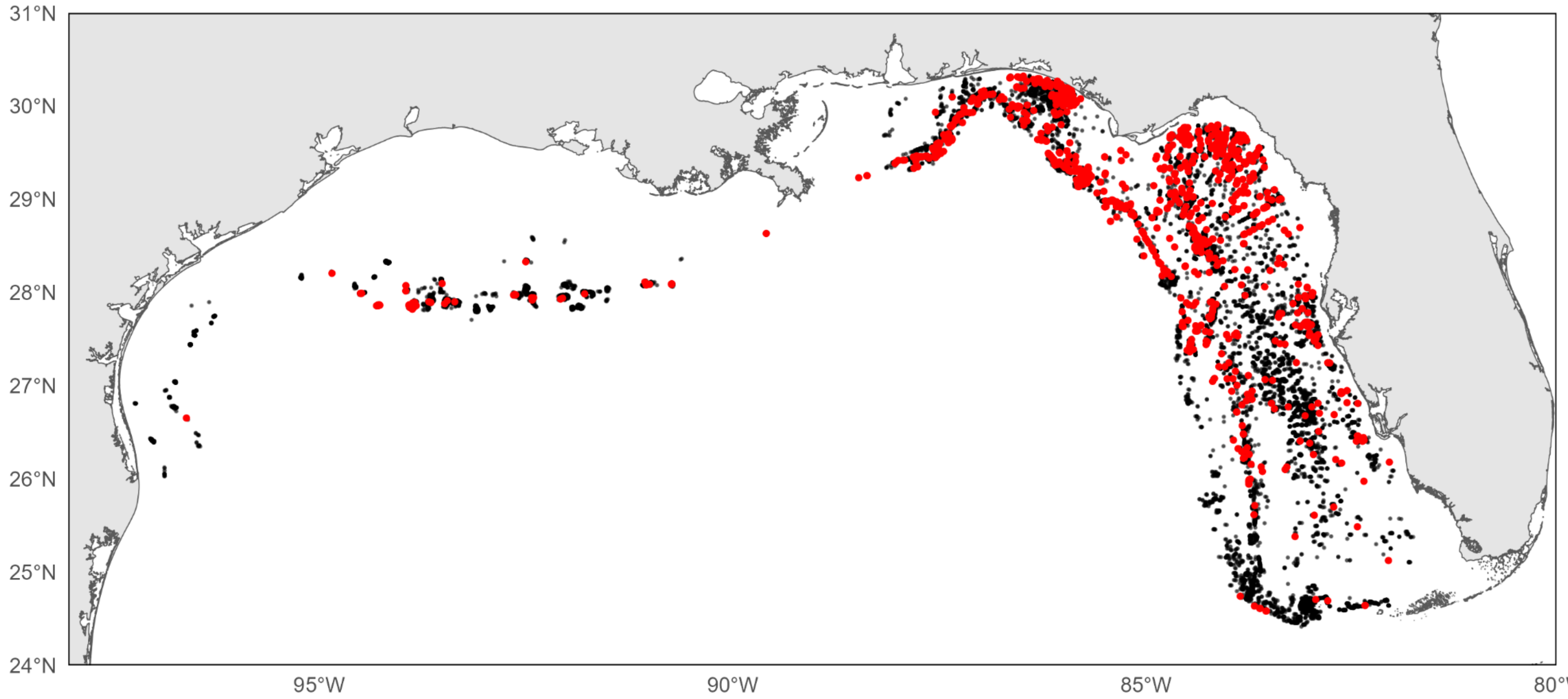

Figure 1. Map of combined video survey effort on natural reefs from 1993 to 2024. Black points indicate sampling sites where no Gags were observed while red points indicate the presence of Gag.

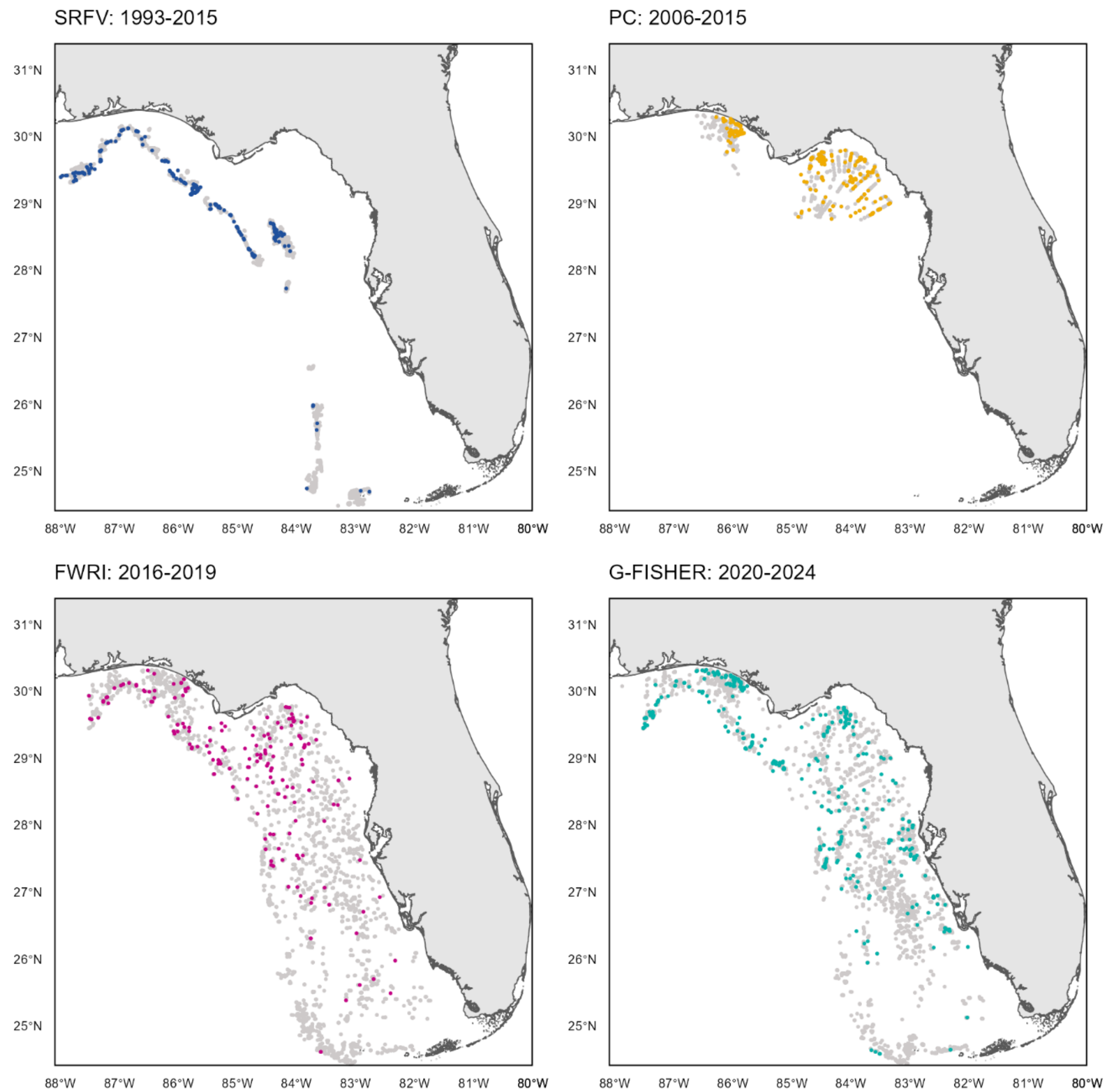

Figure 2. Spatial distribution of video survey effort used for the indices that comprise Set 1. Grey and colored points indicate the absence and occurrence of Gag at sites retained. Note that although the FWRI and G-FISHER surveys appear in separate panels, data were combined to generate a single index for the period of 2016–2024.

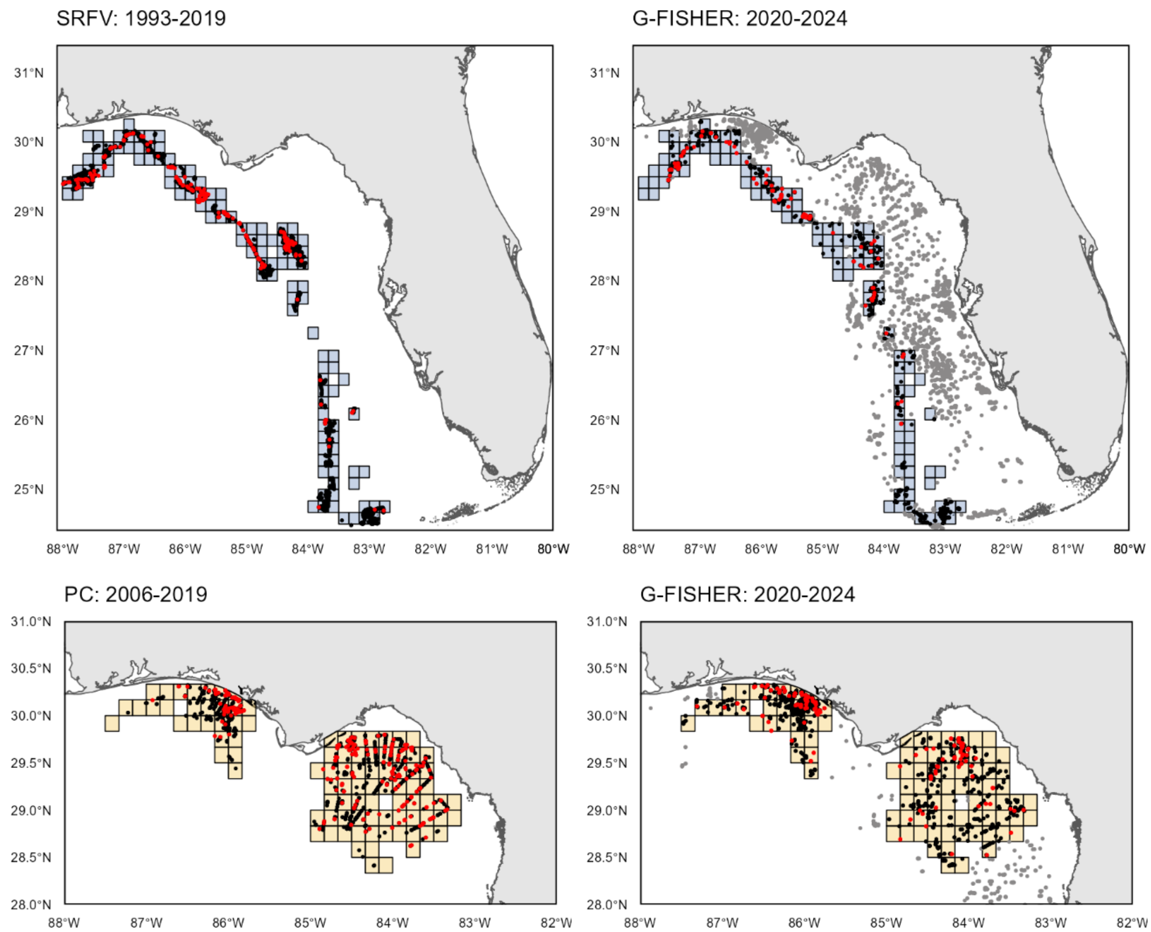

Figure 3. SRFV (top row) and PC (bottom row) survey domains and spatial distribution of survey effort used for the indices that comprise Set 2. Black and red points indicate the absence and occurrence of Gag at sites retained in each index data set. Grey points denote G-FISHER sites which were sampled but not retained in either index data set within Set 2.

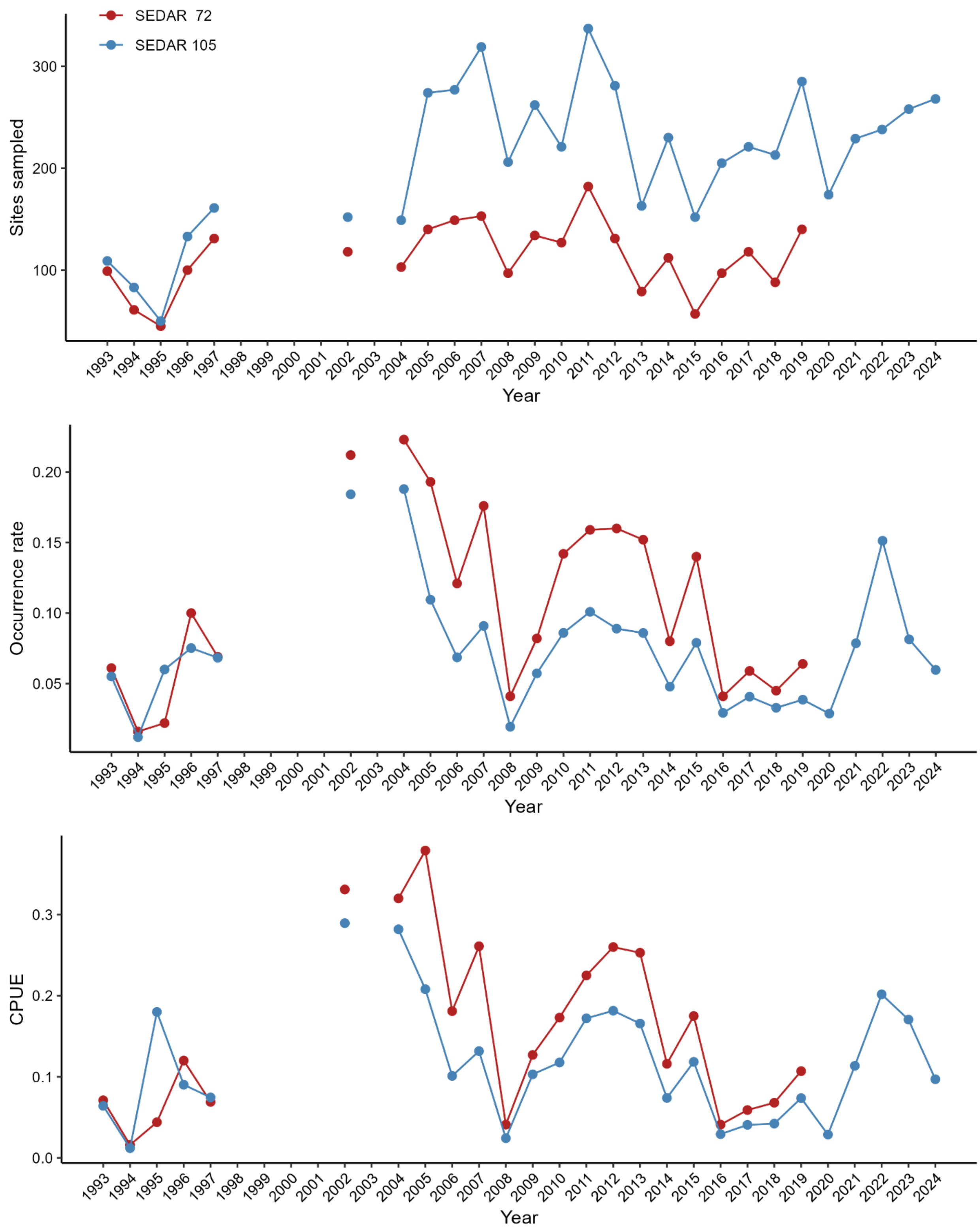

Figure 4. Comparison of SRFV survey effort, occurrence rate, and nominal catch rate of Gag between data sets used in SEDAR 72 and SEDAR 105.

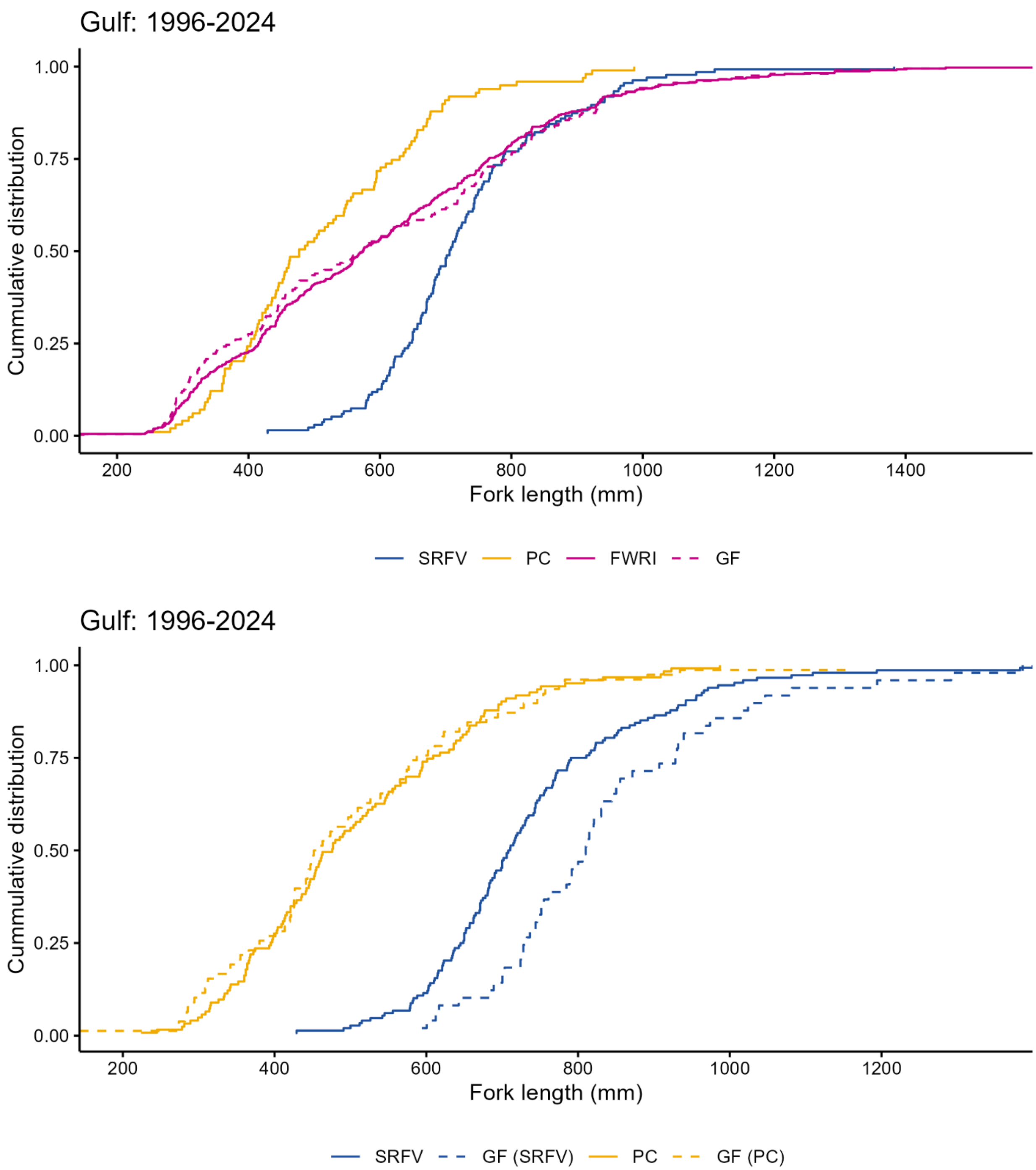

Figure 5. Raw cumulative distribution of Gag video lengths. Lengths associated with Set 1 and Set 2 indices are in the top and bottom panels, respectively.

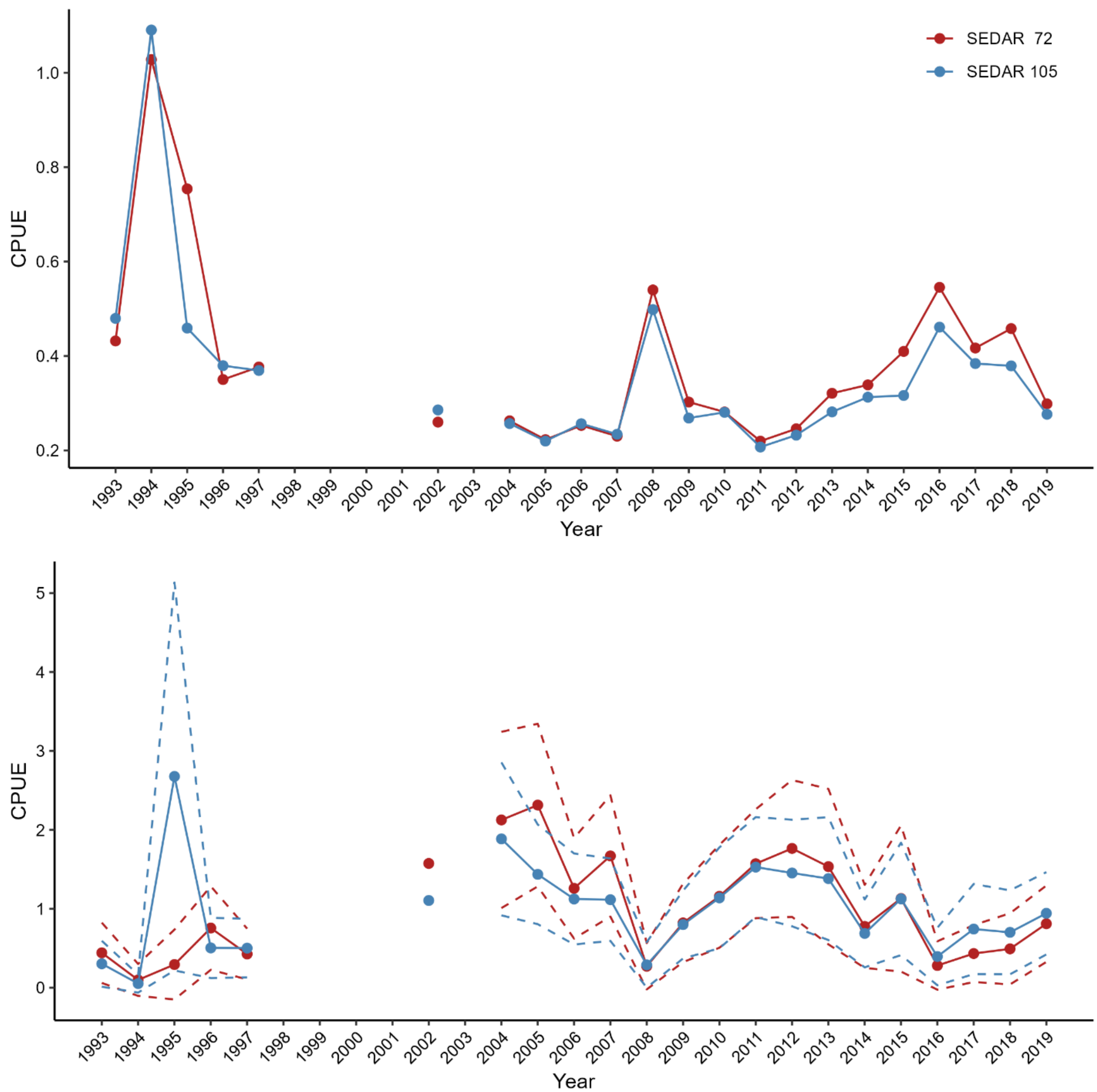

Figure 6. Comparison between SEDAR 72 and SEDAR 105 (Set 2) annual CV and indices (±2 SE) for the SRFV survey from 1993 to 2019.

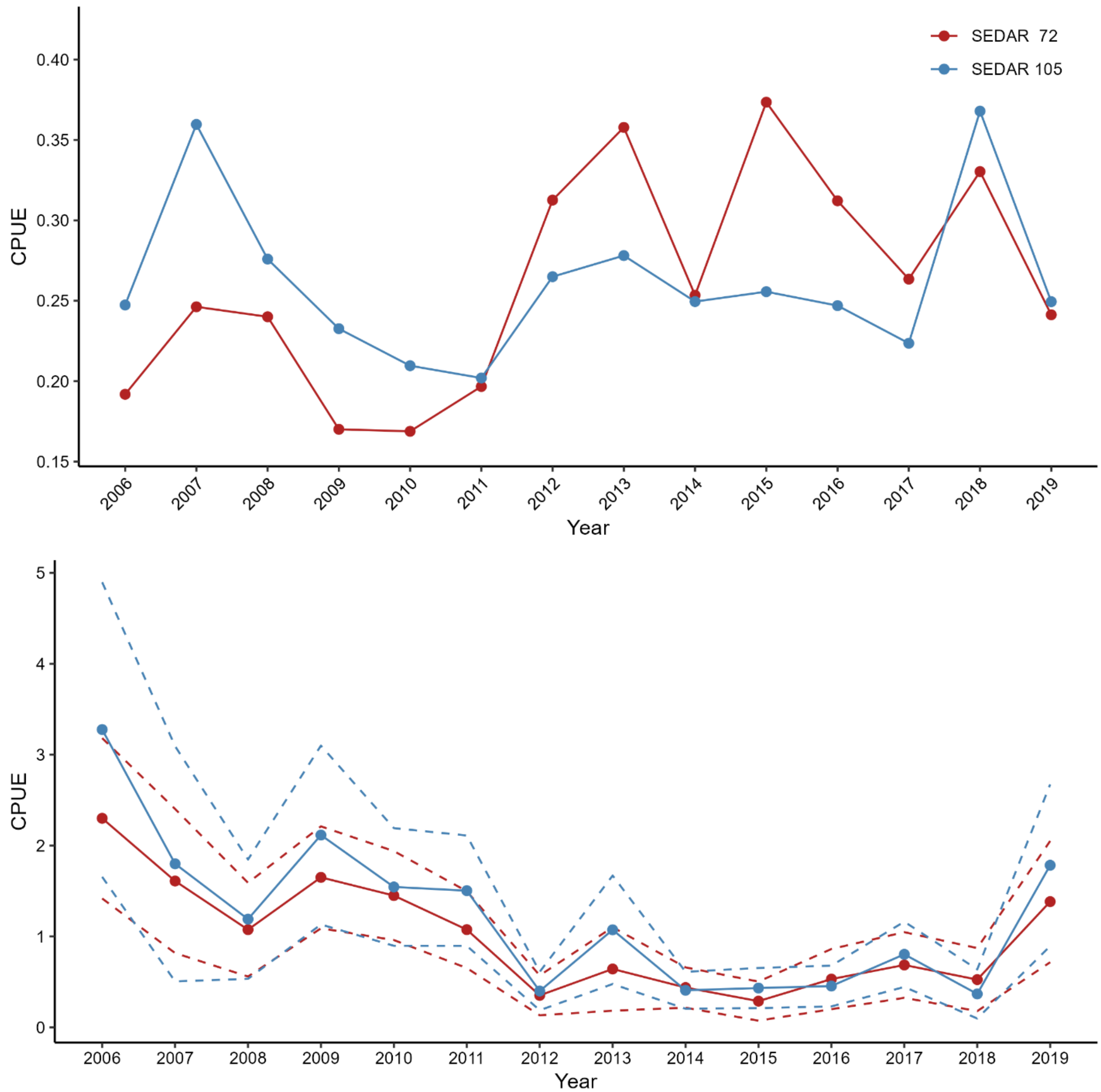

Figure 7. Comparison between SEDAR 72 and SEDAR 105 (Set 2) annual CV and indices (±2 SE) for the PC survey from 2006 to 2019.

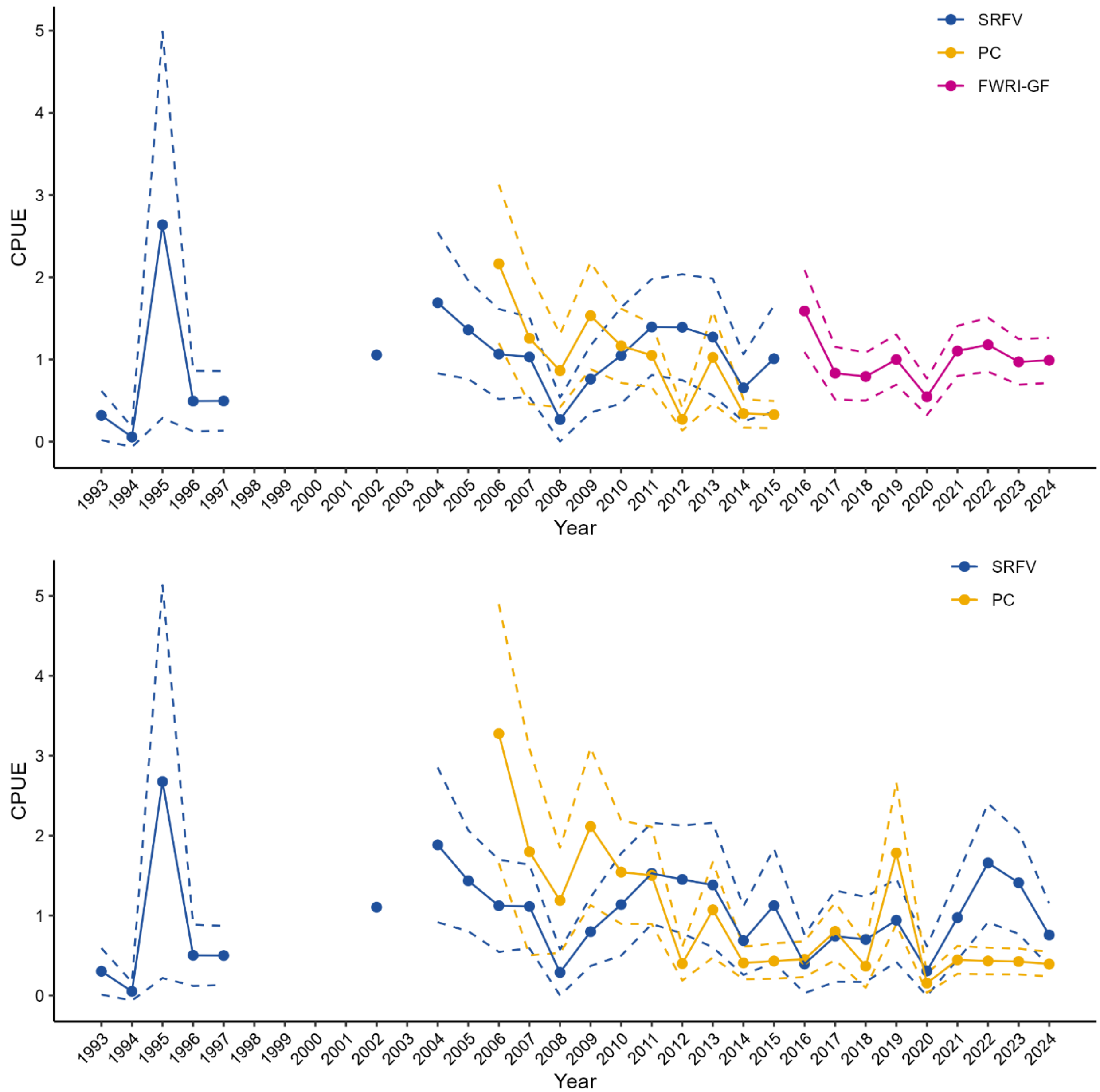

Figure 8. Scaled indices (±2 SE) from Set 1 (top panel) and Set 2 (bottom panel).