Analysis of Recorded Sample Weight vs Length-Weight Equation Derived Sample Weight using Commercial Port Sampling and NEFSC Survey Data

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Introduction

Changes in weight at age have been observed for some, but not all, species in the New England groundfish complex. Weight at age can change due to changes in length at age, changes in the length-weight relationship, or both. An analysis was conducted using the commercial port sampling and NEFSC survey data to examine whether the length-weight relationship has been changing over time. Port samplers record an estimate of the total weight for the sample as well as the length frequency of all fish in that sample. Scientists on the survey record the total weight for each species at a station, measured with a scale, along with length frequency of all the fish in that sample. Applying the length-weight equation to each fish in the samples and summing these estimated weights produces an estimated weight for the samples, denoted here as the “equation” weight. The recorded and equation sample weights were compared for a number of species in order to see if there have been any consistent patterns over time in the difference between these values, which would imply a change in the length-weight relationship.

Methods

The alpha and beta parameters in the length-weight equation $W = \alpha L^{\beta}$ were collected for seven species (Table 1). For the survey data, combined sex parameters from Wigley et al. (2003) were used. For the commercial data, the parameters varied by season, either half-year or quarter, for three species (yellowtail flounder, winter flounder, and fluke) and there were two sets of parameters for witch flounder. For the survey data, parameters varied by season. The seven species were split into eleven stocks (Table 2) following the stock structure used in the most recent GARM (Mayo and Terceiro 2005). The two roundfish, cod and haddock, used conversion factors to relate port sampling landed weight to live weight (Table 3). Commercial length sample data were collected from the WOLEN (1984-1993) and CFLEN (1994-2006) databases by stock and market category within stock (Table 4a). All species had few samples in the mid-1990s and have increased since then. Survey bottom trawl data were collected from the UNION_FSCS_SVCAT and UNION_FSCS_SVLEN databases by stock and season for 1963-2006 (Table 4b).

For each sample *i*, the observed number of fish at each length was converted to a weight of fish using the appropriate length-weight equation and summed to produce the equation weight. Some obvious outliers were discovered in the commercial data and removed from the analysis (Table 5). Commercial recorded and equation weights were summed by year, ignoring the associated landings for each market category and time period. It is assumed that weighting the commercial samples by the landings for each market category and time period would not produce a significantly different pattern than that observed in the raw samples. Data for each survey (spring, fall, and winter) were treated separately, with recorded and equations weights summed for each year in each survey. Comparisons were made by plotting the relative difference (100*(Equation-Recorded)/Recorded) over time for each stock. Increasing trends in relative difference over time imply fish weigh less at length than they did earlier in the time series because the equation weights at length are constant for all years for each species.

Results and Discussion

The relative difference between equation and recorded sample weights by stock show mostly increasing trends over time for survey data but do not show strong trend over time for most stocks using commercial data, with the exception of fluke (Figure 1). There are four other stocks that exhibit some pattern over time using commercial data, the three yellowtail flounder stocks and Gulf of Maine winter flounder. The presence or absence of trends in either commercial or survey data do not appear related to GARM 2005 retrospective patterns (Table 6).

The commercial and survey data produce almost exactly opposite results with fluke the only stock showing a strong trend over time in the commercial data and also the only stock not showing a trend over time in the survey data. A number of hypotheses were explored to explain this difference. There were no correlations with changes in amount of fish sampled over time and trends in the relative difference for a stock in either the commercial or survey data. Trends in relative difference in the survey data were also examined by sex to see if changes in sex ratio may be causing the trends, but results for the two sexes were always similar. Since the commercial observed weights are estimated, there could be a pattern over time in these estimates. Although digit bias was obvious in frequency plots of the commercial recorded sample weights, there did not appear to be trends over time.

There are differences between the data sources that could cause the opposing results. Survey data are a measure of the population and are collected in a much more consistent manner, in terms of the time of year and gear used to catch the fish, than the commercial data. Commercial data are a measure of the exploited population which is landed and integrate over the entire year, multiple gears, and fishing areas. Thus, it is not necessarily a contradiction to have trends in the survey results but not in the commercial results. This can occur if biologically there are changes in the length-weight equation at the population level but the fishery exploits the resource in such a way that it is not observed in the landings. For example, changes in minimum size regulations and types of gear used to catch a given species may be large enough to prevent the commercial data from detecting true changes in the population length-weight relationship. Since the surveys are designed to sample from the entire geographic range of each stock, but the fishery will necessarily concentrate on areas of high abundance that are open to fishing, spatial differences that result in population length-weight relationship changes could be masked in the commercial data. For example, closed areas could provide a refuge for heavy or light fish and thus be detected in the survey data but not in the commercial data. However, many of the stocks which exhibit trends in the survey results do not have obvious closed areas that would provide such a refuge. Other possible causes for trends in the relative differences are year class effects and expansion or contraction of the age/size distribution of the stock over time, but these should appear in both survey and commercial data. Changes in length distribution over time are particularly susceptible to creating artificial trends in relative difference due to the non-linear relationship between length and weight.

Alternatively, there are aspects of the survey data that could make them susceptible to finding incorrect trends, although none appear to have occurred. For example, if changes in spawning timing occurred relative to the surveys, they could produce an apparent increase in weight at length for survey data that was not seen in the commercial data. Since both spring and fall surveys tended to show the same trends over time, spawning does not appear to be a likely cause of the trends in survey relative differences. There have also been some changes in the data collection during the surveys, including changing in 1992 from use of a beam balance to measure species weights to use of electronic scales with mechanics to counteract the rolling of the ship. The effect of this change can be seen in the plots as pre-1992 relative differences are generally more variable from year to year than post-1992 relative differences. It is not at all clear though how this change could cause the noticeable trends over time in the relative differences. The introduction of the Fisheries Scientific Computing System (FSCS) system in 2002 allowed better at sea auditing as data were collected, but again it is not clear how this could cause a trend in relative difference over time.

Many of the stocks do not appear to average zero relative difference over the time period examined for either the survey or commercial data. This could be due to just slightly biased estimates of the length-weight equation, as small changes in the parameters can have large effects on the relative differences. This is clearly seen comparing the Lux and Burnett length-weight equations for witch flounder in the commercial data where a 0.63% change in the beta parameter leads to an average of 9% change in relative difference. Also, the survey length-weight equations of Wigley et al (2003) were computed on a species basis, not a stock basis, so any differences in growth among stocks could cause the relative differences to depart from zero.

Since the commercial data did not detect trends in relative difference over time for most stocks, the use of constant length-weight relationships in the estimation of catch at age, for example using the BioStat program, is justified. Had trends been detected in the commercial data, this would imply that there are changes in the length-weight equation occurring in the exploited population that should be accounted for when converting the sampled fish to total catch.

The survey length-weight equations are only used as an auditing feature for individual fish weights in the FSCS system, they are not used in any calculations of survey stratified mean catches at age. Thus, changes in population length-weight could cause the FSCS auditing feature to alert users more often than it should, but the survey estimates of numbers at age are not impacted. The ability to detect changes in the population length-weight relationship is important because it could be an indication of environmental or ecosystem changes, as explored more fully in other working papers presented here at the GARM.

Conclusions

Results of this study imply changes in the length-weight relationship are occurring in the population, as seen in the survey data for most of the species examined, but are not occurring in the landed catch, as seen in the commercial data for most species.

References

Mayo, R.K.; Terceiro, M., editors. 2005. Assessment of 19 Northeast groundfish stocks through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August 2005. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 05-13; 499 p.

Wigley, S.E., H.M. McBride, and N.J. McHugh. 2003. Length-Weight Relationships for 74 Fish Species Collected during NEFSC Research Vessel Bottom Trawl Surveys, 1992-99. US Dep.Commer., NOAA Technical Memorandum NMFS-NE-171. (http://www.nefsc.noaa.gov/nefsc/publications/tm/tm171/)

Table 1. Parameters for the length-weight relationship ($W = \alpha L^{\beta}$) for seven species by time period or source (commercial), and season (survey).

Commercial data:

Species	Period	LW alpha	LW beta
Yellowtail Flounder	half 1	0.0000019143	3.451000
(all 3)	half 2	0.0000112980	2.937000
Witch	Lux	0.0000013000	3.450000
	Burnett	0.0000013000	3.428400
Winter Flounder	half 1	0.0000099700	3.055236
(GOM and SNE)	half 2	0.0000092500	3.095188
Fluke	qtr1	0.0000026100	3.353000
	qtr2	0.0000029280	3.324000
	qtr3	0.0000028110	3.342000
	qtr4	0.0000068520	3.110000
Cod (GOM and GB)	All	0.0000081044	3.052000
Haddock	All	0.0000071186	3.080540
Plaice	All	0.0000024548	3.345000

Survey data:

Species	Season	LW alpha	LW beta
Yellowtail Flounder	Spring	0.0000042948	3.209900
	Fall	0.0000072240	3.055900
	Winter	0.0000040334	3.240800
Witch	Spring	0.0000018229	3.328900
	Fall	0.0000029509	3.199700
	Winter	0.0000018229	3.328900
Winter Flounder	Spring	0.0000104198	3.043100
	Fall	0.0000088455	3.109100
	Winter	0.0000083839	3.118900
Fluke	Spring	0.0000053287	3.165100
	Fall	0.0000046247	3.215600
	Winter	0.0000041762	3.230500
Cod	Spring	0.0000076539	3.060600
	Fall	0.0000061936	3.126200
	Winter	0.0000077509	3.052700
Haddock	Spring	0.0000074582	3.076600
	Fall	0.0000074217	3.088800
	Winter	0.0000074582	3.076600
Plaice	Spring	0.0000027287	3.312500
	Fall	0.0000029046	3.306200
	Winter	0.0000029046	3.306200

Table 2 *a*. The commercial statistical areas associated with each stock.

Stock	Areas
YT GB	'522','525','550','551','552','560','561','562'
YT SNEMA	'526','537','538','539','611','612','613','614','615','616','617','618','619','620','621','622','623'
YT CCGOM	'511','512','513','514','515','521'
Witch Flounder	All
Winter GOM	'510','511','512','513','514','515','516','517','518','519','520'
Winter SNE	521','526','537','538','539','611','612','613','614','615','616','617','618','619','620','621','622','623','624',
	'625','626','627','628','629','630','631','632','633','634','635','636','637','638','639'
Fluke	All
Cod GOM	'511','512','513','514','515'
Cod GB	'521','522','525','526','537','538','539','550','551','552','560','561','562'
Haddock GB	'521','522','525','526','537','538','539','550','551','552','560','561','562'
Plaice	'511','512','513','514','515','521','522','525','526','551','552','561','562'

Table 2 *b*. The survey strata sets associated with each stock.

Stock	Survey strata
YT GB	Offshore 13-21
YT SNEMA	Offshore 1-2,5-6, 9-10, 69, 73-74
YT CCGOM	Offshore 25-27, 39-40, Inshore 56-66
Witch Flounder	Offshore 22-30, 36-40
Winter GOM	Offshore 26-27, 38-40, Inshore 58-61, 65-66
Winter SNE	Offshore 1-12, 25, 69-76, Inshore 1-29, 45-56
Fluke	Offshore 1-18, 61-76, Inshore 1-61
Cod GOM	Offshore 26-30, 36-40
Cod GB	Offshore 13-25
Haddock GB	Offshore 13-25, 29-30
Plaice	Offshore 13-30, 36-40

Table 3. Conversion factors for port sampling landed weight to live weight, all other species and market categories set to 1.0.

Species	Conversions
Cod	1.17 for whale, large, market, scrod, unclassified, and snapper cod
Cod	1.60 for steaker cod
Haddock	1.14 for large, extra large, medium, scrod, snapper, and unclassified haddock

Table 4 *a*. Number of commercial samples used in analyses by year and stock.

Year	YT GB	YT SNEMA	YT CCGOM	Witch	Winter GOM	Winter SNE	Fluke	Cod GOM	Cod GB	Haddock GB	Plaice
1984	10	70	7	51	17	34	76	52	56	17	79
1985	40	65	17	65	15	56	68	67	99	32	97
1986	27	48	10	64	17	48	84	47	91	25	101
1987	24	37	12	47	8	53	72	41	78	33	76
1988	24	32	13	65	15	45	94	33	77	33	96
1989	22	35	10	35	6	38	83	32	68	22	54
1990	24	33	13	37	13	41	40	38	82	27	76
1991	17	32	14	41	14	34	48	55	92	14	61
1992	16	29	11	30	10	46	42	51	77	32	47
1993	21	13	6	30	8	24	33	23	82	17	31
1994	0	1	0	38	1	0	48	4	13	8	4
1995	3	1	7	26	6	18	35	14	15	3	5
1996	11	13	13	42	17	24	60	71	55	6	44
1997	21	33	23	53	21	46	96	78	80	28	65
1998	14	12	12	22	19	37	100	46	80	25	53
1999	17	15	8	42	8	43	133	14	69	28	94
2000	26	16	61	116	88	70	120	62	147	51	108
2001	35	21	24	43	14	57	115	107	108	72	57
2002	30	27	39	37	29	63	91	137	87	47	45
2003	62	11	63	101	52	51	124	248	97	66	86
2004	83	5	34	112	38	61	199	198	127	73	83
2005	86	7	45	120	50	54	240	341	96	96	75
2006	95	35	46	148	34	91	222	309	174	129	64

Table 4 *b*. Number of survey samples (tows) used in analyses by year and stock.

Year	YT GB	YT SNEMA	YT CCGOM	Witch Flounder	Winter GOM	Winter SNE	Fluke	Cod GOM	Cod GB	Haddock GB	Plaice
1963	54	35	14	74	13	28	9	48	45	112	127
1964	75	58	16	107	15	59	18	84	85	184	170
1965	67	54	11	90	14	49	8	64	100	183	175
1966	44	49	10	77	7	34	5	49	64	112	130
1967	27	43	4	33	2	37	14	26	41	58	63
1968	46	75	6	75	11	49	30	57	68	87	126
1969	85	107	8	122	12	71	26	71	106	111	180
1970	55	86	14	87	14	46	12	52	74	69	123
1971	49	78	9	78	12	51	25	52	71	61	124
1972	72	76	14	89	15	79	77	66	122	112	140
1973	50	76	10	81	10	158	271	55	92	65	109
1974	45	40	12	81	11	97	175	50	68	57	103
1975	47	38	12	65	6	64	165	65	76	70	129
1976	53	47	24	76	15	95	171	66	77	77	124
1977	66	67	42	138	38	179	225	122	146	117	224
1978	92	95	28	189	34	227	167	137	166	192	269
1979	97	105	61	151	50	193	145	140	187	205	268
1980	87	124	51	107	45	202	164	93	115	132	162
1981	62	122	41	82	33	204	209	60	116	117	137
1982	46	62	34	54	30	113	160	50	78	68	108
1983	50	60	37	71	34	107	140	57	64	79	120
1984	33	50	22	80	34	102	118	48	73	63	105
1985	38	42	28	73	34	110	144	54	79	78	114
1986	31	39	28	67	32	89	132	52	69	48	96
1987	20	28	27	38	26	70	117	35	67	44	93
1988	22	38	31	53	31	89	94	51	67	50	102
1989	37	57	16	43	25	79	71	62	76	64	97
1990	36	52	33	39	30	79	88	51	75	52	112
1991	30	48	31	60	29	88	114	42	69	43	106
1992	54	57	33	44	26	114	193	43	72	58	119
1993	33	47	33	79	43	94	189	57	58	61	152
1994	51	47	37	70	39	105	194	54	48	40	141
1995	49	66	38	92	47	129	213	52	66	48	170
1996	44	61	35	64	33	108	219	44	58	56	118
1997	54	75	32	67	35	109	233	42	61	69	132
1998	60	77	37	93	41	135	240	46	72	86	163
1999	63	61	38	77	40	126	271	45	70	66	145
2000	48	58	35	82	36	117	267	42	53	51	121
2001	58	62	33	92	39	116	281	39	64	92	127
2002	44	65	34	93	35	126	304	46	53	76	119
2003	44	35	28	82	27	101	231	37	44	85	117
2004	42	43	23	82	29	103	266	34	59	99	115
2005	43	55	31	76	32	100	212	34	52	100	114
2006	59	75	36	80	39	114	269	47	54	92	140

Table 5. Outliers removed or changed in database prior to analyses.

Stock	Samples Removed/Changed
YT GB	wgtsamp 6192 to 92
YT SNEMA	deleted one sample with wgtsamp = 963
YT CCGOM	none
Witch Flounder	4 samples deleted, wgtsamp = 1349, 1007, 890, 7
Winter GOM	2 samples deleted, wgtsamp = 1155, 400
Winter SNE	none
Fluke	3 samples deleted, wgtsamp = 1080, 800, 486
Cod GOM	nespp4 = 0189 (cod sperm) and 0182 (cod cheeks) deleted
Cod GB	nespp4 = 0189 (cod sperm) and 0182 (cod cheeks) deleted, changed length = 488 to 48,
Haddock GB	none
Plaice	3 sampled deleted, wgtsamp = 2815, 1038, 815

Table 6. Comparison of trends in sample weight relative to weights computed using a fixed length-weight equation for both commercial and survey data, along with retrospective patterns from GARM 2005 for each stock.

	Trend in Sample Weight vs L-W		GARM2005
Stock	Commercial	Survey	Retro?
YT GB	Yes	Yes	Yes
YT SNEMA	Yes	Yes	No
YT CCGOM	Yes	Yes	No
Witch	No	Yes	Yes
Winter GOM	Yes	Yes	Yes
Winter SNE	No	Yes	Yes
Fluke	Yes	No	Yes
Cod GOM	No	Mixed	No
Cod GB	No	Mixed	No
Haddock GB	No	Yes	No
Plaice	No	Yes	No

Figure 1. Relative difference between observed and predicted sample weights for each stock over time, for Survey Spring, Fall and Winter, and for Commercial samples

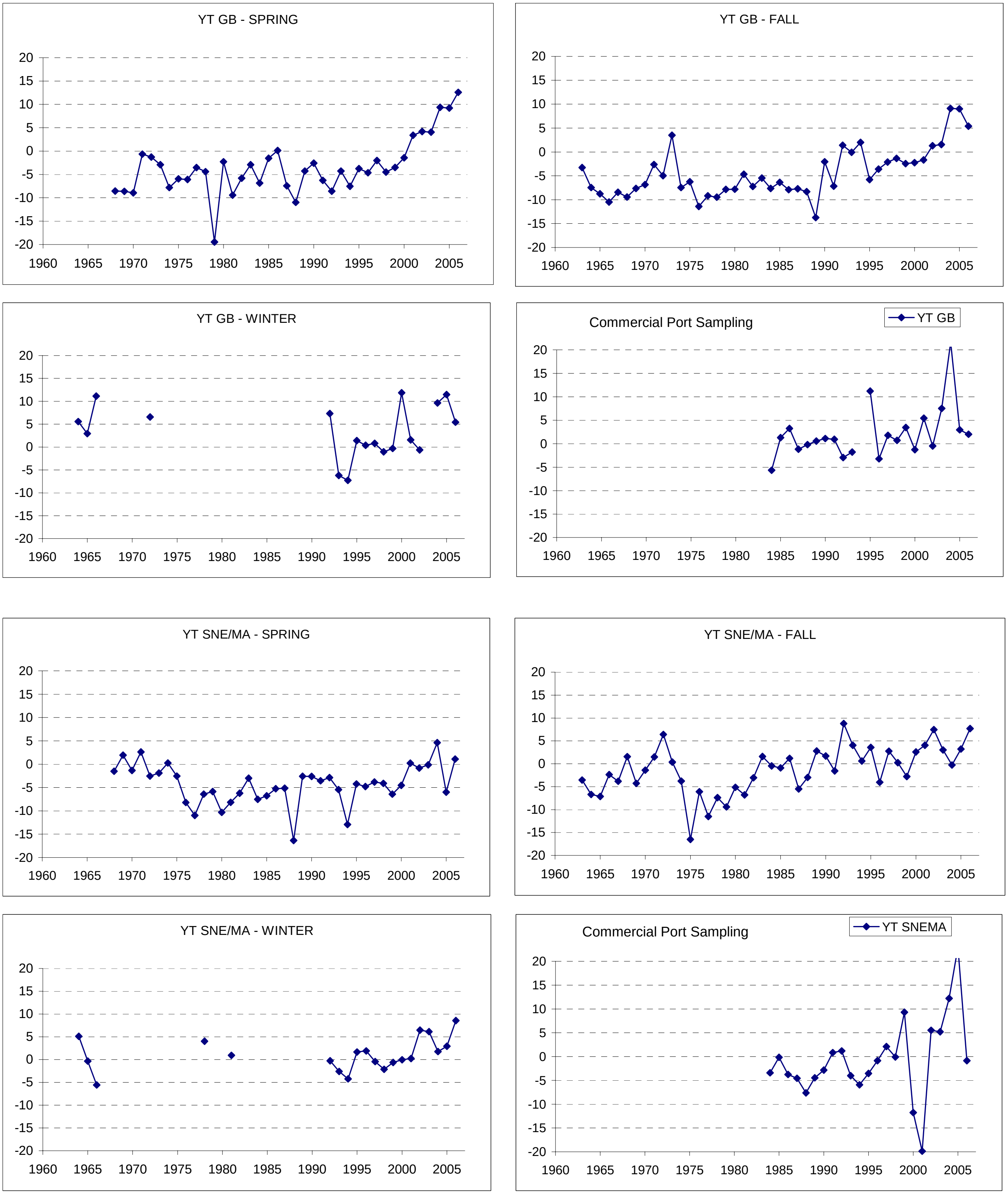
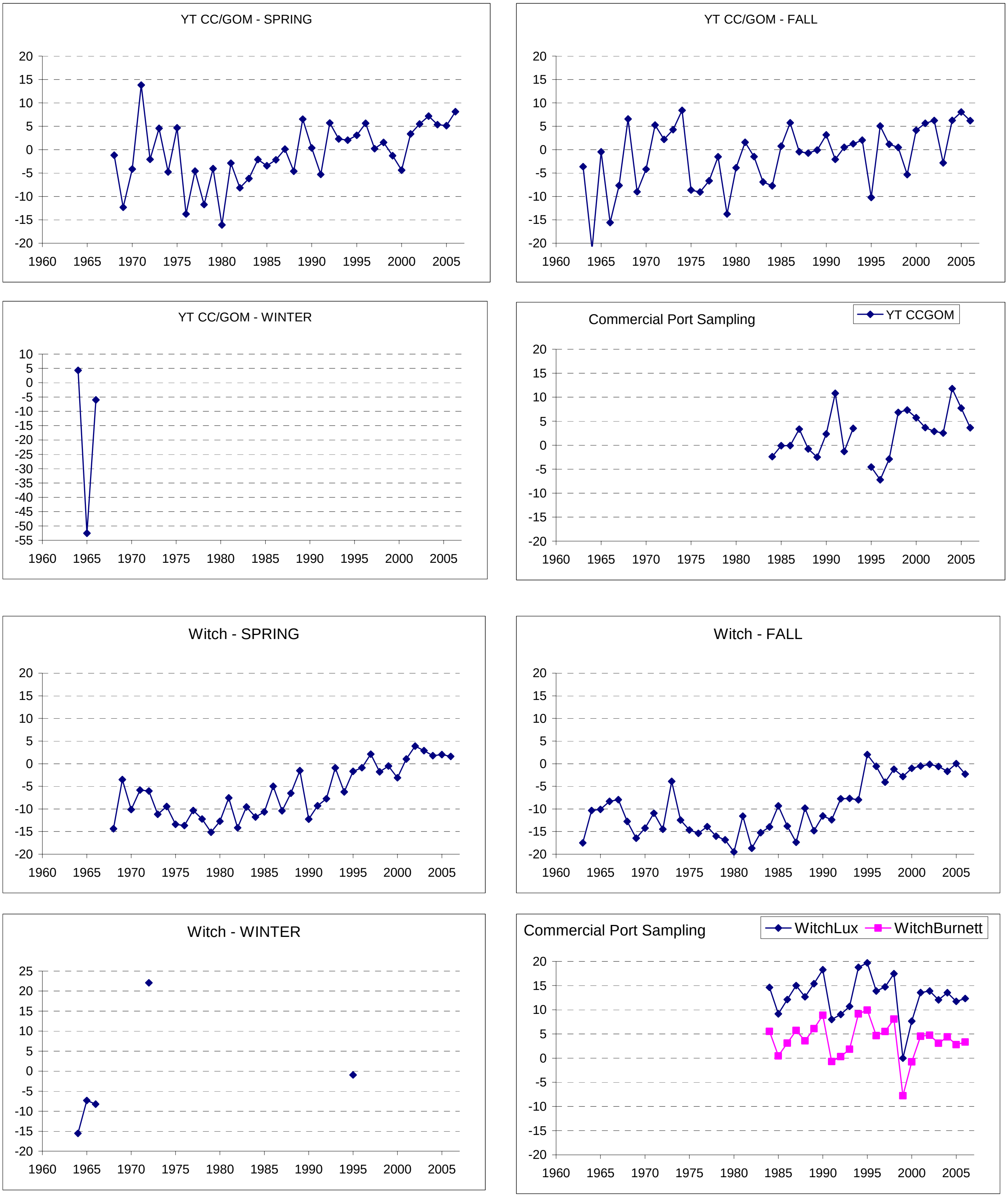


Figure 1 *continued*



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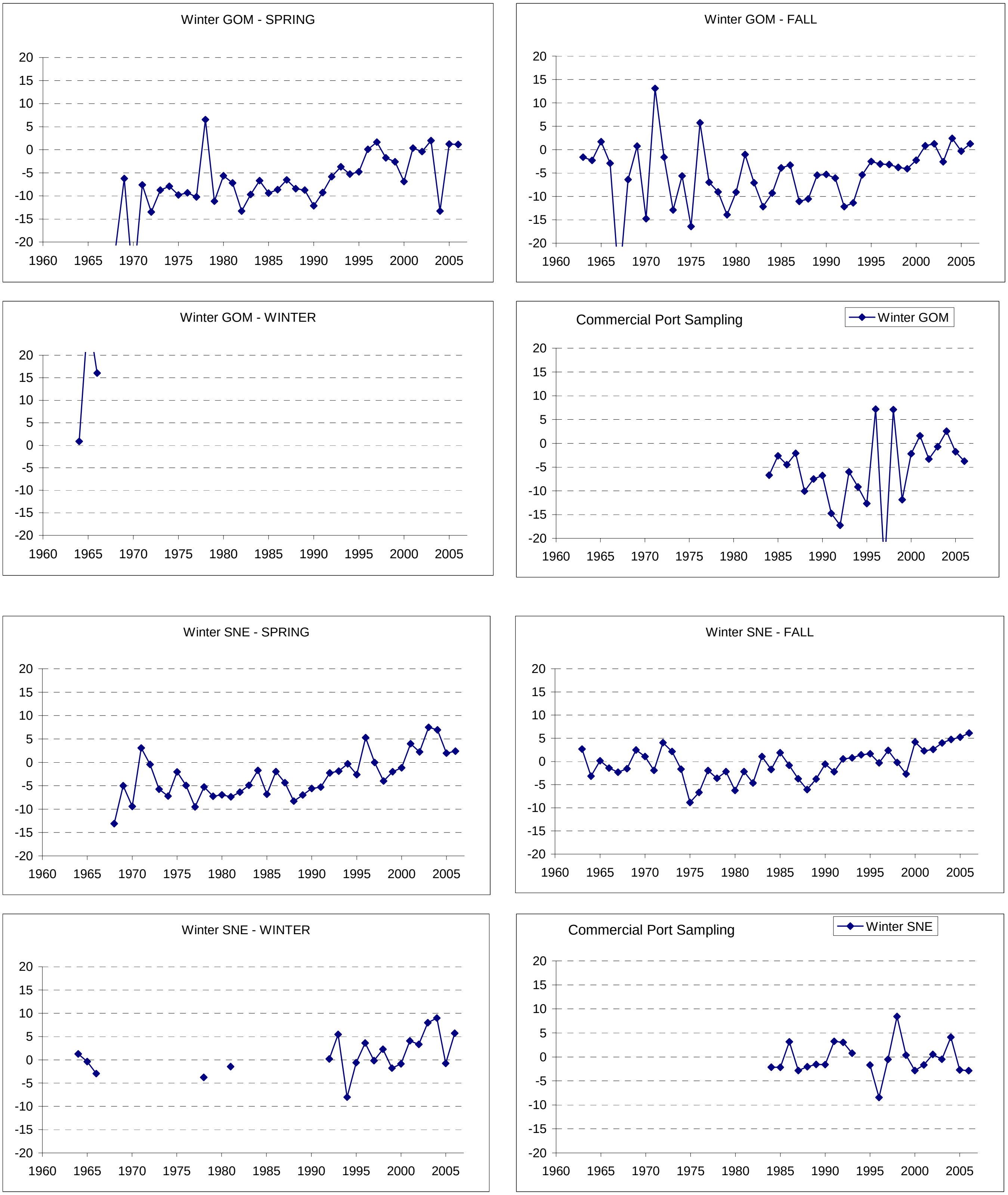

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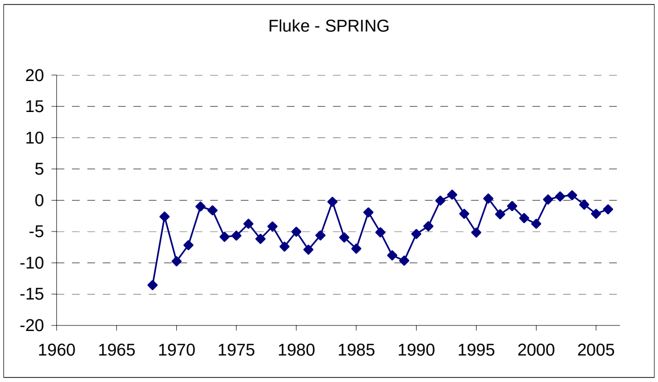

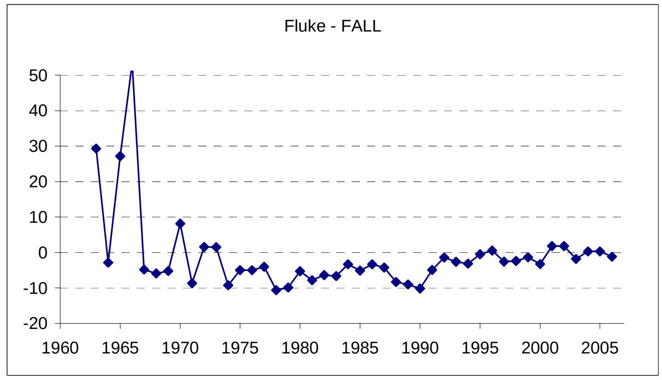

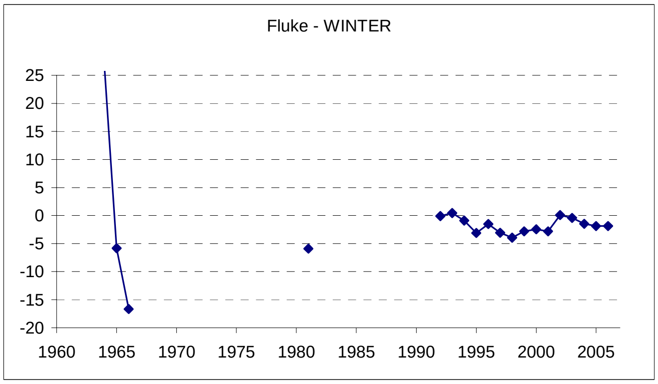

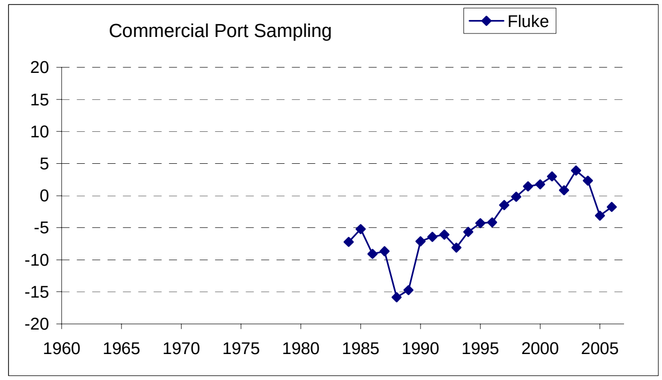

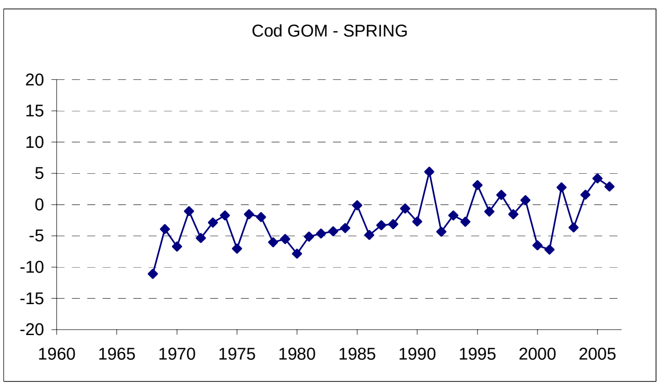

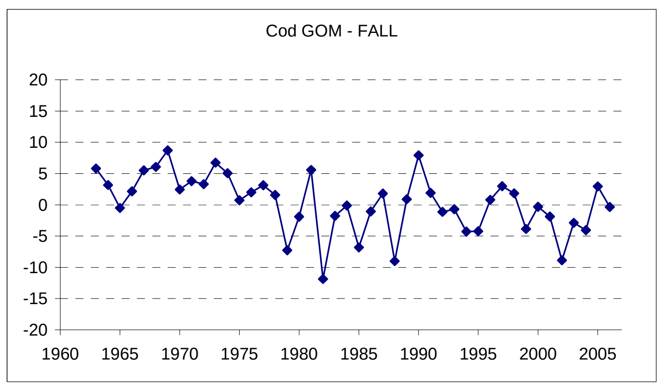

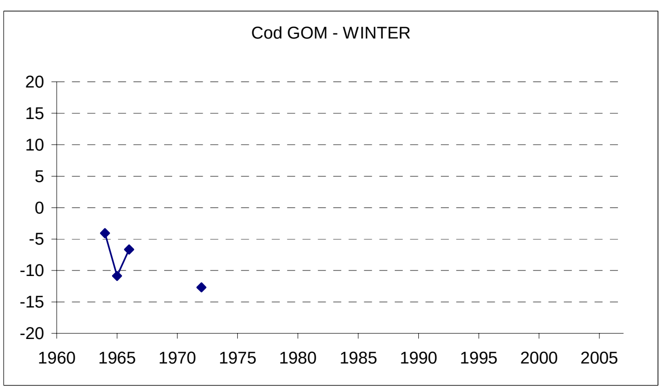

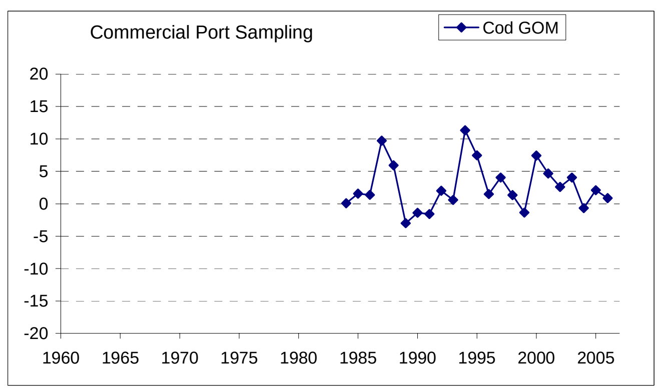

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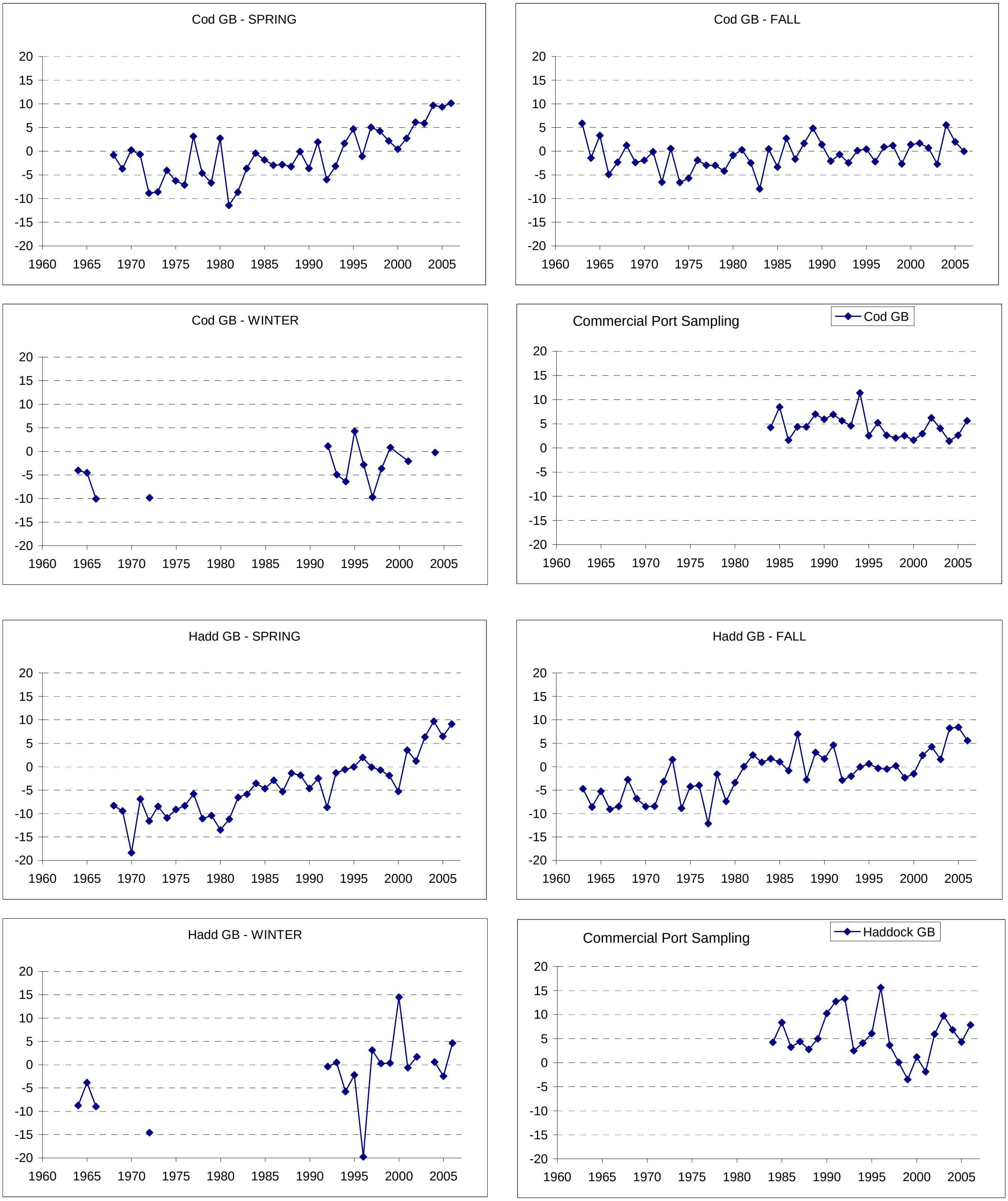

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