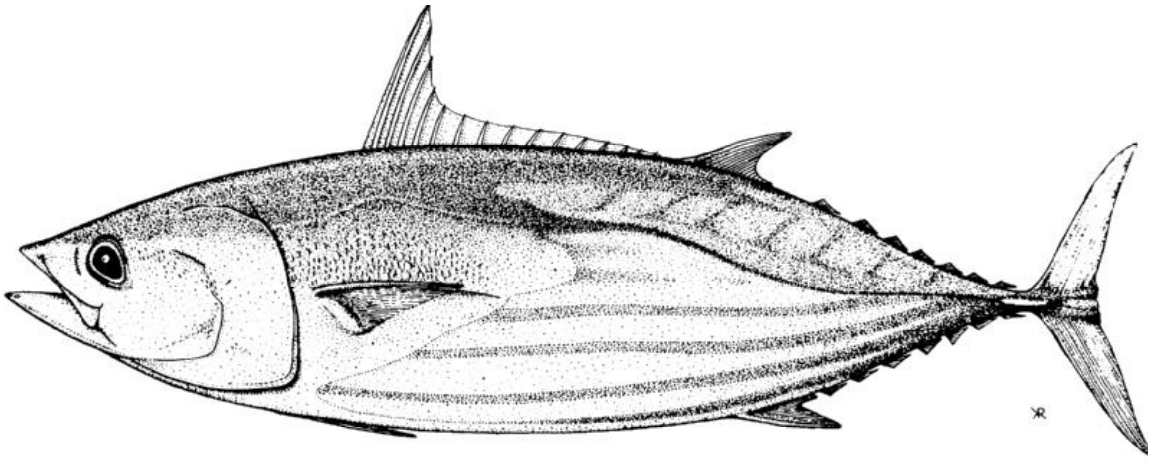
SCTB15 Working Paper

MWG - 6

Application of an ADAPT VPA model to the simulated population data



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Background

Participants in the SCTB Methods Working Group received a data set of a simulated population for testing purposes. An ADAPT VPA model (version 1.5) was fit to the simulated population data to illustrate the performance of the stock assessment model. The ADAPT model exists within assessment programs in the Fishery Assessment Compilation Toolbox (FACT) and is the Woods Hole Assessment Toolbox's successor.

The ADAPT tuned-VPA model was applied to conduct age-structured analyses of the test population using derived input data for: 1) catch (numbers) at age, 2) mean weights by age and year corresponding to the catch, 3) abundance (number) indices with each index representing an age group, 4) natural mortality and 5) catchability. For calculation of the spawning stock biomass (SSB) three additional data types are required: 1) mean weights by age and year corresponding to the spawning stock, 2) maturity ogive by age and year and 3) the fraction of the mortality that occurs prior to spawning.

Methods

Catch-at-age

The ADAPT model requires the number of fish by age class, thus an age/length probability matrix was developed to allocate proportions of a fish at a particular length to various age classes. The approximate upper and lower bounds of length-at-age (FL in cm, age in quarters) were given in the test data. A matrix was estimated by assuming that the: 1) lengths of the fish in each age-class were normally distributed around the midpoint between the upper and lower bounds, and 2) bounds for each age-class contained ~100% of the lengths (midpoint ±4 standard deviations). The probability of length-at-age is illustrated in Figure 1.

Catch in numbers-at-age for each quarter was estimated by decomposing the length frequency samples into age classes and multiplying the proportions by the reported catch. Mean weight-at-age for each quarter was calculated from the relationship given for weight and fork length ($W = 0.00001759L^3$). Rivard weighting was used to calculate the mean weight at age (kg, January 1) for the population.

Temporal stratification of model inputs

The ADAPT model was initially fit to quarterly catch data and 20 quarterly age classes with the last age class including a plus group. The model with a quarterly formulation fit the data very poorly and the trend in stock biomass was negatively correlated with all abundance indices. Given the clear lack of fit the model was not considered reliable. The

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[1] A working document submitted to the 15th Meeting of the Standing Committee on Tuna and Billfish, Honolulu, Hawaii, 22-27 July 2002.

poor performance was probably related to the specification of annual cohorts by the ADAPT model version 1.5. The quarterly data were further aggregated into annual catches and five yearly age classes to accommodate the ADAPT annual stratification.

Abundance (tuning) indices

The VPA was calibrated using five catch rate indices (ages 0–4^+). The indices were calculated as age specific CPUE (numbers at age per unit of effort) and normalized ln(index/mean) prior to tuning. Abundance indices indicate an overall stable trend for all ages with greater interannual variability for age classes 0 and 1 (Figure 2). Age classes 2-4^+ had similar trends with high abundance at the start of the time-series, poor abundance in the late 1960s and the early 1980s with a return to average values in the 1990s.

Assumptions

- Natural Mortality is 0.3 for all age classes and constant over time.
- Catchability is constant over time.
- Maturity ogive for age 0 through 4^+ were: 12.5%, 87.5%, 100%, 100% and 100%, where values are the annual average given in the test data. These values of fraction mature at age were used in age-structured population modeling to provide an index of spawning stock biomass (SSB) through time.

ADAPT VPA model results

Indicators of model fit and precision of estimates

The ADAPT model with iterative re-weighting resulted in a mean square residual of 0.00529. Estimated parameter values and associated statistics are given in Table 1. Estimates of stock size for the terminal year (1998) were more precise for ages 1–4^+ with CVs ranging from 0.11 to 0.14 than for age 0 (0.17). The tuning indices contribute to the overall variance in the model and the amount of variance attributable to a particular index was larger for age 0 (0.26) than older age indices (~0.18) as indicated by its partial variance. After re-weighting, the indices contributed equally (0.2) to the overall variance.

The residual patterns of the age-specific indices showed a non-random trend for all indices (Figure 3). Predicted values were greater than observed values in the initial half of the time-series, but less than observed values in the latter half of the time-series. The non-random trend in residuals requires further investigation.

A non-parametric bootstrap procedure was used to evaluate the uncertainty associated with the estimates of stock size, fishing mortality and SSB (Table 2). One thousand bootstrap iterations were performed to estimate the bias in 1998 estimates. The median estimates of the bootstrap analysis were very similar to the non-linear least squares (NLLS) estimates. The distribution of the F estimates in the terminal year ranged from 0.34 for age 0 to 0.50 for age 1. The SSB was well estimated and slightly higher (380,428 mt) than the NLLS estimate (375,541).

Assessment results

The final ADAPT results for stock size, F, mean and SSB at age are summarized in Table 3. Trends for the mean biomass of the stock and SSB are illustrated in Figure 4.

Values in bold in Table 2 indicate the requested values of mean biomass, SSB and fishing mortality for comparison between models.

Future work

Additional work in testing the ADAPT model with simulated population could include:

- changing the structural assumption of annual cohorts to quarterly in order to retain the temporal resolution of the test data,
- further investigation of the non-random trend in residuals, and
- assessing the influence of the assumption of constant catchability over time.

Table 1. Estimated parameter values and associated SE, T-Statistic and CV's from ADAPT.

Parameter	Estimate	SE	T-statistic	CV
Number age 0	3.03E+04	5.08E+03	5.97E+00	0.17
Number age 1	1.56E+04	2.13E+03	7.33E+00	0.14
Number age 2	6.65E+03	9.06E+02	7.33E+00	0.14
Number age 3	2.58E+03	3.62E+02	7.14E+00	0.14
Number age 4+	1.38E+03	1.50E+02	9.22E+00	0.11
q (index age 0)	2.65E-05	7.26E-07	3.66E+01	0.03
q (index age 1)	5.74E-05	1.56E-06	3.68E+01	0.03
q (index age 2)	1.72E-04	4.68E-06	3.67E+01	0.03
q (index age 3)	4.64E-04	1.27E-05	3.65E+01	0.03
q (index age 4+)	5.35E-04	1.49E-05	3.60E+01	0.03

Table 2. Precision estimates for abundance and fishing mortality at age, and spawning stock biomass from 1,000 bootstrap iterations.

Parameter	Point Estimate	Bootstrap Mean	Percent Bias	80% Confidence Interval	
				Lower Bound	Upper Bound
Number age 0	30300	30700	1.32	25702	40618
Number age 1	15600	15724	0.81	13424	18846
Number age 2	6650	6753	1.60	5609	7835
Number age 3	2580	2615	1.35	2164	3082
Number age 4+	1380	1387	0.28	1211	1587
F age 0	0.35	0.34	0.602	0.29	0.39
F age 1	0.51	0.50	-0.186	0.44	0.57
F age 2	0.54	0.53	0.097	0.46	0.61
F age 3	0.40	0.40	0.500	0.36	0.45
F age 4+	0.40	0.40	0.500	0.36	0.45
SSB mt	375541	380428	1.2	350681	403254

Table 3. Estimates of beginning year stock size (1,000x), fishing mortality, mean and spawning stock biomass (mt) based on an ADAPT VPA from 1962 to 1998.

Stock numbers (1,000x)

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	33855	39556	52783	31135	20980	32064	55512	32326	33004	65439	52076	50877	38250	48982	44508	33801	37519	31405	36589
1	21903	15014	18764	24151	14144	9536	16608	25028	14816	18681	28829	26514	20903	19188	21679	18516	14874	17369	13458
2	8753	6344	5014	7289	7142	3776	3864	6511	7362	5271	8403	8052	9083	6252	6405	6528	5499	5259	4727
3	3587	2807	2062	2121	2742	1947	1502	1704	2670	2605	2216	3294	2849	2831	2167	2354	2254	1948	1724
4+	3330	2577	2009	1780	2168	2062	1535	1352	2004	2571	1767	2612	2374	2698	2015	1907	1849	1784	1478
Total	71428	66298	80632	66476	47176	49385	79021	66920	59856	94568	93292	91349	73459	79951	76773	63106	61996	57765	57977

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
0	61737	25102	29386	57922	30703	21579	29278	42978	27443	20161	20898	31722	34950	33523	38778	40830	31970	29393
1	16644	22123	10756	15575	25843	11968	11452	14461	17399	12379	8094	10895	15533	18073	15739	18963	18733	14791
2	3721	5545	5287	4074	5873	5973	4602	4246	4916	4672	3479	3130	4876	5223	6893	5796	6990	5925
3	1299	1336	1945	1881	1607	2019	2250	1679	1514	1736	1413	1327	1504	2050	2162	2427	2404	2773
4+	1189	1027	1339	1797	1332	1402	2114	1567	1215	1377	1309	1276	1306	1708	1772	2248	2084	2438
Total	84591	55133	48712	81249	65357	42941	49695	64930	52485	40325	35192	48350	58170	60577	65345	70264	62182	55320

Fishing mortality

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	0.51	0.45	0.48	0.49	0.49	0.36	0.5	0.48	0.27	0.52	0.38	0.59	0.39	0.52	0.58	0.52	0.47	0.55	0.49
1	0.94	0.8	0.65	0.92	1.02	0.6	0.64	0.92	0.73	0.5	0.98	0.77	0.91	0.8	0.9	0.91	0.74	1	0.99
2	0.84	0.82	0.56	0.68	1	0.62	0.52	0.59	0.74	0.57	0.64	0.74	0.87	0.76	0.7	0.76	0.74	0.82	0.99
3	0.87	0.86	0.57	0.7	1.05	0.64	0.53	0.61	0.76	0.58	0.65	0.76	0.9	0.79	0.72	0.79	0.76	0.85	1.04
4+	0.87	0.86	0.57	0.7	1.05	0.64	0.53	0.61	0.76	0.58	0.65	0.76	0.9	0.79	0.72	0.79	0.76	0.85	1.04

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
0	0.73	0.55	0.33	0.51	0.64	0.33	0.41	0.6	0.5	0.61	0.35	0.41	0.36	0.46	0.42	0.48	0.47	0.35
1	0.8	1.13	0.67	0.68	1.16	0.66	0.69	0.78	1.01	0.97	0.65	0.5	0.79	0.66	0.7	0.7	0.85	0.51
2	0.72	0.75	0.73	0.63	0.77	0.68	0.71	0.73	0.74	0.9	0.66	0.43	0.57	0.58	0.74	0.58	0.62	0.54
3	0.75	0.77	0.76	0.65	0.79	0.7	0.73	0.76	0.77	0.93	0.68	0.44	0.58	0.6	0.77	0.59	0.64	0.4
4+	0.75	0.77	0.76	0.65	0.79	0.7	0.73	0.76	0.77	0.93	0.68	0.44	0.58	0.6	0.77	0.59	0.64	0.4

Table 3 continued. Estimates of beginning year stock size (1,000x), fishing mortality, mean and spawning stock biomass (mt) based on an ADAPT VPA from 1962 to 1998.

Mean biomass (mt)

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	130457	146090	180904	123387	76488	112775	171820	131298	122563	219730	168133	213976	129593	167143	163889	120359	130819	110978	125339
1	248366	181725	220139	272101	160629	121432	202502	273439	187954	231059	318632	299387	251265	216579	236928	209082	177657	186125	146716
2	172484	126872	110862	150265	132190	82964	86488	138400	151293	118404	175337	166256	174462	128813	132128	131834	113470	103879	87611
3	87251	68749	57389	54888	61509	53124	42774	45585	66806	72153	58100	82932	67736	71652	55921	58721	57046	47947	38985
4+	94616	73347	64828	53854	56012	65341	51376	42490	57821	82778	54522	75769	65910	79306	61657	55192	53861	51219	39197
Total	733174	596782	634121	654495	486828	435636	554960	631211	586436	724123	774723	838321	688967	663493	650523	575188	532853	500149	437846

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
0	191071	92762	102683	192778	118124	91110	111959	137472	98960	72721	77400	119257	102875	141126	128801	147762	128604	111771
1	182260	225953	140131	182544	251082	157079	140393	165423	187298	135813	103498	140073	185410	210053	207125	226742	215636	203207
2	76208	109808	109390	88117	116125	126091	97171	87774	99012	89617	74082	73884	105969	115592	139611	127665	148873	132094
3	33482	33259	48702	50807	39973	51668	58426	42921	38127	41050	37410	39388	41325	55500	54104	66660	64144	82340
4+	35939	30379	38403	55779	39086	41574	63175	47275	35620	37222	40389	44548	42209	54144	52167	71603	64883	84223
Total	518960	492161	439308	570025	564390	467522	471124	480864	459017	376423	332779	417150	477788	576416	581807	640432	622140	613634

Spawning stock biomass (mt)

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	9028	10210	11853	8498	5197	7399	10890	9163	8257	14355	10721	15449	8454	11223	11376	8171	8695	7519	8543
1	174489	88185	108021	124909	77364	57852	93454	121392	92024	109644	145572	134293	126919	99314	111422	101530	84569	86569	69501
2	160782	102009	89857	117495	105599	67505	69213	110363	119547	96098	136747	133178	136827	105811	104048	104073	90811	82978	69466
3	81344	64074	53440	51423	56834	49146	39927	42681	61979	67011	55078	76718	63652	66211	52548	54706	53195	44785	36210
4+	98663	76496	67594	56202	58215	68171	53536	44319	60340	86316	56889	79070	68702	82754	64347	57590	56207	53423	40748
Total	524307	340974	330765	358527	303209	250073	267020	327917	342147	373424	405007	438708	404555	365313	343740	326069	293477	275273	224469

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
0	12654	6270	6753	12851	8317	6414	7767	8984	6695	4996	5212	8029	6289	9858	8301	9969	8984	6959
1	87136	104065	66381	84538	116487	77427	69617	80642	85432	64293	49787	66259	87699	90354	101557	102703	102030	99433
2	61184	86119	86851	71957	91521	98440	79073	69970	78488	71668	59062	59269	83838	92460	108544	105521	118177	105580
3	31129	31162	45104	47236	37582	48104	54353	40309	35792	37951	34720	36414	38689	51527	51052	61608	60019	76038
4+	37506	31701	40076	58198	40784	43386	65931	49336	37171	38780	42148	46341	44014	56469	54438	74675	67695	87531
Total	229610	259318	245165	274780	294692	273771	276741	249241	243578	217687	190929	216312	260529	300668	323892	354476	356905	375541

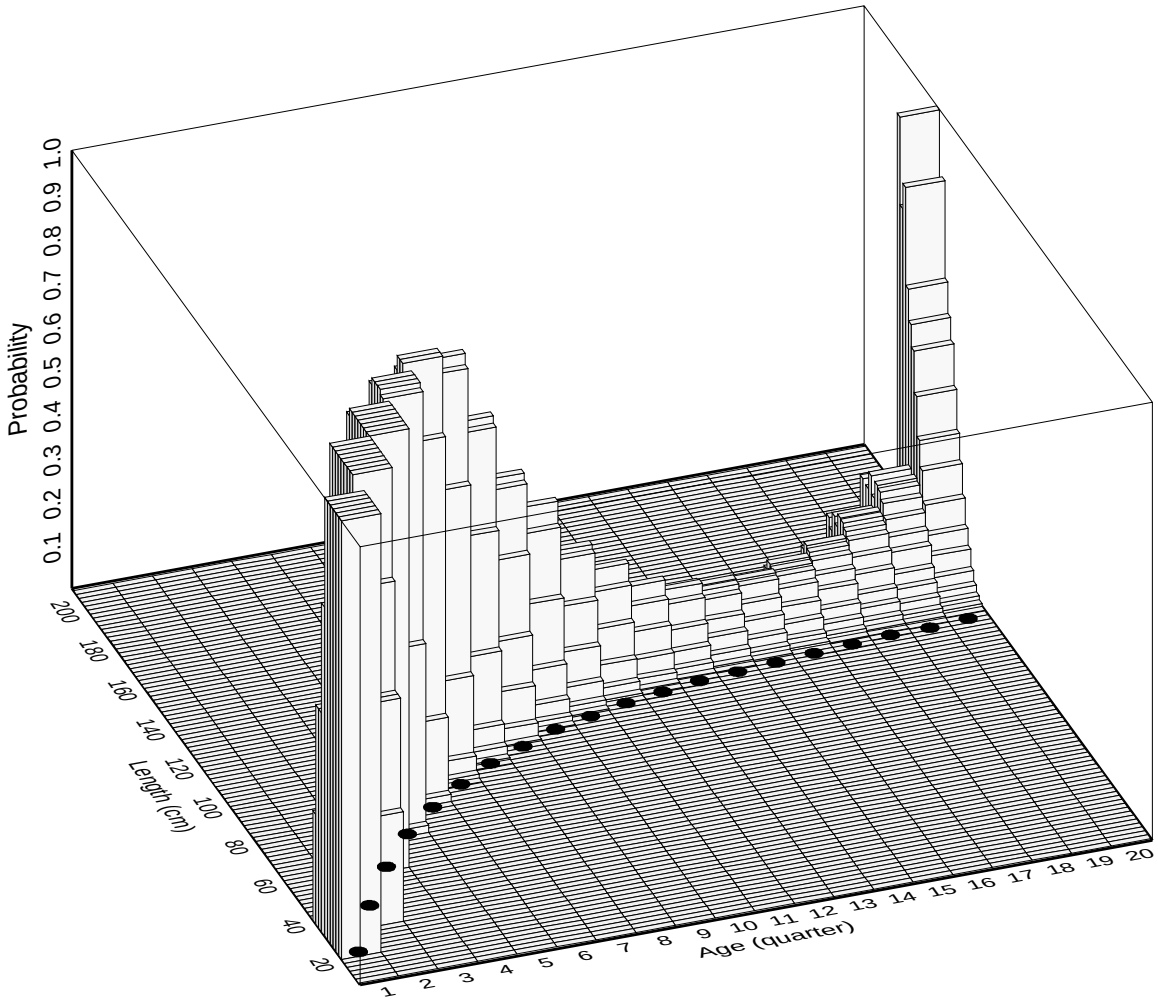

Figure 1. Probability of age-at-length for fish size in the simulated population. Circles indicate lower bound of length-at-age.

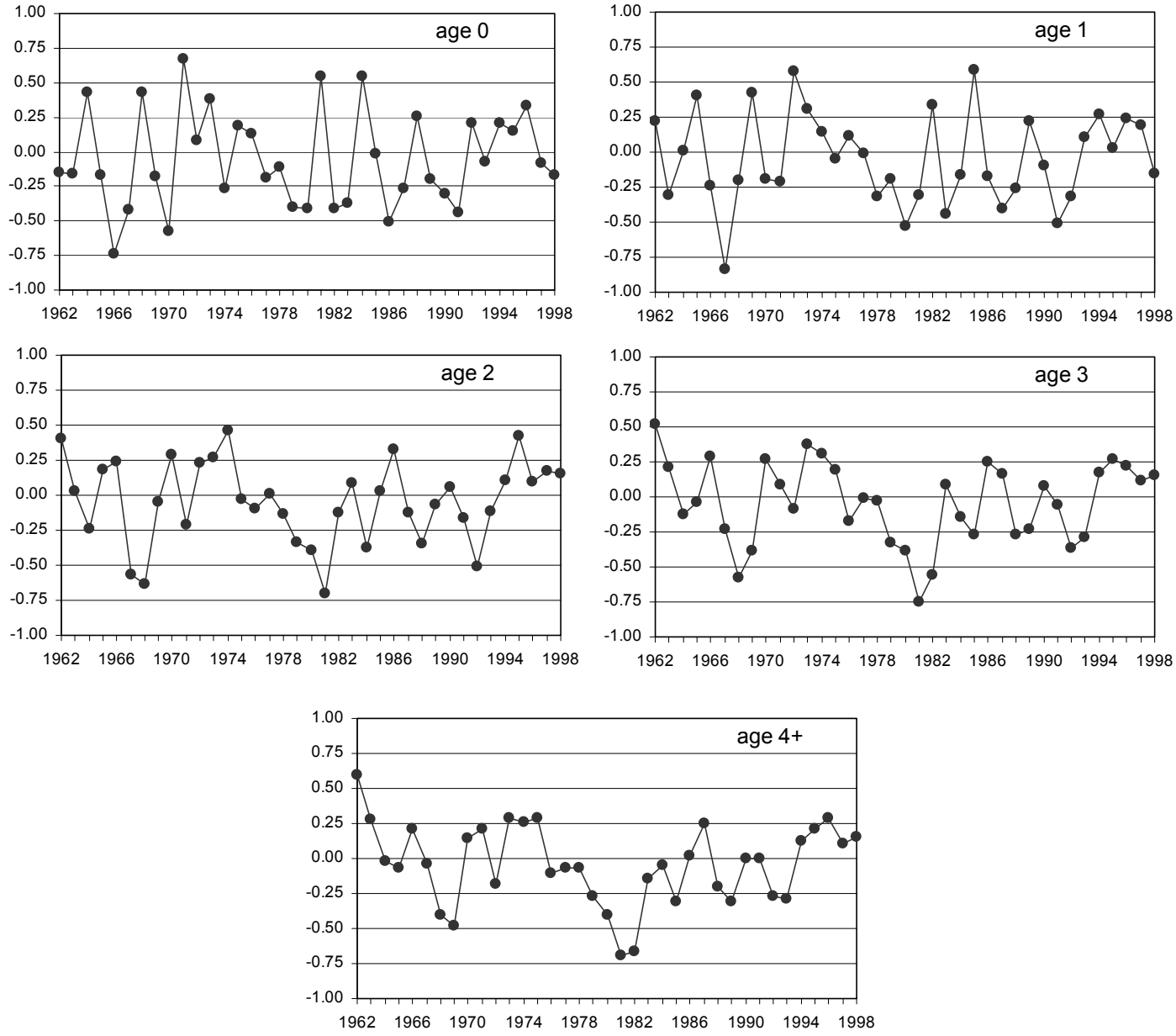

Figure 2. Scaled observed indices (ln(index/mean)) for ages 0–4^{+}.

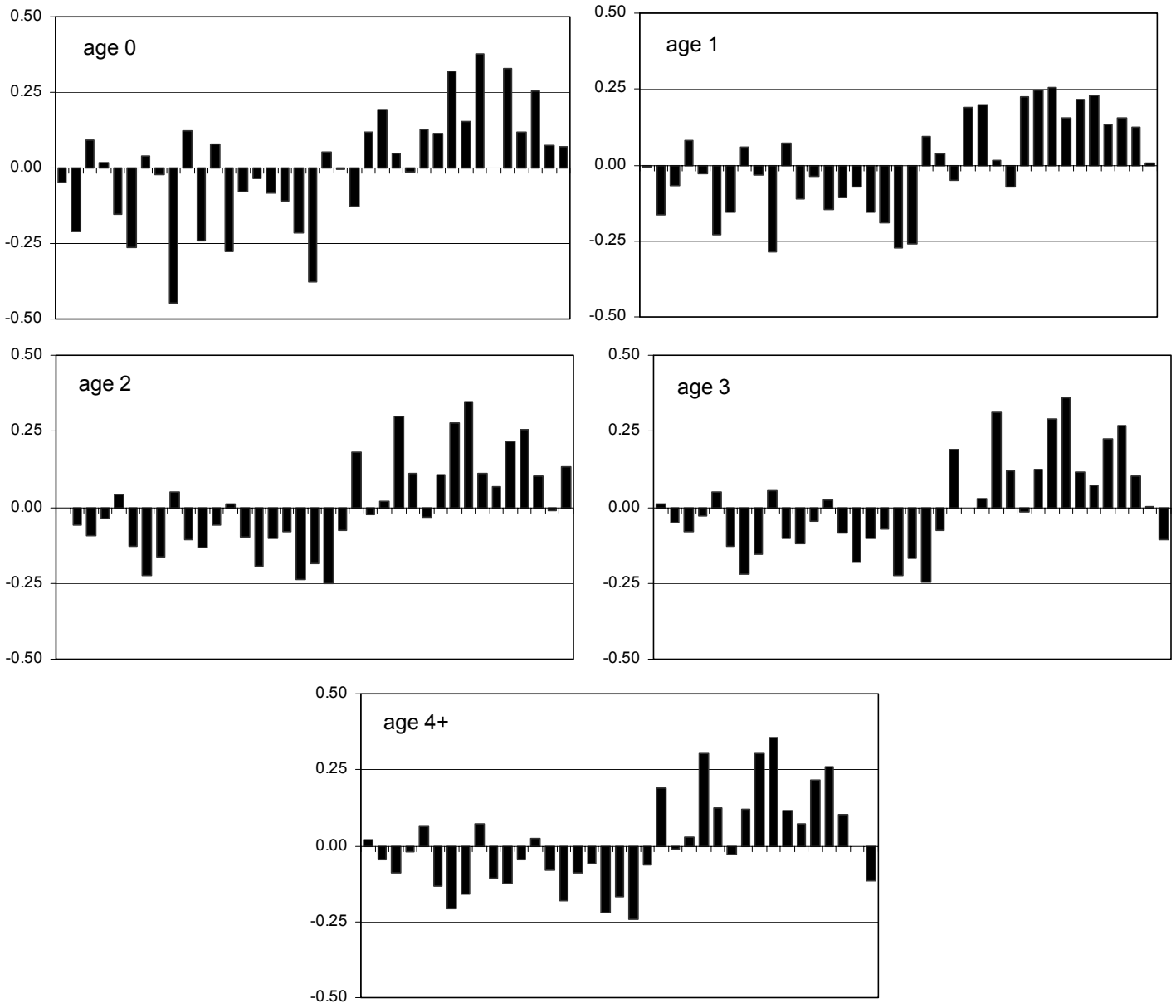

Figure 3. Residual plots (observed-predicted) for ages 0–4^{+} abundance indices from the ADAPT VPA.

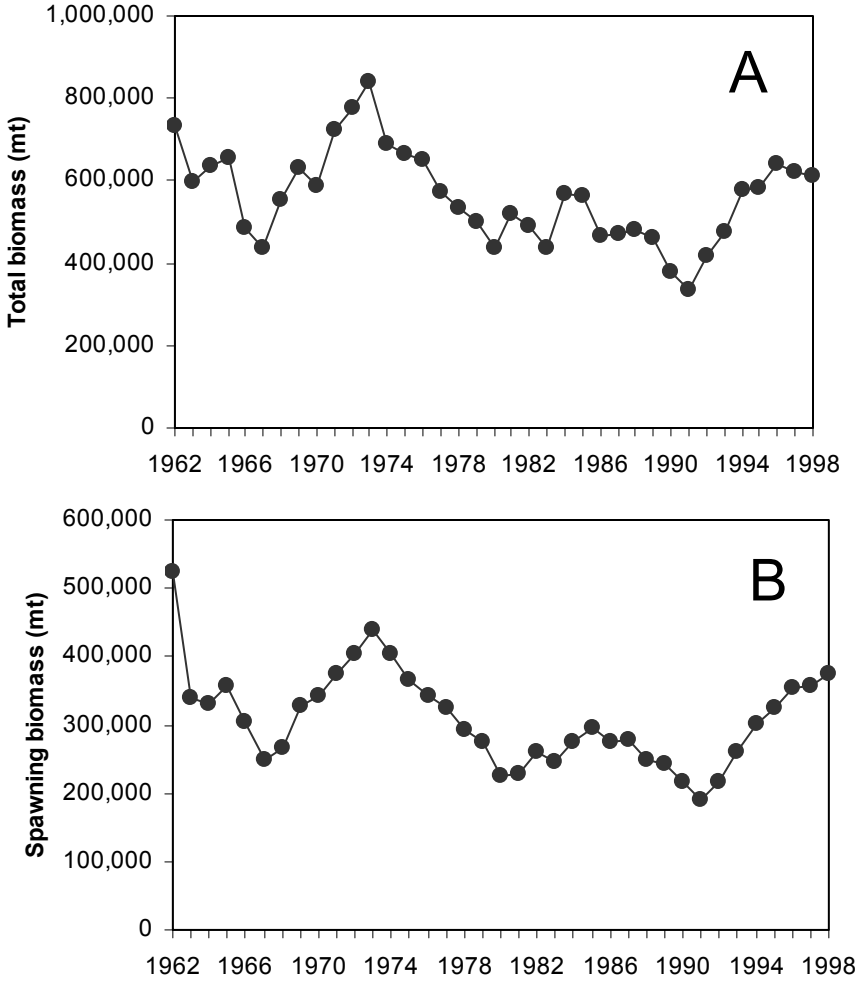

Figure 4. Trend in total (A) and spawning stock biomass (B) from 1962 to 1998.