Comments On
Non-Fishery Collapse of Northern Anchovy off California
MacCall, A.D., W. J. Sydeman, P.C. Davison, and J.A. Thayer.

By

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In my opinion the MacCall et al paper is conceptually one of the most significant papers on the population dynamics of pelagic fishes in the California Current in recent years. The analysis shows that the biomass of the central stock of northern anchovy is extremely variable and that this variability occurs with and without a significant fishery on the stock. For example, their biomass estimates increase more than an order of magnitude in two years, from 128 TMT in 2003 to 2,002 TMT in 2005. They then fall an order of magnitude to 213 TMT in 2007 and then fall another order of magnitude to 19 TMT in 2009. This was during a period without a significant fishery.

The paper provides numerous examples where biomass changes by factors of 2-5 in a single year. Clearly the biomass variations shown in the paper demonstrate that in the central stock of northern anchovy biomass estimates are worth very little for real time management if they are more than 1 year old.

The real importance of the paper is that the results suggest that if the fishery on this stock expands beyond the minor, monitored fishery of the last several decades it will require extensive surveys and annual assessments to manage the fishery. In addition, the paper's results suggest that ecosystem models of the California Current region will require inclusion of the environmental factors forcing the large biomass fluctuations of northern anchovy and the other major stocks of small pelagic fishes before they can be used for resource management purposes.

Comments:

Due to the lack of a recent significant fishery and associated sampling program, and the concentration of this limited fishery at the northern (Monterey Bay) edge of the stocks normal geographical distribution, modeling of the anchovy biomass was restricted to egg and larvae survey data. The total reliance on the egg and larvae surveys suggests that potential bias may occur in the time series of anchovy biomass and this is recognized and some of the sources of bias are addressed by the authors.

The authors point out one of the most significant of these biases (i.e. the distribution pattern of the egg and larvae surveys extends further offshore than the area of high anchovy abundance during low biomass periods) results in hyperstability due to the fact that the anchovy population extends further offshore during periods of higher abundance and contracts to the nearshore area during periods of low abundance. It should also be noted that the offshore areas in the egg and larvae sampling grid have fewer eggs than the nearshore areas even when the biomass is high. This is particularly true in central California.

The expansion and contraction of range is not as simple as stated in the MacCall et al paper because geographical distribution is highly age-dependent in the northern anchovy. The bulk of the young-of-the year (YOY) and age 1 anchovy population is found much closer to shore than the older anchovies (Parrish et al 1985). Note that this occurred during the period of high anchovy biomass (i.e. the mid-1960s to the mid-1980s). During the peak of the anchovy fishery, YOY and age 1 anchovies were concentrated in the very near shore area (i.e. less than 50 fm. depth) and older anchovies were concentrated in deeper water and further offshore (Figure 7 and Table 6). In other words it would take a year or two before a super abundant year-class would have significant biomass outside of the shelf break. This concept is relatively unimportant in the broad biomass trends seen in the paper but it could be very important in an expanded fishery where annual quota management of the stock would be required.

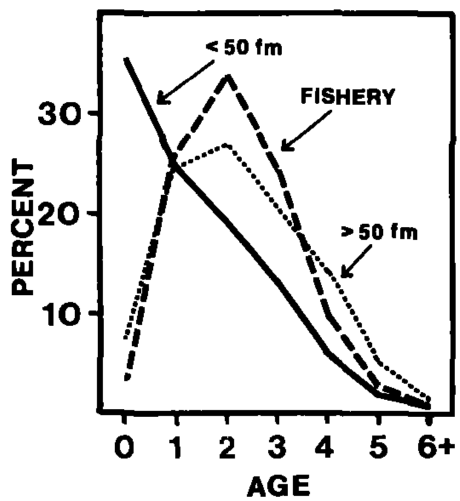

Figure 7. Comparison of the age composition of northern anchovies taken in the San Pedro purse seine fishery with those taken in areas with <50 fathoms and >50 fathoms of water in the mid·water trawl Sea Survey Program. (from Parrish et al 1985)

Table 6. Age composition (%) of northern anchovies taken in shallow and deep-water areas (depth in fathoms). (From Parrish et al 1985)

		Lat. 32°-34°N						
Age	Depth:	5-25	26-50	51-150	151-300	301-500	501-700	701 +
0		56.5	26.3	16.9	7.8	5.5	3.0	6.5
I		20.6	29.5	26.5	27.4	25.8	17.9	15.5
II		12.5	24.1	26.0	27.9	30.6	32.0	26.8
III		7.0	12.3	20.1	22.8	22.7	28.2	27.1
IV		2.5	5.8	6.8	9.1	10.5	13.3	15.3
V		0.8	1.5	3.2	3.6	3.8	4.9	7.2
VI +		0.2	0.5	0.6	1.4	1.1	0.6	1.7
n		1,579	1,492	1,102	2,199	3,704	2,091	1,086

Seasonality and use of aggregated data:

A second source of bias discussed in MacCall et al is that introduced by the irregular pattern of monthly cruises in the egg and larvae surveys. "Failure to account for seasonality is a source of imprecision, and the aliasing resulting from a systematic mismatch of sampling may introduce bias at the decadal scale." The authors used data from January and April separately to partially avoid this bias.

The authors also note that the central California data differ from that in Southern California. "Statistical distributions are strongly skewed, with frequent near- zero abundances and rare large values in central California. Although the overall mean egg and larval abundances for the full area are 17% higher than that for southern California, the measured abundance was at or above that level in only 21% of the years, while central California values are zero in 43% of the estimates."

The seasonality of spawning and fecundity was examined by Parrish et al. (1985) using the maturity stages of central stock northern anchovy taken in mid-water trawls by the Sea Survey Program and the California purse seine fishery during the high abundance period (1966-80) and histological information for the gonads of females taken during the months of February-April from 1977-1984. This information was primarily from the high abundance period when the anchovy fishery in California and Northern Baja California were at their highest level. The maturity stages, spawning incidence and fecundity information derived from these data shows that egg production peaks in March and is highest from February to April; very few anchovies are spawning in January (Figure 10 and Table 3). This makes the January data in the MacCall et al paper somewhat suspect. Note that one-year-old anchovies have peak spawning in February, that age 2 and older anchovy have peak spawning in March and that there is a high percentage of 3 year and older anchovy with a high egg production in April. Neither February nor March were used in the MacCall et al paper.

The MacCall et al egg and larvae time series demonstrate the problem with using the January data. Note that the biomass peak in 2005 has the second highest April egg index (7.137) of the entire series and that the January egg index (0.025) is near zero (MacCall et al Table 2). In contrast the biomass peak in 1963-66 has high egg indices in both January and April.

The April time series implies a very strong biomass peak in 2005; however, the January time series completely misses the 2004-6 biomass peak and it implies a collapsed biomass in 2005.

Age-dependent fecundity:

A related source of bias in the MacCall et al paper is caused by the fact that fecundity (i.e.

eggs per gram body weight) is highly age-dependent. Calculations from the data in Table 10 (Parrish et al 1985) show that the annual egg production per gram body weight is 4.9 times greater for 4+ year-old anchovies than for age 1 anchovies. In the peak spawning month (March) 4+ year-old anchovies produce 11.7 times as many eggs per gram body weight than age 1 anchovies. In January the difference between age 1 and age 4+ is not great (1.3 times) but there are very few anchovies spawning; only 3% of the annual egg production of 1 year olds and 1% of the 4+ year-olds occurred in January in the Parrish et al (1985) data (Table 10). The April difference is about the same as the annual difference (4.7 times).

It appears that the use of January data is questionable due to the very small proportion of spawning that occurs in this month, as small variations in the percent spawning will have relatively large proportional affects. In addition, the choice of January, with very low spawning rates during the peak of the fishery prior to 1985, increases the potential of decadal and inter-annual bias in biomass estimates caused by alterations in the seasonal distribution of egg production.

The second potential source of bias associated with age-dependent egg production is that the egg and larval surveys have no way to distinguish between a spawning population composed primarily of age 1 anchovies vs. one composed primarily of age 3 and age 4+ anchovies. Biomass estimates are likely to be more than twice as high if the biomass is dominated by older anchovies than the situation that occurs when a super abundant year-class occurs during a period of low biomass. In addition if the biomass is smaller due to increased numbers of predators (i.e. California Sea Lions and/or albacore) the increased natural mortality will produce a younger age composition and the resultant biomass estimate would have a low bias due to the reduced egg production associated with a younger population.

The northern stock and the central stock of northern anchovy overlap in Central California with northern stock being found as far south as Monterey and central stock found as far north as San Francisco (Vrooman et al 1981). Therefore expanding the biomass estimate of the northern stock to include central California may introduce bias as the northern stock spawns later in the year than the southern stock, resulting in a low estimate of the biomass of anchovy in central California. I note that due to the present high sea surface temperatures (SST) it is likely that the present population in Central California is primarily from the central stock; however this would not be true in the cold water years at the start of the time series used by MacCall et al. In addition, it is also likely that a much higher proportion of the central stock was in central California in 2015 than in earlier years; again due to the extreme SST values in the whole California Current region.

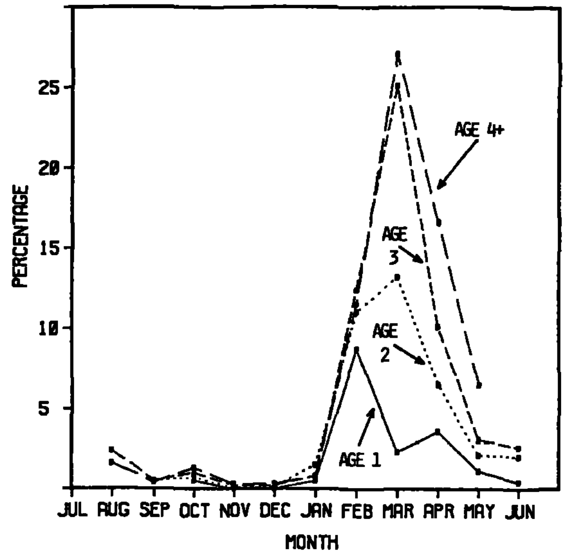

Figure 10. The monthly percentages of female northern anchovies with maturity stages 5+6, by age group. (from Parrish et al 1986).

TABLE 3.—Proportion of maturity stages 5 + 6, number of spawnings and fecundity of female northern anchovies sampled in the Sea Survey Program (lat. 29.5°-34.5°N) and San Pedro fishery.

	July[1]	Aug.[1]	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total[2]	Eggs/g[3]
							First spawning season							
Prop. 5 + 6	0.000	0.000	0.000	0.005	0.000	0.000	0.005	0.087	0.023	0.036	0.011	0.004		
Spawnings	0.000	0.000	0.000	0.155	0.000	0.000	0.155	2.436	0.713	1.080	0.341	0.120	5.3	
Wt. (g)	—	—	11.2	11.1	12.0	11.0	11.4	11.6	12.8	13.7	15.4	13.6		
No. eggs	0	0	0	832	0	0	860	13,793	4,536	7,438	2,687	819	32,514	2,803
							Second spawning season							
Prop 5 + 6	0.002	0.000	0.005	0.007	0.001	0.001	0.015	0.110	0.132	0.065	0.021	0.020		
Spawnings	0.062	0.000	0.150	0.217	0.030	0.031	0.465	3.080	4.092	1.950	0.651	0.600	11.9	
Wt. (g)	15.5	15.5	17.4	16.8	17.2	16.3	16.2	15.6	16.5	17.7	18.3	17.5		
No. eggs	492	0	1,357	1,887	268	261	8,881	24,626	34,866	17,980	6,230	5,462	102,174	6,550
							Third spawning season							
Prop. 5 + 6	0.022	0.024	0.005	0.010	0.002	0.002	0.008	0.124	0.251	0.101	0.031	0.026		
Spawnings	0.682	0.744	0.150	0.310	0.060	0.062	0.248	3.472	7.781	3.030	0.961	0.780	19.2	
Wt. (g)	18.3	18.3	19.1	19.3	19.2	19.3	19.1	18.0	20.7	22.2	20.9	22.7		
No. eggs	6,527	7,120	1,506	3,148	606	630	2,489	33,836	85,360	35,891	10,655	9,467	205,819	11,434
							Fourth-plus spawning seasons							
Prop. 5 + 6	0.021	0.016	0.004	0.013	0.003	0.003	0.008	0.115	0.271	0.166	0.065	0.056		
Spawnings	0.651	0.496	0.120	0.403	0.090	0.093	0.248	3.220	8.401	4.980	2.015	1.680	23.5	
Wt. (g)	20.1	20.1	20.9	21.8	22.3	22.2	23.6	23.3	26.6	26.5	25.7	25.7		
No. eggs	6,914	5,268	1,330	4,680	1,071	1,102	2,952	37,390	110,293	67,123	26,454	18,136	322,957	13,861
							All spawning seasons combined							
Prop. 5 + 6	0.017	0.021	0.008	0.011	0.002	0.002	0.010	0.107	0.151	0.094	0.044	0.012		
Spawnings	0.527	0.651	0.240	0.341	0.060	0.062	0.310	2.996	4.681	2.820	1.364	0.360	15.1	

[1]Missing data estimated from adjacent months.
[2]Includes 5% correction for spawning incidence bias.
[3]Total eggs/February weight.

Conclusions:

The biomass estimates in the MacCall et al paper cannot be used to estimate the 2016 biomass of the northern stock of anchovy. The paper clearly shows that the population can increase, or decrease, an order of magnitude in two years. The last year of the biomass time series is 2011 and the last year-class in this estimate was the 2010 year-class. Essentially the entire spawning population of 2011 is now dead. Clearly with northern anchovy a 5 year old biomass estimate is not significantly better at estimating current biomass than a 25 year old biomass estimate.

To estimate the recent abundance of anchovy the authors are forced go beyond their analysis to note that there have been very few anchovy eggs and larvae taken since 2011 and they conclude, "The current anchovy biomass off California is estimated at 10 to 20 thousand metric tons". I note that the last available catch statistics are for 2014 when 10,377 mt of anchovy were taken in the Monterey Bay ports and only 132 mt in Southern California. I agree that the recent central stock anchovy biomass in Southern California has been at a very low level; however, when the catches at the cold water edge of the anchovy's stocks range is greater than the minimum biomass estimate I have to wonder if geographical, seasonal, or environmental bias is causing problems.

The central stock extends into Mexico and due to data limitations the authors did not include anchovies spawning in Mexican waters in their estimates. This results in an underestimation of the total spawning biomass, and the underestimation would be expected to be at a maximum during the cold years when the biomass level was consistently above average and at a minimum during the recent warm period.

It is possible that the anomalously high SST in 2015 has displaced the bulk of the central anchovy stock to north of Point Conception and a considerable proportion of the biomass may be north of Point Reyes. The recent reports of large numbers of YOY anchovy in Southern California could be southern stock again due to the anomalously high SST. The northern boundary of this stock in 1967 was in the vicinity of Punta Baja (Vrooman et al 1981).

The recent biomass of adult anchovy in Southern California appears to be very low. The biomass in central and northern California may be low, but the 10,337 mt of anchovy landed at Monterey Bay ports in 2014 and the probability that high SST may have displaced a portion of the biomass to the north of the egg and larvae sampling grid suggests that the biomass of the central stock north of Point Conception is not nearly as reduced as the biomass south of Conception.

Although not discussed in the MacCall et al paper the starvation of California sea lions and its relationship to the low abundance of small pelagic fishes has been much in the news. I think it is time to suggest that the California sea lion population, which has increased by a factor of five since the start of the MacCall et al anchovy time series, is currently above carrying capacity. It clear that the present low anchovy abundance is due to environmental factors and the sharp decline in the sardine abundance was clearly primarily caused by a series years with near complete reproductive failure. Taking a few thousand tons of anchovy in central California is not going to affect the forage fish biomass around the Channel Island breeding grounds.

References:

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