

## AGE-COMPOSITION CHANGES IN THE ANCHOVY, *ENGRAULIS MORDAX*, CENTRAL POPULATION

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### ABSTRACT

Age composition sampling of anchovy reduction fishery landings detected major changes in the past four years (1977-1980). Weak year classes spawned in 1974 and 1975, a large increase of a major predator, and greatly increased catches by the combined Mexico-California reduction fisheries have caused a major change to a much younger anchovy population. Prior to 1977, the fisheries exploited mostly 2- and 3-year-old fish with substantial catches of older fish. Since 1977, ages 0 and 1 have heavily dominated catches, and older age groups have diminished. Under the present high fishing pressure nearing 400,000 tons per year, failure of two successive year classes could depress anchovy stocks to undesirably low levels.

### RESUMEN

Por medio de los muestreos tomados de los desembarques de la pesquería de reducción de anchoveta para determinar la composición en edades, se descubrieron grandes cambios durante los últimos cuatro años (1977-1980). Pequeñas generaciones desovadas en 1974 y 1975, la población aumentada de un depredador importante, y el aumento en las capturas de las pesquerías de reducción combinadas de México y California han sido causas de un cambio mayor en una población mucho más joven de anchoveta. Antes de 1977, las pesquerías explotaban por la mayor parte a peces de 2 y 3 años con capturas substanciales de peces de más edad. Desde 1977, los peces de edades 0 y 1 han dominado las capturas, y se han disminuido los grupos de más edad. Bajo la alta explotación actual, acercándose a 400,000 tons. anuales, el fracaso de dos generaciones sucesivas podría deprimir las existencias de anchoveta hasta niveles muy bajos y desfavorables.

### INTRODUCTION

The California Department of Fish and Game has routinely sampled the anchovy reduction fishery of

southern California since its inception in 1965. The basic objective of this sampling program is to monitor the impact of the fishery on population age structure and to assess year class strength.

Until recent years, no major changes in anchovy age composition were detected by the reduction fishery sampling. During the four years of 1977-1980 there was a pronounced shift to a much higher proportion of young age groups and fewer large old fish. Concurrent with this change the combined anchovy catch of California and Mexico reached a record high of 386,000 short tons in 1980, and a major predator, the Pacific mackerel, *Scomber japonicus*, has greatly increased in numbers.

### METHODS

Anchovy reduction fishery landings at San Pedro, southern California, are sampled during the fishery season, which was from September 15 to May 15 for the years 1965-1978, and since 1978, from September 15 to June 30, with a closure February 1 to March 31. A maximum of 30 samples, each weighing 250 grams, is randomly drawn from each 5,000 short tons landed.

Age determination is made from otoliths by the method described by Collins and Spratt (1969). Age composition of individual 5,000-ton strata are combined to estimate the age composition of the fishery season landings. Age and size composition of reduction seasons' landings of all southern California and most Mexican landings have been published since inception of the California fishery (Collins 1969, 1971; Chavez et al. 1977; Spratt 1972, 1973a, b; Sunada 1975, 1976, 1977, 1979a, b, in press; Sunada and Silva 1980).

Due to sampling bias, the true age composition of the anchovy central population has not been determinable by fishery catches, which undersample ages 0 and 1 and slightly undersample old age groups (Mais 1974). For reasons not clearly understood, the youngest age groups are not fully recruited to the purse seine-based fishery. It must be kept in mind that these data reflect age composition of the fishery catch and

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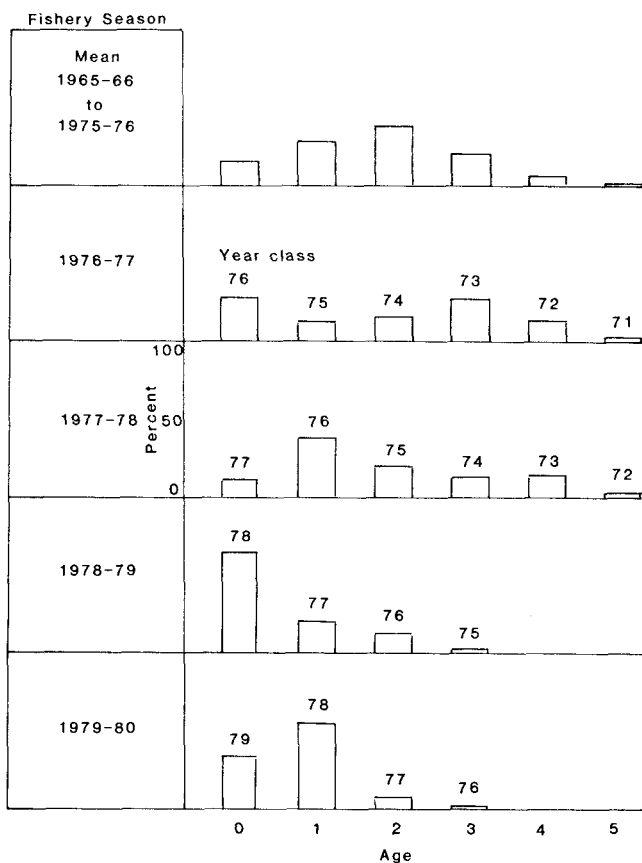


Figure 1. Age composition of California anchovy reduction fishery, by numbers of fish.

not the population. Their chief value is as an index of population age-structure change.

## RESULTS

### *Fishery Age Composition 1965 to 1976*

During the first 11 fishery seasons, no major changes in age composition occurred. A typical season catch/age composition consisted mainly of 1, 2, and 3-year-old fish, a relatively low percentage of age 0, and progressively much diminished percentages of 4-year-olds and older (Table 1). The mean age composition for the first 10 seasons (there was an insignificant catch in 1967-68 season) was 10% age 0 (range 2.4-27.0%), 27% age 1 (range 10.5-50.8%), 37% age 2 (range 22.4-48.5%), 20% age 3 (range 8.2-34.0%), 5% age 4 (range 1.5-12.0%), and 1% age 5 (range 0.1-3.2%), (Figure 1, Table 1). The relatively low percentages of ages 0 and 1 strongly indicate these age groups are not fully vulnerable to the fishery. Age 1 fish exceeded Age 2 in only two of the 11 seasons.

In these first 11 years, the California reduction catch fluctuated considerably until reaching a maxi-

TABLE 1  
 Age Composition<sup>1</sup> of Anchovy Reduction Fishery of Southern California

Season	Age						
	0	1	2	3	4	5	6
1965-66	4.5	14.7	48.5	23.4	7.5	1.3	0.1
1966-67	6.9	22.9	38.1	23.0	7.5	1.4	0.2
1967-68	1.4	12.6	26.3	30.7	19.3	9.1	6.6
1968-69	18.5	45.9	22.4	8.2	4.3	0.6	0.1
1969-70	27.0	27.8	35.2	8.3	1.5	0.1	Tr
1970-71	4.0	32.1	40.2	20.1	3.1	0.5	Tr
1971-72	11.3	51.0	26.8	8.4	2.4	0.2	0
1972-73	9.5	25.9	47.6	14.2	2.3	0.4	Tr
1973-74	6.9	20.2	35.3	30.8	6.2	0.6	Tr
1974-75	4.6	18.5	39.5	26.4	9.6	1.3	0.1
1975-76	2.4	10.5	37.7	34.0	12.0	3.2	0.2
1976-77	27.8	12.0	16.2	27.9	13.4	2.5	0.2
1977-78	10.5	37.7	20.3	14.0	14.1	2.4	0.2
1978-79	65.1	19.6	13.1	1.6	0.5	0.1	0
1979-80	34.5	55.2	8.8	1.3	0	0	0

<sup>1</sup>Percent of age group by numbers of fish.

imum of 156,000 short tons in 1975 (Table 2). The Mexican catch earlier was much lower but sharply increased after 1973. By 1975 the combined California-Mexico catch was 217,000 tons (Table 2).

### *Fishery Age Composition 1977 to 1980*

Weak year classes spawned in 1974 and 1975 apparently were the cause of a major change in catch age composition when these year classes became fully recruited to the fishery. In the 1976-77 season, the 1974 year class as 2-year-olds comprised only 16% of the catch, the lowest contribution of any previous year class at this age. This was also the only season thus far that more 3-year-old fish (1973 year class) were caught than 2-year-olds (Figure 1).

TABLE 2  
 Annual Catch Record<sup>1</sup> of California and Mexican Anchovy Fisheries

Year	California	Mexico	Total
1965	0.2	10	10
1966	27	15	42
1967	32	23	55
1968	14	16	30
1969	65	4	69
1970	93	31	124
1971	44	22	66
1972	67	34	101
1973	131	17	148
1974	81	48	129
1975	156	61	217
1976	122	79	201
1977	110	157	267
1978	11	143	154
1979	56	272	328
1980	47	339	386
	1,056	1,271	2,327

<sup>1</sup>In 1,000 short tons. Sources: California landings, California Department of Fish and Game; Mexico landings, Instituto Nacional de Pesca, 1965-1978, and Departamento de Pesca, 1979-80.

The 1975 year class comprised the second lowest (20%) of 2-year-olds up to that time in the 1977-78 season (Figure 1). This was also the only season there was a higher percentage of 4-year-olds (1973 year class) than 3-year-olds (1974 year class).

By the 1978-79 season, the weak 1974 and 1975 year classes as 3- and 4-year-olds had nearly disappeared from the fishery. The 1976 year class, which appeared strongly at ages 0 and 1, faded at age 2. Age 0 fish (1978 year class), for the first time in the history of the fishery, became the dominant (64%) age group in the catch (Figure 1). The highest percentage of any previous age 0 fish (1976 year class) was 28%. Ages 0 and 1 combined comprised over 84% of the age composition for this season (Figure 1).

The dominance of young fish continued and intensified in the 1979-80 season. Nearly 90% of the catch was composed of ages 0 (1979 year class) and 1 (1978 year class). Ages 2 (1977 year class) and 3 (1976 year class) comprised the lowest percentages for these age groups in the history of the fishery (Figure 1).

The age composition of these last two seasons' catches is radically different from the previous 12. The young age groups, which previously were considered not fully recruited, now grossly dominate the fishery.

Most California landings from 1965-1977 were heavily weighted toward the fall portion of the fishery season. Fall landings during this period were composed mainly of the older age groups (2, 3, and 4+ year olds) with few 1-year-olds and almost no fish of the incoming year class (age 0). The younger age groups normally appeared in spring landings. In the 3 seasons, 1978-79, 1979-80, and 1980-81, fall landings have been poor relative to those of spring and have contained an abnormally high proportion of young fish. This was particularly true of the 1978 year class, which was prevalent in California and Mexican catches during the fall of 1978.

During the 1977 to 1980 period, the commercial catch fluctuated greatly. The California catch plummeted from 110,000 tons in 1977 to 11,000 tons in 1978, increased to 56,000 tons in 1979, and was 47,000 tons in 1980 (Table 2). Since 1979, fishing seasons were approximately six weeks longer than in previous years. The Mexican catch fluctuated less with a slight dip from 1977 to 1978 and a substantial increase to 339,000 tons in 1980 (Table 2). The combined California-Mexico 1980 catch of 386,000 tons is the highest to date. The Mexican fishery has surpassed and greatly exceeded the California fishery the past

four years (Table 2). Some of the Mexican catch is comprised of a southern stock not exploited by California fishermen.

#### *Virtual Population of Year Classes 1968 to 1977*

The California reduction catch of each year class during its lifetime was estimated for year classes 1968 through 1977 (Table 3). The fishing fleet and effort did not fluctuate much while these year classes were in the fishery; so these catches or virtual populations should be a rough index of year-class strength. These data show the 1972 year class to be the strongest, with a catch of 142,000 tons, and the 1977 year class the weakest, with a catch of 22,000 tons. Strong successive 1970-1973 year classes produced the high California catch levels sustained from 1972 to 1977 (Figure 2, Table 2). Of the four year classes following 1973, three were weak (1974, 1975, and 1977) and one (1976) was mediocre (Figure 2). These year classes have been in the fishery during the three fishing seasons (1977-78, 1978-79, and 1979-80) of much reduced California catches and during the period when age composition shifted toward younger fish. They have also been present when acoustic, larvae, and egg production surveys have indicated a smaller anchovy population (Mais 1978, 1979, 1980; Stauffer 1980; Stauffer and Parker 1980).

Some assessment of year class strength can also be derived from the Mexican catch of the 1976 and later year classes when that fishery became fully geared up. The catch of the 1976 year class in California was mediocre relative to those of other year classes taken

TABLE 3  
Anchovy Reduction Catch<sup>1</sup> by Year Class: 1968-1980

Year class	Catch (in short tons)		Total
	California	Mexico	
1968	67,000	—	67,000
1969	82,000	—	82,000
1970	119,000	7,000	126,000
1971	119,000	23,000	142,000
1972	142,000	61,000	203,000
1973	123,000	71,000	194,000
1974	48,000	58,000	106,000
1975	33,000	41,000	74,000
1976	66,000	152,000	218,000
1977	22,000	72,000	94,000
1978	48,000 <sup>2</sup>	409,000 <sup>3</sup>	457,000
1979	still in fishery		
1979	12,000 <sup>2</sup>	155,000 <sup>3</sup>	167,000
1980	—	101,000 <sup>3</sup>	101,000

<sup>1</sup>Data from California Department Fish and Game Fishery Monitoring and Instituto Nacional de Pesca, Mexico.

<sup>2</sup>To June 15, 1980.

<sup>3</sup>To January 1, 1981, extrapolated from California catch data.

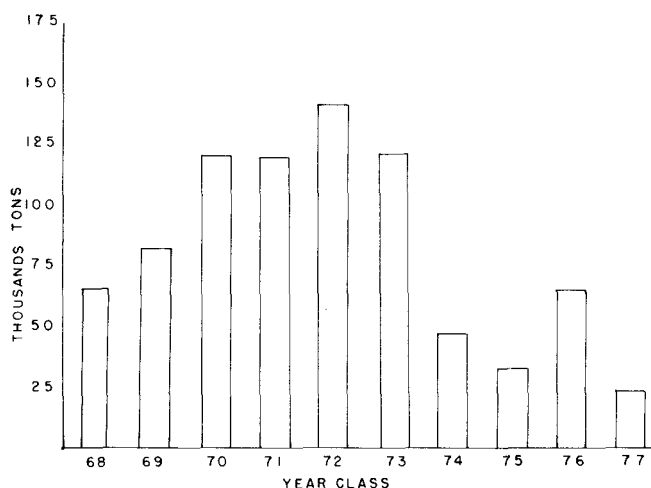


Figure 2. California anchovy reduction catch by year classes 1968 to 1977.

in California. This year class, however, appeared strongly in the Mexican catch of 1977 and 1978. More fish of the 1976 year class were taken (152,000 tons) in Mexico than the strong 1972 year class (142,000 tons) in the California catch. The weakness of the 1977 year class was also reflected in the Mexican catch of 72,000 tons relative to the 1976 and 1978 year class catches of 152,000 and 409,000 tons respectively (Table 3). The Mexican catch of 1978 year class thus far greatly exceeds that of any preceding year class in either California or Mexico. This year class will contribute more than 450,000 tons to the combined California and Mexico fisheries during its lifetime and must be ranked one of the strongest of all to date (Table 3). However, its relative strength may have been exaggerated by the increased effort by the Mexican fishery since 1976.

**Year Class Catch by Age**

The catch of each year class by age also strongly indicates that the fishery has shifted sharply in recent years to very heavy exploitation of year classes in the

younger age groups and a much diminished catch of older fish of the same year class. In the California fishery the proportion of catch of age 0 fish ranged from 2.7 to 26.7% from year classes 1968 to 1975, with a mean of 9.4% (Table 4). The catch percentage of this age group for the 1976 and 1977 year classes was 45 and 36% respectively. There has been a drastic decline in catches of these year classes as 3-year-olds and older. The range of percent of catches as 3-year-olds for year classes, 1968-1974, was 6.7 to 33.9% with a mean of 22.5%. The range of this category for the 1975-1977 year classes was 0.5 to 3.2% with a mean of 2.4%. The highest percentage of these last 3 year classes is less than half the lowest percentage of the seven earlier year classes. There was essentially no catch of 4- and 5-year-old fish of 1974-1977 year classes (Table 4).

Cumulative catch at age for the 1972 and 1977 year classes illustrates this change (Figure 3). The 1972 cumulative catch curve for year classes is typical of those of 1968-1973 with relatively small contribution of age groups 0 and 1, major contribution of 2 and 3, and measurable quantities of 4- and 5-year-old fish. The catch curve of the 1977 year class is typical of those of recent years with high contribution of ages 0 and 1, low contribution of ages 2 and 3, and no catch of 4- and 5-year-olds.

The combined contribution of 0- and 1-year-olds expressed as a percentage of year class catch were plotted against a similar combination of 3- and 4-year-olds for the 1968-1977 year classes (Figure 4). The catch percentage of the younger group ranged between 20 and 25% for the strong 1970-1973 year classes and from 40 to 87% for the weak 1974, 1975, and 1977 year classes. This same combined age group comprised 88% of the mediocre to strong 1976 year class.

TABLE 4  
 California Anchovy Reduction Catch of Year Classes 1968-1977 by Age Group.

Year class	Catch <sup>1</sup>	Catch Percent by Age Group						Total
		0	1	2	3	4	5	
1968	67,166	7.2	33.7	47.9	6.7	2.7	1.8	100%
1969	81,573	26.7	31.5	17.2	13.3	9.2	1.9	100
1970	119,000	2.7	22.5	30.3	31.2	9.4	3.8	100
1971	118,356	5.1	16.4	36.0	26.0	14.3	2.2	100
1972	141,740	5.0	17.2	32.4	33.9	10.0	1.3	100
1973	122,897	6.8	17.5	42.8	24.1	8.8	0	100
1974	47,837	11.1	31.0	35.8	22.0	0	0	100
1975	32,514	10.4	39.6	46.7	3.2	0	0	100
1976	65,555	45.0	43.3	11.2	0.5	0	0	100
1977	21,719	36.3	51.4	11.3	1.0	0	0	100

<sup>1</sup>Short tons; data from California Department of Fish Game Fishery Monitoring

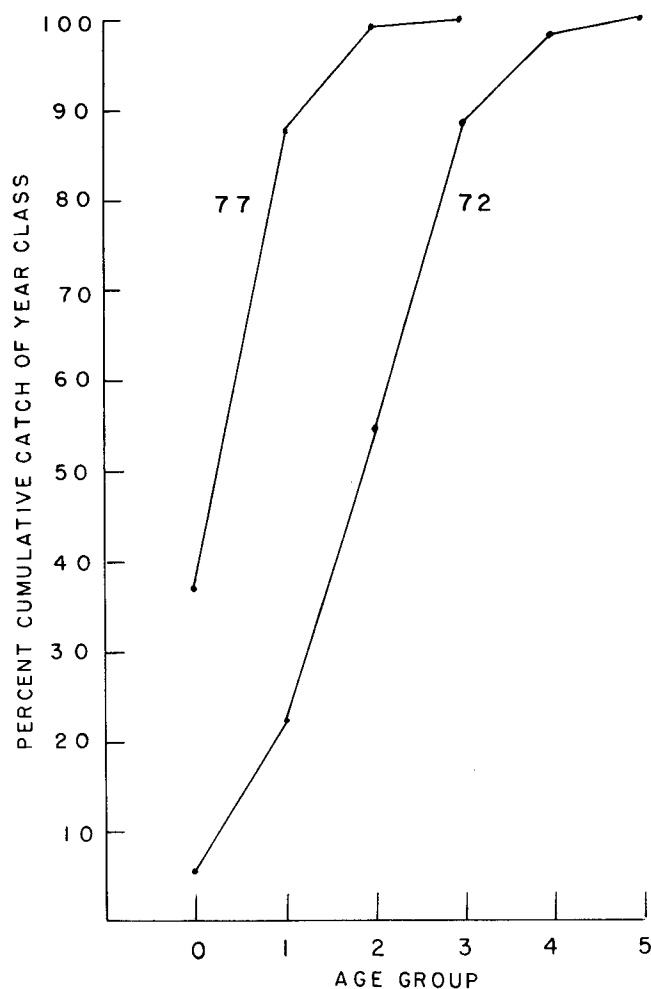


Figure 3. California cumulative catch by age of anchovy year classes 1972 and 1977.

The catch percentage of the older group ranged from 33 to 44% for the strong year classes (1970-1973) and from 1% to 22% for the weak ones (1974, 1975, and 1977). The contribution of this age group by the 1976 year class was only 0.5% (Figure 4).

## DISCUSSION

The main questions raised by the recent shift in the age structure of the central anchovy population are its causes and effects. Of the five year classes prior to and including 1978, three were weak (1974, 1975, and 1977), one was strong (1978), and the 1976 year class appeared strong in Mexico and mediocre in California. Concurrent with the shift to a younger population, there have been record high catches, principally by Mexico, a large increase in a major predator, the Pacific mackerel, and a decrease in the population size as estimated by acoustic, larvae, and egg production surveys.

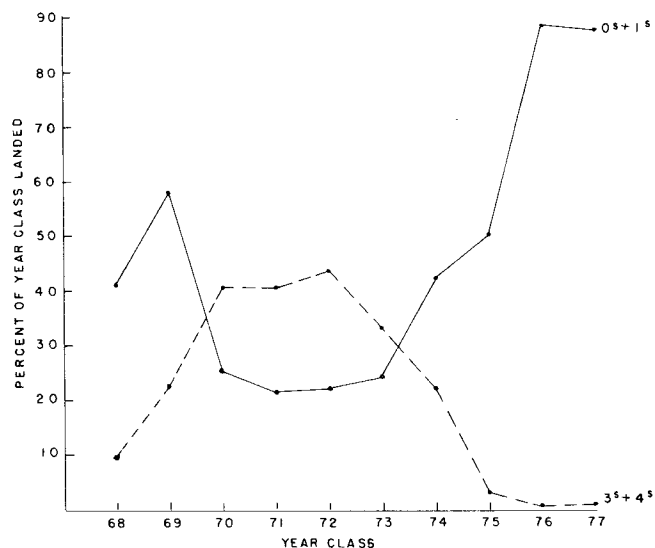


Figure 4. California anchovy reduction catch of year classes 1968-1977 at combined ages 0-1 and 3-4.

Based on data of past years, predation by Pacific mackerel alone has not resulted in a young and reduced anchovy population. In 1963, larvae surveys by the National Marine Fisheries Service estimated an all-time high of 4.66 million tons in the central stock of anchovy spawner biomass. This and the preceding 2 years also had high Pacific mackerel population ranging from 96,000 to 137,000 tons as estimated by Parrish and MacCall (1978). Although the Pacific mackerel population has increased greatly since 1976, recent population estimates (Klingbeil 1976, 1977, 1978, 1979, 1980) are lower than the 1961-63 period. Limited sea-survey midwater trawl data in 1963 indicated an adult anchovy age composition consisting mainly of 2-, 3-, and 4-year-old fish with 3-year-olds predominating, (Heimann 1969).

The relative weakness of three of the last five year classes (1974-1978) together with the combined mortality of the fishery and the Pacific mackerel predation are the most likely causes of age-structure shift and decrease in population size.

The 1978 year class appears to be very strong. If weak year classes were the cause of age-structure change, the 1978 year class should persist in the fishery at ages 4 and 5 and should shift the age structure back to the pattern of the early 1970's. If, however, this year class disappears after age 3, as did the 1976 and 1977 year classes, increased mortality, with the fishery the most likely source, must be considered the major cause of altered age structure.

The present anchovy fishery age composition and

the lower population levels the past three years should be viewed as a danger sign to the health of the central population and must be watched very closely. With the recent record high in California-Mexico catches, heavy exploitation of ages 0 and 1 and a scarcity of older fish, a failure of two consecutive year classes such as occurred in 1974 and 1975, could sharply reduce the population level to undesirably low levels.

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