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A STUDY OF POPULATIONS OF THE ANCHOVETA, *Cetengraulis mysticetus*, BASED ON MERISTIC CHARACTERS

by
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(Con resumen en español)

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UN ESTUDIO SOBRE POBLACIONES DE LA ANCHOVETA

(Cetengraulis mysticetus) BASADO EN CARACTERES NUMERICOS

por

Gerald V. Howard

RESUMEN

Este estudio ha sido hecho con el propósito de determinar si los caracteres numéricos de las anchovetas indican que existe más de una población de este pez en la zona en que se encuentra la especie, comprendida entre México y Perú. El interés en dicha especie radica en el hecho de que éste es el pez de carnada usado principalmente para la pesca de los atunes "aleta amarilla" y "barrilete" en el Pacífico Oriental.

Los especímenes que han sido examinados, se tomaron de las muestras recogidas por los barcos atuneros de California en seis de las mejores localidades en que se pesca la anchoveta, las cuales comprenden casi toda la zona en donde se encuentra la especie, a saber, Bahía de Almejas en la costa exterior de Baja California, Guaymas y Punta Ahome en el Golfo de California, el Golfo de Fonseca, el Golfo de Panamá y el Golfo de Guayaquil. Cuatro caracteres numéricos fueron escogidos para su estudio: los que presentan 1) las vértebras, 2) los radios de la aleta dorsal, 3) los radios de la aleta anal y 4) las branquispinas del primer arco branquial. Mediante el uso de películas con rayos X, se contaron las vértebras en un total de 1,500 peces, es decir, 250 de cada una de las seis mencionadas localidades. En relación con los otros caracteres, se examinaron 125 anchovetas de cada área, o sea, un total de 750 ejemplares, habiendo sido hecho el conteo por medio de un microscopio binocular. Los especímenes tenían un largo *standard* entre 80 y 165 milímetros.

Se encontró que las cifras de los mencionados caracteres numéricos no varían por el sexo; y que en cuanto a las vértebras, a los radios de la aleta dorsal y a los radios de la aleta anal, los números no tienen una relación de importancia con el tamaño (largo) del pez. El número de las branquispinas aumenta con el tamaño de las anchovetas. La relación no es linear, y como no era posible dar con una ecuación representativa de la regresión, se acudió a una curva empírica de promedios para indicar las cifras que arrojan todas las localidades.

Se hizo un análisis de las variantes para establecer las diferencias de significación entre los promedios de conteo en las diversas áreas. Se han constatado notables variaciones entre ciertas localidades, en lo que respecta a las cifras relativas a las vértebras y a los radios de la aleta anal. Un estudio de las variantes, tomando en cuenta las desviaciones entre los números obtenidos en el conteo de branquispinas y lo que se esperaba con base en una línea empírica indicativa de la regresión, ha demostrado que existen grandes diferencias entre las poblaciones de anchovetas entre México y Perú. Las cifras correspondientes a los radios de la aleta dorsal resultaron similares en todas las áreas.

Tres grupos de población se perfilan con base en los números correspondientes a las vértebras y a los radios de la aleta anal: 1) Bahía de Almejas; 2) Guaymas, Punta Ahome y el Golfo de Fonseca; 3) Panamá y Guayaquil. Las localidades comprendidas en los grupos 2 y 3 parecen ser distintas entre sí en cuanto a las cifras sobre branquispinas. En consecuencia, se ha llegado a la conclusión de que las poblaciones en las seis localidades deben ser provisionalmente consideradas como grupos diferentes. Es de notar que se hacen necesarios los experimentos de marcación, a fin de verificar estos resultados y determinar si se efectúa una mezcla parcial entre las poblaciones. El presente estudio, por su naturaleza, no permite apreciar una mezcla parcial entre las diversas reservas de la especie.

La información relativa al ambiente en las seis areas objeto de nuestras investigaciones, se circunscribe, en su mayor parte, a la temperatura tomada por los *clippers* atuneros. No se observó ninguna relación de importancia entre las temperaturas y las cifras correspondientes a los caracteres numéricos.

SUMMARY

This study was undertaken to determine whether meristic characters indicate that more than one major population of anchovetas occurs in the range of the species from Mexico to Peru. Interest in this species lies in the fact that it is the principal bait fish used to catch yellowfin and skipjack tunas in the Eastern Pacific.

Specimens examined were from collections made by California tuna fishing vessels at six major baiting localities covering nearly the entire range of the species, namely, Almejas Bay on the outer coast of Baja California, Guaymas and Ahome Point in the Gulf of California, Gulf of Fonseca, Gulf of Panama, and Gulf of Guayaquil. Four meristic characters were selected for study: vertebrae, dorsal fin rays, anal fin rays, and gill rakers on the first gill arch. Vertebral counts, using X-ray film, were

taken from a total of 1,500 fish, 250 each from each of the six localities. For the other characters, 125 anchovetas were examined from each locality for a total of 750, the counts being made with the aid of a binocular microscope. Specimens were between 80 and 165 mm. standard length.

It was found that counts of the various meristic characters do not vary with sex and that for three characters, vertebrae, dorsal and anal fin rays, the counts bore no significant relationship to the length of the fish. Gill raker counts increase with the length of the anchovetas. The relationship is not linear, and as it was not possible to find a useful theoretical equation to describe the regression, an empirical average curve was drawn to represent the data from all localities.

Analyses of variance were used to test for significant variation between means of the meristic counts from different localities. Significant differences were found between certain localities using vertebrae and anal fin rays. An analysis of variance, using the deviations of the observed gill raker counts from the expected on the basis of an empirical regression line, demonstrated further differences among the populations of anchovetas between Mexico and Peru. Dorsal fin ray counts were similar in all localities.

On the basis of the vertebral and anal fin ray counts, three population groups are indicated: 1. Almejas Bay, 2. Guaymas, Ahome Point, and Fonseca, 3. Panama and Guayaquil. The localities within groups 2 and 3 appear to be distinct from each other from gill raker counts. It is, therefore, concluded that the populations in the six localities should be provisionally considered as separate. It is noted that tagging experiments are necessary to verify these results and to determine whether partial inter-mixing of the populations takes place. The present analysis is not, by its nature, able to detect partial inter-mixing of the several populations.

Information concerning the environment in the six localities is confined, for the most part, to temperature readings taken by tuna clippers. No obvious relationship between temperature and counts of meristic characters was observed.

ACKNOWLEDGEMENTS

Success with the bait fish studies, as with many other of the Commission's investigations, depends to a great extent upon the continuing co-operation of the captains and crews of the fishing vessels. In the present instance, sincere thanks are extended to the fishermen who are collecting the bait samples on which this and other studies are based. Acknowledgement is also made to the Scripps Institution of Oceanography for making available certain equipment and facilities.

INTRODUCTION

Over 80 per cent of the yellowfin and skipjack tunas caught in the Eastern Pacific are taken by vessels employing the live bait fishing method. Several fishes are used as bait, most of them belonging to the anchovy and herring families. They are found in bays and estuaries from California to Peru. The most important species, because of its wide distribution and the fact that it lives well aboard the tuna clippers, is the anchoveta, *Cetengraulis mysticetus* (Günther). More than 60 per cent of the tuna landed by live bait vessels during 1951 and 1952 was caught with this bait species.

The expansion of the yellowfin and skipjack fishery, and the consequent increasing need for more live bait makes it necessary to find answers to various questions concerning the utilization of the bait resources in a manner which will provide maximum yields. When a species of fish is exploited over a great part of its range, as is the case for the anchoveta, it is important to know whether that species consists of a single widespread population or a number of independent or semi-independent populations. In the first instance, the whole population is open to exploitation at any point in its range, while in the second case, the exploitation of one population has little or no effect on the others.

Different populations of the same species usually exhibit morphological differences as a result of different environments during the period of life when the structures in question are fixed, or through genetic differences resulting from natural selection during long periods of geographical isolation. Whether differences in structure result from heredity or environmental factors is not of great importance, as long as they are sufficiently stable to indicate real differences between populations. Structural differences between populations are commonly detected by measuring body proportions and counting meristic characters, the latter generally being simpler to study.

The present study was undertaken to determine the extent of variation in counts of meristic characters of the anchoveta from six principal baiting localities between Mexico and Peru.

METHODS

Sampling

The anchovetas examined were obtained from collections made by Calfiornia tuna fishing vessels. As a continuing part of the Commission's bait-fish research, a number of vessels are collecting random samples of specimens from their bait catches. These samples, consisting of 100 to 400 fish, are frozen aboard and turned over to the Commission's representative when the vessel returns to port.

The six localities from which samples of anchovetas, used in this study were collected are: Almejas Bay on the outer coast of Baja California, Guaymas and Ahome Point in the Gulf of California, the Gulf of Fonseca, the Gulf of Panama, and the Gulf of Guayaquil (see Figure 1). These areas cover almost the entire range of the species which extends, according to Hildebrand (1943), from the Gulf of California to Sechura Bay, Peru.

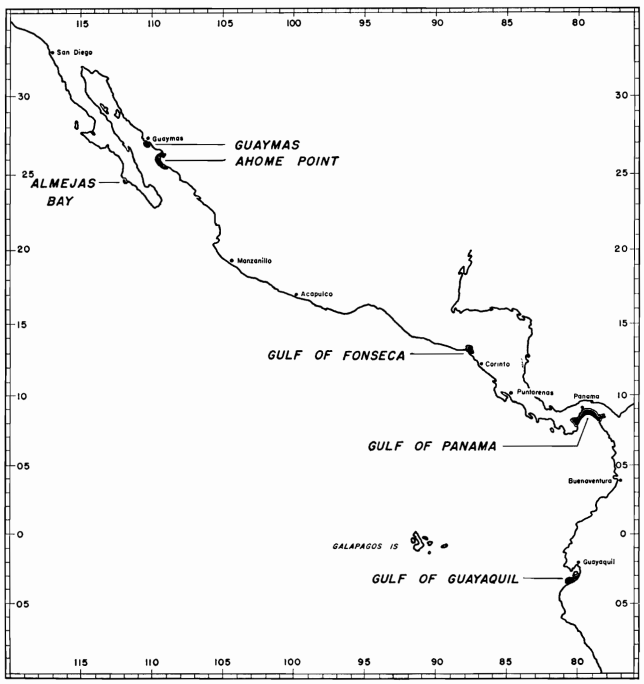

FIGURE 1. Map showing the six principal baiting localities for the anchoveta *(Cetengraulis mysticetus).*

The fish examined for meristic variations were between 80 and 165 mm. standard length, the majority being between 110 and 145 mm. This range covers the largest and smallest fish appearing in the 30 samples examined. The smaller interval, 110 to 145 mm. corresponds to the size of anchovetas most commonly taken for bait. Evidence suggests that the small fish are about one year old while those above 140 mm. have reached three or more years.

Counts of the meristic characters were made from a specified number of fish from the first five samples received from each of the six localities, rather than from a single sample for each area. This procedure was followed to learn whether differences occur between samples from the same area.

Specimens making up the specified number for each of the 30 samples (5 samples from each of the 6 localities) were selected according to size, in order to give a fairly even representation of the range of sizes encountered in each sample, rather than to represent the length-frequency distribution. This manner of selection is more efficient in determining whether the characters selected are size-connected (Schaefer, 1948).

The standard length of the fish, measured from the tip of the snout to the end of the silvery area on the caudal peduncle after scales are removed from the area, was recorded to identify length with fin ray and gill raker counts. Records were not kept of lengths for vertebral counts. For clupeoid fishes, it is well established that the number of vertebrae is determined at an early age, before hatching or during the larval stage (Tester, 1949). Any increase in the number of vertebrae with size within a given year class probably results from older fish hatching under a lower average temperature (McHugh, 1942 and 1951; Rounsefell and Dahlgren, 1945; Tester, 1949; Tester and Hiatt, 1952), and it is sufficiently small to be neglected (Rounsefell, 1930; Tester, 1937 and 1938).

After establishing, using a sample of 50 males and 50 females from one locality (Almejas Bay), that the counts of the meristic characters do not vary with sex, in the anchoveta, fish were not identified as to sex. This finding of no difference between sexes is in contrast to the finding of McHugh (1951) for the northern anchovy *(Engraulis mordax mordax),* where sexual differences were noted for several meristic characters. However, investigators working with other clupeoid fishes, e.g., Tester (1937) for the Pacific herring *(Clupea pallasii),* Blackburn (1950) for the Australian anchovy *(Engraulis australis),* and Tester and Hiatt (1952) for the Hawaiian anchovy *(Stolephorus purpureus)* have found that, at least for vertebrae, sex need not be considered as a source of variation.

Characters Selected and Number Counted

Four meristic characters were selected for counting, vertebrae, anal fin rays, dorsal fin rays, and gill rakers on the first gill arch on the left side. Vertebral counts were made of 1,500 fish, consisting of five samples of 50 fish from each of the six localities. For the other characters, 25 fish were taken from each of the 30 samples, for a total of 750. As explained, the five samples used for each area were the first five received. Dates on which they were collected are as follows:

Almejas Bay - April 7, Sept. 29, Oct. 1, and Nov. 5, 1951; Jan. 22, 1952.

Guaymas - April 25, May 5, May 24, May 29, and July 2, 1951.

Ahome Point - April 16, April 23, May 10, June 7, and June 15, 1951.

Gulf of Fonseca - May 5, May 8, June 5, July 30, and Aug. 4, 1951.

Gulf of Panama - June 14, June 16, June 30, July 3, and Aug. 15, 1951.

Gulf of Guayaquil - Sept. 29, Sept. 30, Oct. 1, and December 8, 1951; Jan. 3, 1952.

Counting

Vertebral counts were made from X-ray photographs, 25 or more fish being placed on a sheet of X-ray film 14 x 17 inches. This method is less laborious than clearing and staining, dissection, or boiling the fish and removing the flesh. Also, the latter method cannot be used for specimens preserved in formalin.

The total number of vertebrae is defined as the total number of segments, including the atlas and urostyle. As recorded by Clothier (1950), the atlas of the anchoveta is smaller than the other vertebrae and is sometimes difficult to find. It is best identified by first locating the most anterior neural spine. The other end point, the urostyle, is easily recognized. Vertebral columns were counted at least twice to ensure accuracy.

Counts of fin rays and gill rakers were made under a dissecting microscope. For the gill raker counts, the complete gill-arch was removed and mounted on a piece of cork or heavy cardboard, the upper and lower limbs being held apart with pins. The latter procedure was necessary because of the large number and length of the gill rakers, as well as their proximity to each other.

Dorsal and anal fin ray counts include all rays, however small, which could be seen without dissection. Extreme care was exercised in examining the posterior rays for branching, particularly for the last one or two rays of the anal fin which branch close to the base, and which might otherwise be counted twice. All counts were repeated as a check.

Anchoveta gill rakers are long, slender and very delicate. Because of the large number on each arch, damage usually resulted during the counts. For this reason, repeat counts were not practical.

TABLE I. Gill raker counts from the first gill arch of 50 male and 50 female anchovetas by size groups.

	Size Groups (Length of Fish by 5 Millimeter Intervals)															
	125 — 129		130 — 134		135 — 139		140 — 144		145 — 149		150 — 154		155 — 159		160 — 164	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
	124	133	128	135	132	133	128	137	129	134	133	132	145	128	146	
	123		130	131	129	131	131		123	128	130	128	129	124		
					132		128		123	128	133	134	130	129		
					130		127		135	126	131	128	134	133		
					137		128		134	131	135	128	130	132		
							124		135	131	132	130		137		
									134		134	134		137		
									131		138	135		133		
									134		129	130		137		
									128		137	132		143		
									134		136	134		134		
									129		137	135		132		
									127		134	127		136		
											133	138		126		
											129	133		130		
											138	131		137		
												128		136		
												126		134		
												130				
												130				
Totals	2	1	2	2	5	2	6	1	13	6	16	20	5	18	1	0
Mean Count	123.5	133.0	129.0	133.0	132.0	132.0	127.7	137.0	130.5	129.7	133.7	131.2	133.6	133.2	146.0	

TABLE II. Analysis of variance of gill raker counts of 50 male and 50 female anchovetas.

	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Males	Total	48*	944.5	
	Among size groups	6	340.8	56.80
	Within size groups	42	603.7	
Females	Total	49	713.0	
	Among size groups	6	102.0	17.00
	Within size groups	43	611.0	
	Within size groups-same sex	85	1214.7	14.29
	Among size groups-males	6	340.8	56.80
	Among size groups-females	6	102.0	17.00
	Between sexes	1	11.2	11.20
	Among groups	13	454.0	34.92
Null hypothesis	$\sigma^2_{sexes} = 0$, $F = 14.29/11.20 = 1.28$, df = 85 and 1			

* 1 male specimen in the group 160 - 164 mm. eliminated (see Table I) from the analysis.

RESULTS

Variation of Counts With Sex

No complicated statistical analyses were necessary to establish that the vertebral and anal fin ray counts do not vary with the sex of the anchoveta. From the sample of 100 fish (50 males and 50 females) from Almejas Bay, the average vertebral count was 41.16 ± 0.06 for the males and 41.24 ± 0.07 for the females. Similarly, the average anal fin ray counts were 22.24 ± 0.12 and 22.22 ± 0.11 respectively. The differences are not significant. Reference is made to the dorsal fin ray counts in the section on page 15.

The gill raker counts, tabulated according to the length of the fishes by 5 mm. groups are given in Table I. Analysis of variance of gill raker counts in the two sexes (Table II) follow methods outlined by Snedecor (1946, Chap. 10). The process involved partitioning the variance among size groups into three component parts - among the seven size groups of males, among the seven size groups of females, and between sexes, in order to identify the latter.

Best estimate of the variance of individuals of the same sex and size is 14.29. A test of the null hypothesis that there is no significant difference between sexes is provided by the variance ratio $F = 14.29/11.20 = 1.28$ demonstrating that gill raker counts do not appear to vary with the sex of the anchoveta.

TABLE III. Vertebral, dorsal and anal fin ray counts, according to samples and localities.

Locality and Samples		Vertebrae: No. of Fish with Counts of: 39	40	41	42	43	Total	Mean
Almejas Bay	1		3	36	11		50	41.16
	2		1	36	13		50	41.24
	3		3	37	10		50	41.14
	4		2	34	13	1	50	41.26
	5		3	39	8		50	41.10
	all		12	182	55	1	250	41.18
Guaymas	1	1	2	43	4		50	41.00
	2		6	37	7		50	41.02
	3		4	40	6		50	41.04
	4		3	41	6		50	41.06
	5		3	40	7		50	41.08
	all	1	18	201	30		250	41.04
Ahome Point	1			46	4		50	41.08
	2	1	2	40	7		50	41.06
	3		7	37	6		50	40.98
	4		2	43	5		50	41.06
	5		5	39	6		50	41.02
	all	1	16	205	28		250	41.04
Gulf of Fonseca	1		2	39	9		50	41.14
	2		2	41	7		50	41.10
	3		3	38	9		50	41.12
	4	1	1	42	6		50	41.06
	5		1	45	4		50	41.06
	all	1	9	205	35		250	41.10
Gulf of Panama	1		5	36	9		50	41.08
	2		3	43	4		50	41.02
	3		1	43	6		50	41.10
	4		2	42	6		50	41.08
	5		2	44	4		50	41.04
	all		13	208	29		250	41.06
Gulf of Guayaquil	1		2	44	4		50	41.04
	2		5	40	5		50	41.00
	3		1	41	8		50	41.14
	4		3	40	7		50	41.08
	5		5	41	4		50	40.98
	all		16	206	28		250	41.05
All Localities— All Samples		3	84	1207	205	1	1500	41.08

Locality and Samples		Dorsal Fin Rays: No. of Fish with Counts of: 13	14	15	16	17	Total	Mean
Almejas Bay	1		4	16	5		25	15.04
	2	1	7	13	4		25	14.80
	3		2	14	9		25	15.28
	4		4	17	4		25	15.00
	5		2	22	1		25	14.96
	all	1	19	82	23		125	15.02
Guaymas	1	1	3	19	2		25	14.88
	2		2	20	3		25	15.04
	3		2	23			25	14.92
	4			20	5		25	15.20
	5		1	20	4		25	15.12
	all	1	8	102	14		125	15.03
Ahome Point	1		1	18	6		25	15.20
	2		4	16	5		25	15.04
	3		1	19	5		25	15.16
	4		2	22	1		25	14.96
	5		1	16	8		25	15.28
	all		9	91	25		125	15.13
Gulf of Fonseca	1		4	19	2		25	14.92
	2		4	18	3		25	14.96
	3		2	22	1		25	14.96
	4		3	17	5		25	15.08
	5		3	18	4		25	15.04
	all		16	94	15		125	14.99
Gulf of Panama	1		2	19	4		25	15.08
	2		3	19	3		25	15.00
	3		3	17	5		25	15.08
	4		4	14	7		25	15.12
	5		4	15	6		25	15.08
	all		16	84	25		125	15.07
Gulf of Guayaquil	1		4	17	4		25	15.00
	2		2	19	4		25	15.08
	3		1	20	3	1	25	15.16
	4			20	5		25	15.20
	5		4	17	4		25	15.00
	all		11	93	20	1	125	15.09
All Localities— All Samples		2	79	546	122	1	750	15.05

Locality and Samples		Anal Fin Rays: No. of Fish with Counts of: 18	19	20	21	22	23	24	25	Total	Mean
Almejas Bay	1			2	3	11	8		1	25	22.16
	2			2	4	12	7			25	21.96
	3			1	3	12	8	1		25	22.20
	4				5	8	8	4		25	22.44
	5			1	3	12	9			25	22.16
	all			6	18	55	40	5	1	125	22.18
Guaymas	1		2	4	8	9	2			25	21.20
	2			2	12	7	4			25	21.52
	3			2	12	10	1			25	21.40
	4			2	13	7	3			25	21.44
	5	1		4	8	10	2			25	21.28
	all	1	2	14	53	43	12			125	21.37
Ahome Point	1			5	7	8	4	1		25	21.56
	2		1	4	8	11	1			25	21.28
	3		1	1	9	9	4	1		25	21.68
	4			2	7	14	2			25	21.64
	5				7	15	2	1		25	21.88
	all		2	12	38	57	13	3		125	21.61
Gulf of Fonseca	1			3	8	11	3			25	21.56
	2			1	10	11	3			25	21.64
	3		1	3	6	13	2			25	21.48
	4		1	1	5	12	6			25	21.84
	5			1	11	10	3			25	21.60
	all		2	9	40	57	17			125	21.62
Gulf of Panama	1				2	15	6	2		25	22.32
	2			1	5	13	5	1		25	22.00
	3		1		2	19	2	1		25	21.96
	4			3	6	11	4	1		25	21.76
	5				8	13	4			25	21.84
	all		1	4	23	71	21	5		125	21.98
Gulf of Guayaquil	1			1	6	8	8	2		25	22.16
	2			1	4	12	8			25	22.08
	3			1	8	10	4	2		25	21.92
	4				5	12	5	3		25	22.24
	5			1	8	10	4	2		25	21.92
	all			4	31	52	29	9		125	22.06
All Localities— All Samples		1	7	49	203	335	132	22	1	750	21.80

Number of Vertebrae

The vertebral counts obtained from the various samples and localities are presented in Table III. The range is small, between 39 and 43 vertebrae (see Figure 2). In each locality, the majority of the anchovetas have 41 vertebrae, 80 per cent of the 1,500 fish falling into this category.

Individual samples within the various localities were tested for evidence of significant variation between means (Table IV). The evidence of the analysis is that each series of five samples within a given locality was drawn from a common population. This is shown for the combined data by the variance ratio for "between samples - same locality" and "within samples - same locality". A similar comparison,

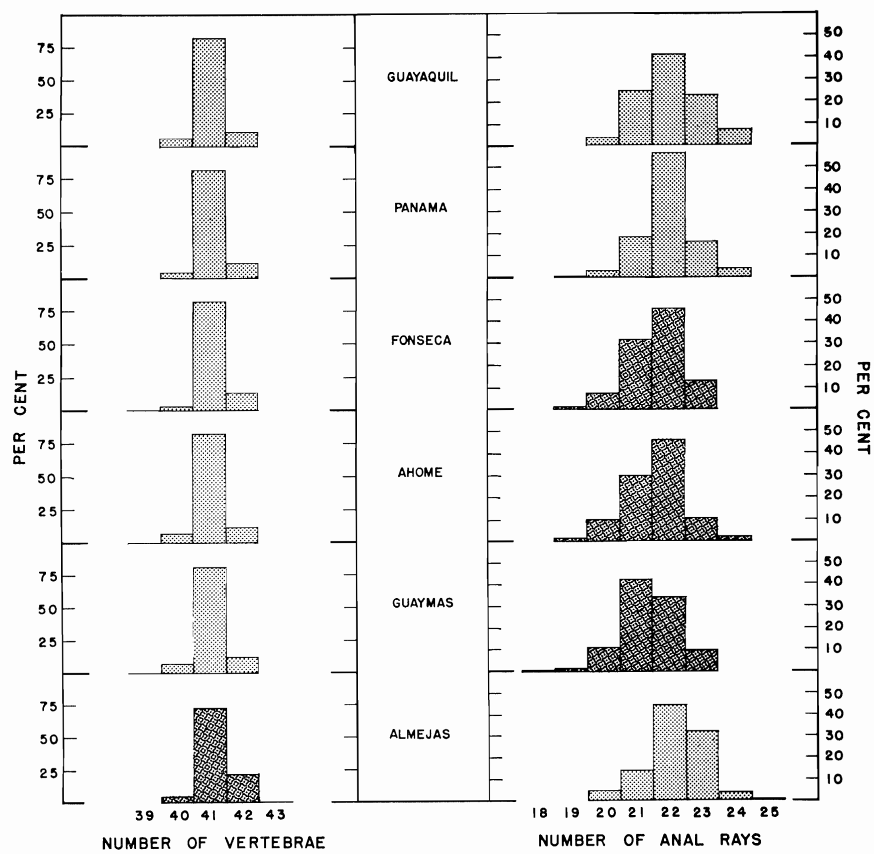

FIGURE 2. Anchoveta vertebrae and anal fin ray counts shown as percentage frequency distributions according to locality. Localities for which the average counts are not significantly different are indicated by similar shading.

in the upper part of the table, for each locality separately, gave the same sort of results. The fact that samples contained fish of varying lengths, not equally represented in all samples, indicates that the vertebral count does not vary significantly with size of fish.

TABLE IV. Analysis of variance of vertebral counts.

Locality	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Almejas Bay	Between Samples	4	0.9	0.23	0.92
	Within Samples	245	62.0	0.25	
Guaymas	Between Samples	4	0.2	0.05	0.24
	Within Samples	245	51.4	0.21	
Ahome Point	Between Samples	4	0.3	0.08	0.42
	Within Samples	245	47.3	0.19	
Gulf of Fonseca	Between Samples	4	0.3	0.08	0.42
	Within Samples	245	45.4	0.19	
Gulf of Panama	Between Samples	4	0.2	0.05	0.29
	Within Samples	245	40.8	0.17	
Gulf of Guayaquil	Between Samples	4	0.8	0.20	1.18
	Within Samples	245	42.6	0.17	
All Localities	Total of all Samples	1499	295.9		
	Between Localities	5	3.7	0.74	3.70*
	Within Localities	1494	292.2	0.20	
	Between Samples-Same Locality	24	2.7	0.11	0.55
	Within Samples-Same Locality	1470	289.5	0.20	

*Significant - probability of occurrence by chance less than 0.01.

The data as a whole were then tested to determine if the samples from the various localities could have been drawn from one homogeneous population, by comparing variation between localities with variation within localities. The observed variance ratio ($F = 0.74/0.20 = 3.70$) exceeds 3.02, the value tabulated for a probability of 0.01 of chance occurrence. With respect to vertebral number, it was, therefore, concluded that the anchovetas from the six areas are composed of more than one population.

The heterogeneity among localities results entirely from the inclusion of the Almejas Bay fish which have a higher average number of vertebrae than the remaining localities (Table III). A test for the other five areas, excluding Almejas Bay, indicates no difference among them (Table V).

TABLE V. Analysis of variance of vertebral counts from all localities except Almejas Bay.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total of all Samples	1249	229.9		
Between Localities	4	0.6	0.15	0.83
Within Localities	1245	229.3	0.18	
Between Samples-Same Locality	20	1.8	0.09	0.47
Within Samples-Same Locality	1225	227.5	0.19	

Finally, to ascertain whether each individual locality differs significantly from Almejas Bay with respect to mean vertebral count, counts from the latter were compared with those from each of the other areas. Except for Fonseca, the values of F obtained corresponded to probabilities of less than 0.01 that they belong to a common population. With Fonseca, the probability was between 0.05 and 0.025 that the fish from the two areas belong to the same population.

Number of Dorsal Fin Rays

The dorsal fin ray counts, according to sample and locality, are given in Table III. Counts range from 13 to 17 with over 70 per cent of the anchovetas having 15 fin rays. No differences were perceived for sex, length, or locality. Analyses of the data showed that there were no significant variations. Dorsal rays do not appear to be a useful character for identifying races of anchovetas.

Number of Anal Fin Rays

The anal fin ray counts shown in Table III range from 18 to 25 with about 90 per cent of the fish in all localities having 21 to 23 rays but with variation associated with locality within this range (see Figure 2).

Before examining the means of the various areas for significant variation, consideration was given to the possibility that the number of anal fin rays might be a function of the length of the fish. Nothing striking was suggested by calculating the average length of the fish having each fin ray number, either by localities or as a whole. Therefore, for each locality, a correlation coefficient between length and ray count was computed as follows:

Locality	**r**	
Almejas Bay	0.106	
Guaymas	0.042	df = 123
Ahome Point	0.137	
Gulf of Fonseca	0.041	5 per cent level = 0.174
Gulf of Panama	—0.057	1 per cent level = 0.228
Gulf of Guayaquil	0.210*	

*Significant at 5 per cent level

Only the anchovetas from Guayaquil show a correlation of even borderline significance between length and number of anal fin rays. For the other localities, values of r are well removed from the point of significance. From this evidence, it appears that the anal fin ray count does not change with size of fish.

Analyses of variance (Table VI) demonstrated that the series of five samples from any given area was drawn from a homogeneous parent population. In this test, the five Panama samples produced the largest value of F (1.64) but even this corresponds to a probability of between 0.10 and 0.25 that the samples were drawn from a homogeneous population. Significant variation exists among the means of the various localities, the variance ratio (F = 12.56/0.82 = 15.32) being highly significant, indicating that the six areas contain more than one population.

TABLE VI. Analysis of variance of anal fin ray counts.

Locality	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Almejas Bay	Between Samples	4	2.9	0.73	0.84
	Within Samples	120	103.8	0.87	
Guaymas	Between Samples	4	1.6	0.40	0.47
	Within Samples	120	103.4	0.86	
Ahome Point	Between Samples	4	4.8	1.20	1.36
	Within Samples	120	105.0	0.88	
Gulf of Fonseca	Between Samples	4	1.8	0.45	0.59
	Within Samples	120	91.5	0.76	
Gulf of Panama	Between Samples	4	4.6	1.15	1.64
	Within Samples	120	84.3	0.70	
Gulf of Guayaquil	Between Samples	4	2.1	0.53	0.58
	Within Samples	120	109.4	0.91	
All Localities	Total of all Samples	749	678.2		
	Between Localities	5	62.8	12.56	15.32*
	Within Localities	744	615.4	0.82	
	Between Samples-Same Locality	24	17.8	0.74	0.89
	Within Samples-Same Locality	720	597.5	0.83	

*Significant - probability of occurrence by chance less than 0.01.

Unlike the situation which occurred for the vertebral counts, no single locality appears to be responsible for the heterogeneity between the means of the anal fin ray counts. To determine what geographical differences exist, means of the counts from each locality were compared with those from every other locality. The resulting values of F, calculated by the method described by Snedecor (1946, p. 227) are tabulated in Table VII, and lead to the conclusion that two population groups may be identified between Mexico and Ecuador, by anal ray counts, namely, (1) Guaymas - Ahome - Fonseca, and (2) Almejas - Panama - Guayaquil. While the Almejas Bay fish do not differ significantly from those collected in Panama and Guayaquil, on the basis of average number of anal fin rays, they do differ significantly from those found in the three intervening localities, Guaymas, Ahome, and Fonseca, which themselves form a homogeneous population with respect to anal ray counts. From this geographical consideration, it is concluded that Almejas Bay is a separate population.

TABLE VII. Values of F resulting from analyses of variance used to compare anal fin ray counts of each locality with each other locality.

	Value of F				
Locality	Almejas Bay	Guaymas	Ahome Point	Gulf of Fonseca	Gulf of Panama
Almejas Bay					
Guaymas	48.96*				
Ahome Point	23.84*	4.14			
Gulf of Fonseca	23.06*	5.13	0.02		
Gulf of Panama	3.42	29.62*	10.58*	10.60*	
Gulf of Guayaquil	1.02	34.80*	14.61*	14.58*	0.60

*Significant - probability of occurrence by chance less than 0.01.
Data required for above calculations obtained from Tables III and VI.

Number of Gill Rakers

As in other anchovies, gill rakers in the anchoveta increase in number with the length of the fish. It was found that the relationship between the two variates is not linear and cannot be made linear by any simple transformation. Therefore, it is not possible to apply the ordinary analysis of covariance.

Faced with non-linear regression, the problem arose of eliminating the effect of length. This was done by fitting an empirical curve to the data as a whole, and using the deviations of the observed gill raker counts from the expected, as determined by the curve, to compare the gill raker counts from various localities. If the null hypothesis, that there is no difference between gill raker counts of fish of the same length from different localities is satisfied, there will be no significant differences in the deviations from the curve. Conversely, if the hypothesis is not satisfied, the average deviations will differ between localities.

To establish the hypothetical curve, shown in Figure 3, gill raker counts of 734 of the 750 fish were tabulated according to 5 mm. length intervals from 110 to 159 mm. The few (16) smaller and larger anchovetas above and below this range were discarded so as not to have less than ten fish in any 5 mm. interval. The means of the lengths and gill raker counts were calculated for the fish falling in each interval. These data were then plotted graphically and the points joined to form a regression line. Being somewhat irregular, the line joining the points was smoothed by inspection.

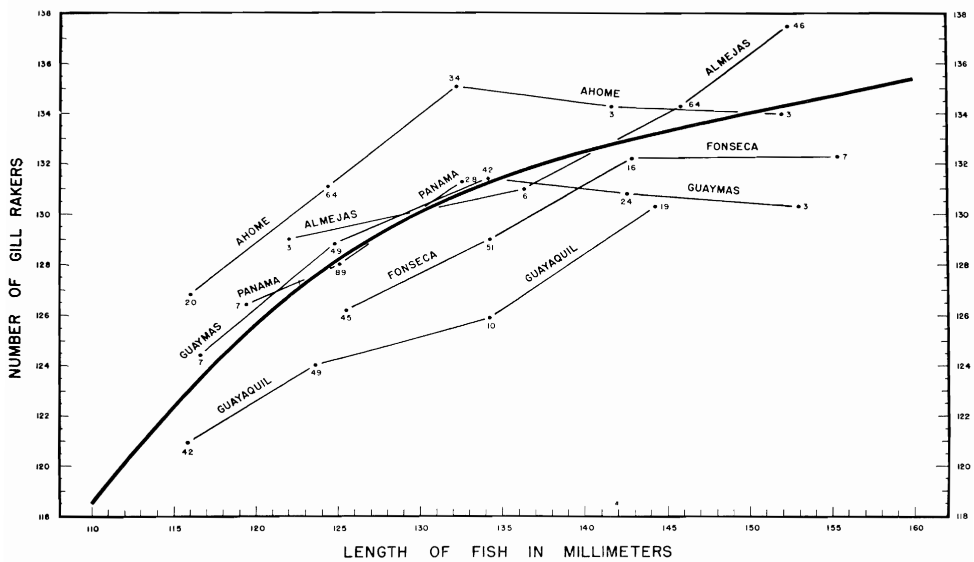

FIGURE 3. Relationship between number of gill rakers on the first gill arch and length of fish in millimeters. Heavy line denotes the empirical curve describing the relationship as determined by counts from all localities. Light lines indicate the relationship for the individual localities. For the latter, numbers of specimens, on which each point is based, are shown.

It was hypothesized that if the anchovetas from the six localities belong to a common population with respect to gill raker counts, the average deviations from the line will be no greater than expected to arise by chance. The analysis of variance of deviations from the empirical curve is shown in Table VIII. It was found, first, that the deviations of gill raker counts among samples taken at the same locality are greater than might be expected by chance from the variation of deviations of counts within samples. This is true not only for the combined data (F = 3.77), but also for three of the six individual localities (Guaymas, Fonseca, Guayaquil). Whether this represents real differences between groups of fish from the same place, or may be in part due to the failure of the empirical curve to properly represent the true relationship between length and gill raker count, is impossible to say. In any case, in order to allow for this, the mean square between samples from the same locality (69.14) should be used to judge the significance of the differences between localities. The resulting value of F (671.93/69.14 = 9.72) is highly significant, indicating that there are real differences between localities in gill raker counts for fish of the same length.

TABLE VIII. Analyses of variance of deviations of gill raker counts from empirical curve of length versus gill raker count.

Locality	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Almejas Bay	Between Samples	4	70.00	17.50	0.97
	Within Samples	114	2053.27	18.01	
Guaymas	Between Samples	4	521.46	130.37	7.69*
	Within Samples	120	2033.85	16.95	
Ahome Point	Between Samples	4	82.41	20.60	1.06
	Within Samples	119	2315.34	19.46	
Gulf of Fonseca	Between Samples	4	664.48	166.12	8.17*
	Within Samples	115	2337.99	20.33	
Gulf of Panama	Between Samples	4	69.26	17.32	0.95
	Within Samples	120	2191.87	18.27	
Gulf of Guayaquil	Between Samples	4	251.84	62.96	3.69*
	Within Samples	116	1979.97	17.07	
All Localities	Total of all Samples	733	17931.40		
	Between Localities	5	3359.66	671.93	9.72*
	Within Localities	728	14571.74	16.13	
	Between Samples - Same Locality	24	1659.45	69.14	3.77*
	Within Samples - Same Locality	704	12912.29	18.34	

*Significant - probability of occurrence by chance less than 0.01.

The next step was to determine what geographical differences in gill raker counts may be responsible for the heterogeneity between localities. Since it has been demonstrated that the six localities do not make up a common population with respect to gill raker counts, the data were inspected to find out what are the differences between baiting localities. The major differences are apparent from the graphical presentation of Figure 3.

As explained on page 18, data from all localities were combined to prepare the line showing the relationship between length and number of gill rakers (Figure 3). Points showing the means of the lengths and number of gill rakers by 5 mm. intervals of length were plotted. These points were used to draw by inspection, the hypothetical curve. In the same illustration, the relationship between gill raker counts and length for each of the various localities is also shown by plotting the mean for each locality for each 10 mm. interval of length. Points for the individual localities were not plotted at 5 mm. length intervals because in several instances, intervals at either end of the range contain only one to six fish and tended to confuse the picture. Even with the 10 mm. intervals, as few as three specimens are represented. The numbers of specimens on which each point of Figure 3 is based are shown by numbers adjacent to the points.

When the individual localities are compared with the hypothetical curve, it is noted that Almejas Bay, Guaymas, and Panama fall close to this curve, whereas Guayaquil is well below and Ahome Point is well above. Evidently, the Guayaquil (and perhaps Fonseca) anchovetas have a smaller number of gill rakers, and the Ahome Point fish have a larger number, than do the other areas. The differences do not indicate latitudinal variation, nor do they show that the counts are more similar for localities which are closer to each other. The graphical presentation seems to indicate that at least three separate groups may be recognized on the basis of the gill raker counts: (1) Almejas - Guaymas - Fonseca - Panama, (2) Ahome Point, and (3) Guayaquil. Fonseca may be significantly different from Almejas-Panama-Guaymas.

DISCUSSION

On the basis of meristic characters, there appears to be more than one population of anchovetas between Mexico and Ecuador. Significant variation was found between localities for counts of vertebrae, anal fin rays, and gill rakers. The anchoveta populations of the six major baiting areas studied are separated on the basis of these characters as follows:

Vertebrae	**Anal Fin Rays**	**Gill Rakers**
1. Almejas Bay	1. Guaymas, Ahome Point, Gulf of Fonseca	1. Almejas Bay, Guaymas, Gulf of Panama
2. All other areas	2. Almejas Bay, Gulf of Panama, Gulf of Guayaquil	2. Ahome Point
		3. Gulf of Fonseca (?)
		4. Gulf of Guayaquil

For anal fin ray counts, Almejas Bay anchovetas are similar to those found in Panama and Guayaquil but different to those from more nearly adjacent localities (Guaymas, Ahome Point, and Fonseca). Also, Almejas Bay fish have a significantly higher number of vertebrae than those in any of the other places. Taking these differences into consideration, it is rather clearly shown that the anchovetas in Almejas Bay are a distinct or local population.

Fish taken from Guaymas, Ahome Point, and Fonseca were found to have the same average number of vertebrae and anal fin rays. They appear, however, to differ in gill raker counts.

Although Panama anchovetas are not different to those from Guayaquil on the basis of either vertebral or anal ray counts, they do have a higher average number of gill rakers. Besides a significant difference in anal rays, Panama fish also have a higher gill raker count than fish at Fonseca, the locality immediately to the north.

Table IX summarizes these meristic count differences between localities. Each locality is distinct from every other locality for one or more of the characters examined.

TABLE IX. Each locality compared with each other locality on the basis of differences in the average numbers of vertebrae, anal fin rays, and gill rakers.

	Distinctive Characters*				
Locality	Almejas Bay	Guaymas	Ahome Point	Gulf of Fonseca	Gulf of Panama
Almejas Bay					
Guaymas	V-A				
Ahome Point	V-A-G	G			
Gulf of Fonseca	V-A-G	G	G		
Gulf of Panama	V	A	A-G	A-G	
Gulf of Guayaquil	V-G	A-G	A-G	A-G	G

*V = difference in vertebral count
A = difference in anal ray count
G = difference in gill raker count

So far as the writer is aware, studies of influence of environment on meristic characters of fishes have not been undertaken in sub-tropical or tropical waters, but it is generally accepted that in temperate waters, the mean value of meristic characters of fishes is influenced by environmental factors, particularly temperature during the early development of the fish larvae. Counts vary inversely with temperature (Schmidt, 1921; Vladykov, 1934; McHugh, 1951; Táning, 1952). Several hundred surface water temperature readings were extracted from a sample of the 1951 and 1952 logbook records kept by tuna fishing vessels to see if temperature is related to meristic counts of the anchovetas. For each baiting locality, the monthly minimum and mean temperature was determined. Superficial examination of the surface water temperatures did not suggest any relationship between meristic counts and temperature in the various localities.

It is possible that salinity may affect meristic counts. Work in the Gulf of Nicoya in Costa Rica, which until 1948 supported a large population of anchovetas, indicates that there is probably a wide variation in the salinity in the areas supporting anchovetas. There is an estuary at the head of the Gulf of Nicoya, and with the possible exception of Almejas Bay, estuaries are also found at the other localities. Salinities in Nicoya vary from 22 to 32 parts per thousand, having the highest concentrations in the fall and winter months.

Whatever their cause, genetic or environmental, the observed differences in meristic counts indicate that there is not free inter-change of anchovetas between the six principal baiting areas, though there could be partial inter-mixing. Until tagging experiments are undertaken to measure the degree of migration, there is adequate evidence to indicate that the anchoveta populations in the several major baiting localities should be provisionally considered as being separate stocks.

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