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Management of fishery resources in the Gulf of Nicoya, Costa Rica; Methods and preliminary results

by

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Abstract: Coastal tropical fishery resources are commonly harvested from small vessels with relatively unsophisticated gear such as hand lines, traps and nets. Although these artisanal fishing practices are not as productive, on a per unit basis as those used in more advanced temperate zone fisheries, substantial fishing effort is nonetheless generated by the magnitude of operating units. Available resources may, in many cases, be overexploited. The successful development of tropical artisanal fisheries requires that appropriate management measures be applied so that maximum harvests may be sustained without depleting resources.

Research conducted in the Gulf of Nicoya, Costa Rica, during the period July, 1976 to June, 1977 was aimed at developing data collection and analysis techniques for assessing tropical fishery resources harvested by artisanal fleets. Length frequency data obtained from commercial landings were analyzed to determine the growth rate of a predominant species in the commercial catch *(Micropogon altipinnis)*. Some preliminary results are presented.

The University of Rhode Island, in cooperation with the Departamento de Pesca y Caza Marítima of the Ministerio de Agricultura y Ganadería in Costa Rica, initiated an interdisciplinary study of biological, economic and sociological aspects of the artisanal fishery in the Gulf of Nicoya, Costa Rica, in July, 1976. Biological data were collected continuously over the course of one year. The principal objective of this research was to design systems of data collection and analysis which could be applied generally to the development and management of tropical artisanal fishery resources. The project was funded by a 211(d) grant awarded to the University of Rhode Island by the U. S. Agency for International Development.

A successful plan for fishery development and management requires an initial biological assessment of available resources. A specific objective of the resource assessment portion of this project was to apply the Beverton-Holt yield model to individual species populations in the Gulf of Nicoya in order to predict the maximum sustainable yield per recruit which each species population could support and the optimum amount of fishing effort required to provide it. Data collection methods and analytical techniques will be critically evaluated in order to determine

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the conditions under which the procedures which were tested in Costa Rica could or could not be applied to tropical artisanal fisheries in other areas.

The population parameters which are required by the Beverton-Holt yield model are growth and mortality rates. The data source for parameter estimation was length frequency and catch and effort data obtained from samples of commercial landings in Puntarenas, the principal landing site for the artisanal fleet in the Gulf. Additional data obtained on board commercial shrimp trawlers and gill net vessels provided important accessory information. During the period July, 1976 to June, 1977 over 1400 landings were sampled and over 40,000 length measurements were obtained for fifteen different species. These fifteen species accounted for an estimated 70% of the commercial artisanal landings in Puntarenas during July-December, 1976. Table 1 presents the percent composition of nine principal species and three commercial groups (each composed of various species) landed by the artisanal fleet during July-December, 1976 as estimated from landings surveys.

TABLE 1

*Estimated percent composition, by weight, of artisanal catch based on samples of commercial landings **
Gulf of Nicoya: July-December, 1976

Species or commercial classification	Gill nets	Hook & line	Long line	All gear
Cynoscion albus	11	16	1	11
Cynoscion stolzmanni	4	3	1	3
Cynoscion squamipinnis	14	6	1	11
Cynoscion phoxocephalus	1	3	1	1
Centropomus undecimalis	5	2		4
Micropogon altipinnis	21	8	15	18
Lutjanus argentiventris	1	6	1	1
Lutjanus guttatus	1	3	2	1
Scomberomorus maculatus	8			6
Sea catfish	10	23	35	15
Shark	17	16	28	18
Miscellaneous	10	13	17	11

* Total landed weight sampled was 67,972 kgs and was distributed as follows: 72% in gill nets, 20% by hook and line, and 8% by long line. Total number of landings sampled was 625. Data courtesy Oficina de Pesca, Ministerio de Agricultura y Ganadería, Puntarenas. Surveys were *not* conducted on a random basis and therefore data are approximate.

Corvina agria *(Micropogon altipinnis)* is harvested principally with long lines and gill nets. The gill net fishery is conducted almost exclusively with large mesh bottom nets (5.5-6 inch stretch mesh) and is most active in Zone 4 "inside" the Gulf during the wet season (May-November); the fishery is forced "outside" the Gulf to Zones 6 & 7 by strong north winds during the dry season (December-April).

Figure 1 shows the designated fishing zones in the outer and inner reaches of the Gulf of Nicoya as they were adopted for use during this study.

Length frequencies for corvina agria were compiled by length class on a monthly basis by fishing zone and gear type. The importance of compiling length data separately for different fishing zones was evident when data obtained from the same gear for zones 4,6 and 7 were compared. Not only was the mean size at capture (l_c) smaller by six centimeters "outside" the Gulf (Fig. 2), but there was no obvious increment in size from one month to the next as there was "inside" the Gulf (Figs. 3 and 4).

These data, incidentally, raised questions concerning the size selectivity of gill nets as they are used in the Gulf. In fact, a linear regression of maximum body depth versus total length predicted that l_c in a six inch mesh should be 57 cm. There was no immediate explanation of why l_c inside the Gulf was larger. The suggestion was that smaller fish simply were not available for capture. Heavy exploitation by the shrimp fleet, which is only permitted to operate outside the Gulf, may have been responsible for reducing the mean size at capture in zones 6 and 7.

METHODS

Monthly length frequency distributions compiled for Zone 4 in 5.5-6 inch mesh gill nets during July-December, 1976 (Fig. 3) were analyzed to determine the number of size groups present in each monthly catch record, and the mean length for each size group. Polymodal frequency analysis was performed with the aid of a computer program (ENORMSEP) which determined the number of inflexion points in a cumulative frequency curve by means of successive polynomial regression analyses and estimated the mean length, variance and percent composition of each normally-distributed size group by means of iterative solutions of maximum likelihood parameter estimates. The mathematical analysis was developed by Hasselblad (1966) and the program by Tomlinson (1971) and Yong & Skillman (1975).

There are certain sources of error which are inherent in this technique. For example, the variances of individual mean lengths become excessive when there is considerable overlap between adjacent size groups or when sample size is low. Nevertheless, it was preferable to simple visual analysis since overlapping size groups often produced visually misleading frequencies in the zone of overlap.

Since the ENORMSEP program generated results for two, three or four size groups for each monthly catch record, two criteria were used to select the most acceptable modality:

1) the lowest chi-square statistic revealed which analysis produced the least divergence between predicted and observed length frequencies, and

2) the only acceptable modality was the one which accounted for all the size groups present in preceding samples, excepting groups of older fish which could be assumed to no longer remain vulnerable to capture.

Once mean length values for individual catch records were determined, monthly increments in mean length for given size groups were used to determine the annual instantaneous growth rate (K) and the theoretical maximum length attained by individuals in the population (L_∞) by fitting the von-Bertalanffy growth function*

* The von-Bertalanffy function is known to mathematically approximate the growth history of fish of determinable ages and is applied generally to fish populations.

$$l_t = L_\infty \left(1 - e^{-K(t - t_o)}\right)$$

where l_t = the length at any time (or age) t
t_o = the age at which growth begins

to observed length increments by means of a second computer program developed by Fabens (1965). Mean lengths were entered into the program as if they were lengths at release and recapture for individual fish since this program was designed to deal with tag and recapture data. *An overriding assumption in the selection of monthly length increments was that size groups were represented in successive months at equal or increased mean lengths* until they reached a size that was no longer exploited by the gear, i. e. growth interpretations which assumed *reductions* in mean length between successive months were not accepted. Positive growth was, in fact, a condition required by the Fabens program.

RESULTS

Polymodal frequency analysis: Mean lengths obtained by computer analysis (Table 2) were arranged into modal length increments for four size groups and were ranked according to relative age (Table 3).

TABLE 2

Monthly mean lengths, variances and percent compositions for component size groups of Micropogon altipinnis *as determined by computerized polymodal frequency analysis*

Zone 4, 5.5-6 inch mesh gill nets

Month	Sample size	Mean length (cm)	Variance (cm)	Percent Composition
July	342	65.0	161.8	38.2
		68.2	109.0	61.8
August	580	56.5	21.5	3.0
		62.1	47.7	33.2
		65.8	120.8	37.9
		69.1	73.7	26.0
September	258	53.8	41.5	4.4
		62.0	77.7	35.0
		67.8	109.1	60.7
October	338	59.3	84.2	8.3
		65.0	61.2	52.4
		68.5	83.0	39.3
November	129	59.1	5.6	3.9
		63.6	8.5	17.6
		67.2	16.5	45.6
		70.4	29.9	33.0
December	198	65.1	73.2	57.5
		68.9	29.4	42.5

TABLE 3

Monthly mean length increments of component size groups (in cm) for Micropogon altipinnis *as determined by computerized polymodal frequency analysis Zone 4, 5.5-6 inch mesh gill nets*

Group	July	August	Sept.	Oct.	Nov.	Dec.
A				59.3	63.6	65.1
B		62.1	62.0	65.0	67.2	68.9
C	65.0	65.8	67.8	68.5	70.4	
D	68.2	69.1				

The mean monthly length increments for these four size groups were 2.9, 1.7, 1.4, and 0.9 cm, respectively. As predicted by the von-Bertalanffy growth function, each group grew more slowly than the preceding (and younger) group. The mean lengths presented in Table 3 are shown as arrows in the monthly length frequency distributions in Figure 3.

Estimation of K and L_∞ : A fit of the von-Bertalanffy growth function to the length increment data for all four size groups according to the Fabens program produced the following parameter estimates when the length at which growth begins (length at t_0) was arbitrarily set equal to 0.5 cm:

Maximum limiting length L_∞ = 79.25 cm
Instantaneous annual growth rate K = 1.53
Maximum age at L_∞ = 49 months

The precision of these estimates was indicated by the changes in parameter estimates between the fifteenth and twentieth (and last) iteration. The estimate of K varied by only .062 while L_∞ varied by 8.7×10^{-4} cm.

As indicated by the growth curve produced by the estimated parameter values (Fig. 5), the predicted growth of *Micropogon altipinnis* was very rapid. According to the model, the maximum life span was four years and more than 75% of the growth was achieved in the first year. Within the size range 60-75 cm, *M. altipinnis* was predicted to grow slightly more than a centimeter per month.

DISCUSSION

The preliminary nature of these results must be emphasized. It is especially risky to base growth rate estimates on only six months of data and to fit an entire growth curve to such a limited range of points. An anticipated extension of University of Rhode Island/Ministry of Agriculture joint research in 1979 should permit growth rate estimation for a wider range of sizes by means of a tag and recapture study in the Gulf.

Given the occasionally high variances reported for certain mean lengths as determined by ENORMSEP (Table 2), the precision of mean length estimation was not, in many cases, very good. For an individual group sample size of 100, for example, a variance of 100 cm would produce an interval estimate of ± 2 cm at a 95% confidence level. High variance seemed to be unavoidable, given the considerable overlap between adjacent size groups and the mathematical procedure used to perform the polymodal frequency analysis. Note that there was no obvious relation between low sample size and high group variance. Considerably more length frequency data are required in order to arrive at a more convincing growth rate estimate.

As a means to further confirm the results of the polymodal frequency analysis and the subsequent growth rate estimate, available length frequency data were compiled for 15-day periods and analyzed visually. A preliminary examination of some of these data was encouraging. Significant mean length increments were observed within months in Zone 4 (Fig. 6) and also for bi-monthly length distributions obtained from the hook and line and long line fisheries in Zone 7 (data not shown). The observed increment of the predominant mode in the hook and line data during the 60-day period from late January to late March, 1977 (54-60 cm) conformed exactly to the increment predicted by the growth curve. The data in Figure 6 suggested that growth did indeed exceed one centimeter per month.

The gill net fishery for corvina agria inside the Gulf of Nicoya apparently harvested as many as four size groups simultaneously within the length range 60-75 cm during July-December, 1976. According to the predicted growth history of this species, however, only a single year class should be represented in this size range, i. e. fish in their second year of growth. Length frequency data collected by sex in zones 6 and 7 indicated that female *M. altipinnis* were larger than males. Sexual dimorphism in size would produce adjacent and overlapping size groups such as those observed in the available catch records.

Additional size groups within a year class would be produced if there were more than one spawning season within a year. Such behavior is not uncommon in tropical species (Munro *et al.*, 1973). An average annual length frequency curve for *M. altipinnis* captured in 5.5-6 inch mesh gill nets in Zone 4 (Fig. 2) revealed two broadly overlapping size groups with modal lengths approximately 3 cm apart. These are assumed to represent male and female fish of the two-year age class. The average annual length frequency curve for zones 6 and 7 for the same year (Fig. 2) showed a single broad size group, perhaps because at this reduced size male and female size groups overlapped to such an extent that they could not be distinguished visually.

Assuming that corvina agria do, in fact, grow at such a rapid rate, what are some of the implications of such rapid growth? From the point of view of data analysis, the fact that each size group remains in the exploitable phase for only a few months means that parameter estimation techniques which rely on a long time series of data for individual size groups must be replaced by techniques which emphasize repeated analyses for different population cohorts over short time periods. Averaging of estimated parameter values for a number of cohorts is required in order to reduce sampling errors such as those produced by seasonal variations in growth or mortality for individual cohorts. In addition, methods which

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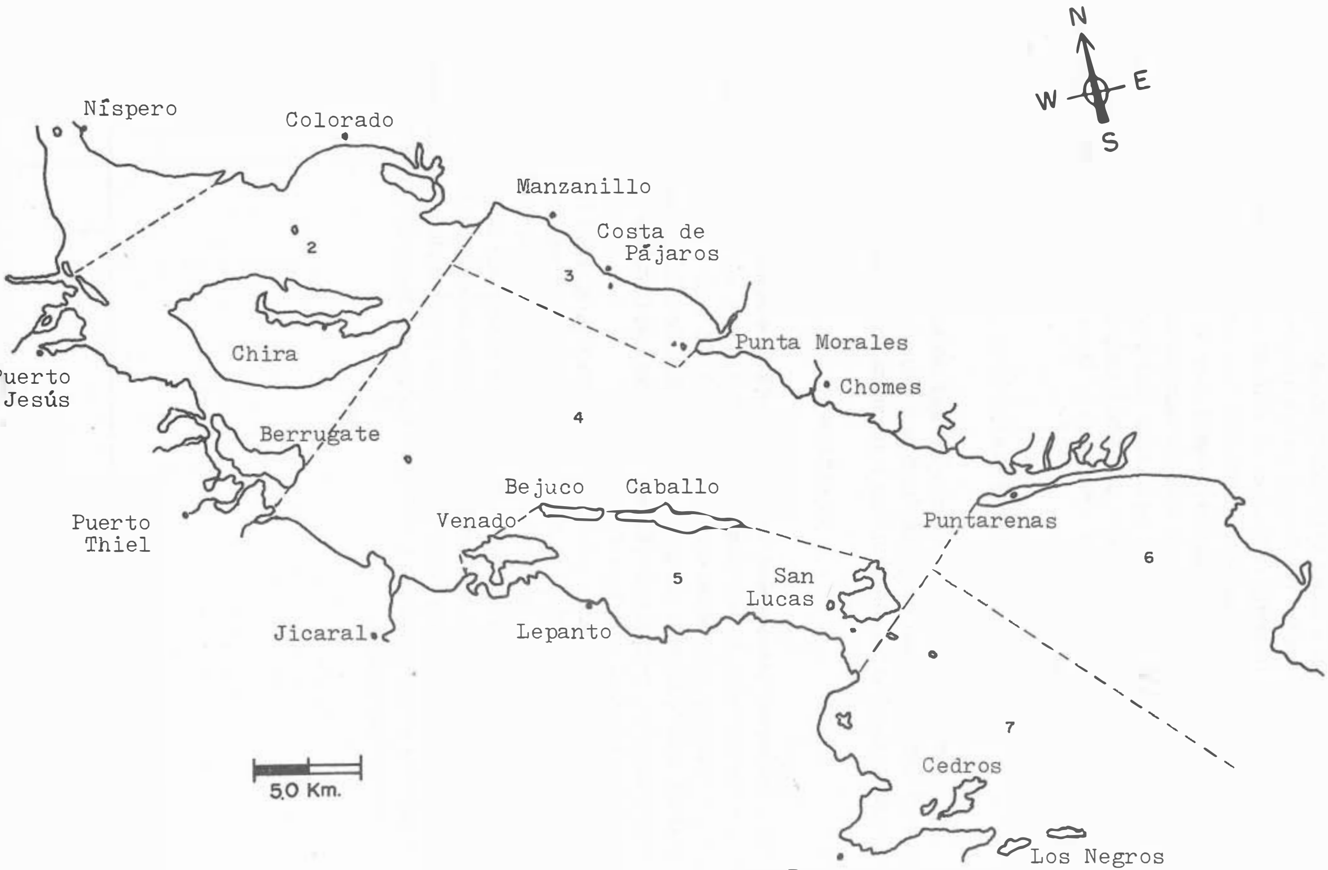
Fig. 1. Map of the Gulf of Nicoya, Costa Rica, showing seven fishing zones and the principal islands and landing sites for the artisanal fishing fleet.



N
E
W
S
Níspero
Colorado
Manzanillo
Costa de Pájaros
2
3
Chira
Punta Morales
Chomes
Puerto Jesús
Berrugate
4
Bejuco
Caballo
Venado
Puerto Thiel
Puntarenas
6
5
San Lucas
Jicaral
Lepanto
7
Cedros
5.0 Km.
Los Negros
Paquera
wgm

1

require at least several year-classes to be represented simultaneously–such as "catch curve" analysis to compute total mortality rates–can not be used.

From the point of view of resource management, the exploitation of a population composed of a single year class of recently-recruited fish means that the resource is very vulnerable to physical and ecological factors that might damp recruitment. Physical oceanographic factors such as temperature which affect the survival rate of eggs and larvae are, fortunately, less variable in the tropics. On the other hand, an annual instantaneous growth rate as high as 1.5 has enormous implications for the fishery. At that rate, the biomass of fish which would be added to the population each year would be so high that it would be difficult to overfish the stock, especially if a size selective gear which only harvests older, mature fish is used. Such conclusions are only speculative, however, until information on mortality rates is available.

ACKNOWLEDGMENTS

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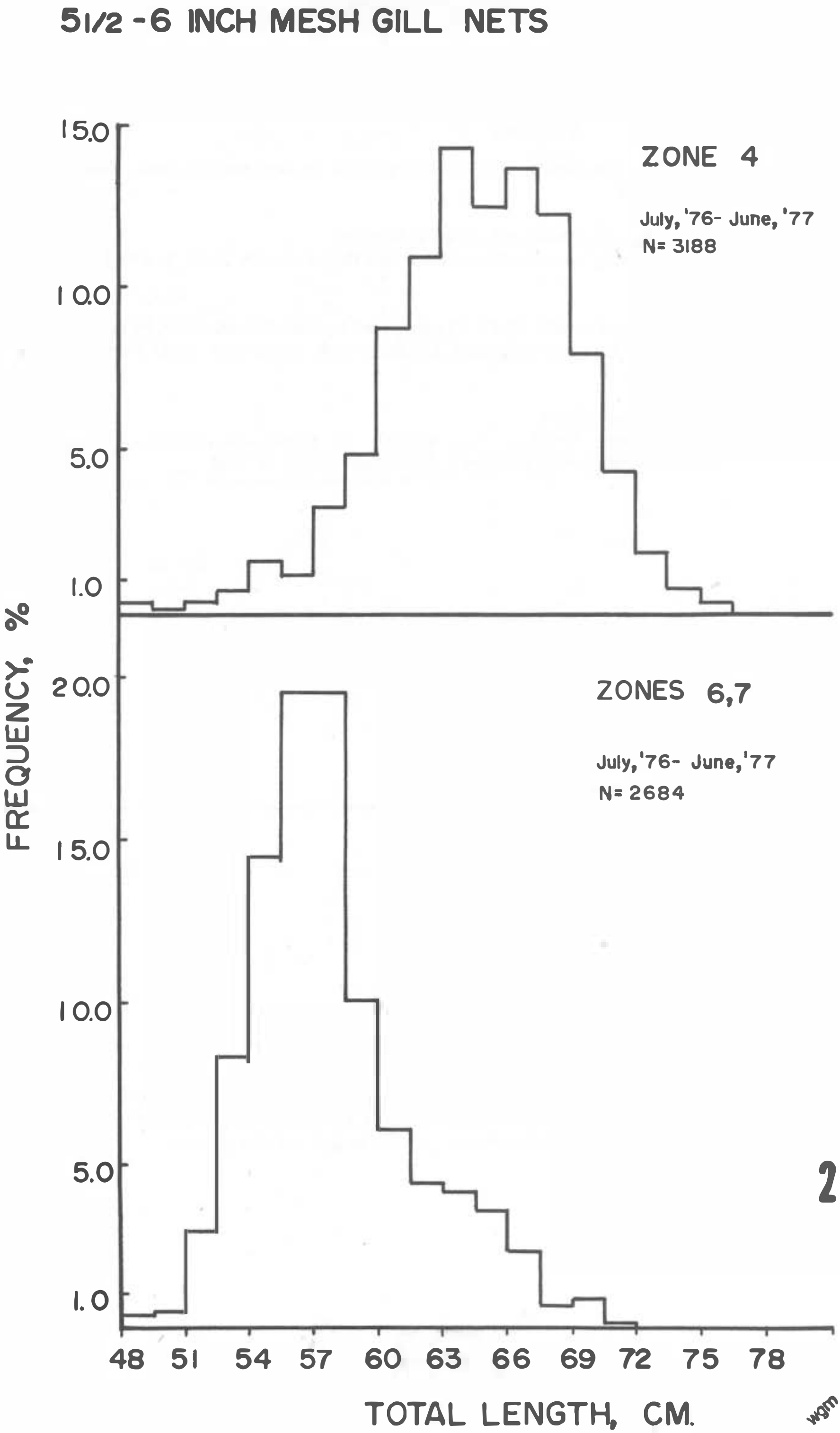
RESUMEN

Se estudiaron datos sobre longitud en 1845 ejemplares de corvina agria *(Micropogon altipinnis)* de los desembarques de la flota artesanal en Puntarenas, Costa Rica, durante seis meses consecutivos en 1976 y se determinó la longitud promedio de cada conjunto de peces durante cada mes. Luego se calculó la tasa instantánea anual de crecimiento (K) de la función von-Bertalanffy a través de los incrementos en longitud con respecto al tiempo.

Para cuatro conjuntos de peces, cuyos tamaños promedios fueron entre 59 y 71 cm, se calculó un valor de K igual a 1,53 y una longitud máxima (L_∞) de 79,25 cm. Según estos resultados, la corvina agria en el Golfo de Nicoya alcanza 60 cm en el primer año, crece más de 1 cm por mes durante el segundo año y tiene un ciclo de vida de cuatro años. Un crecimiento tan notorio aumentaría la biomasa de la población muy rápidamente y haría más difícil una sobre-explotación del recurso. Estos resultados son preliminares y se deben confirmar a través de otro estudio, por ejemplo, uno de marcación.

Fig. 2. Annual mean length frequency distributions for *Micropogon altipinnis* captured in 5.5-6 inch mesh gill nets, Zone 4 and Zones 6 and 7, during the period July, 1976 to June, 1977.


5 1/2 - 6 INCH MESH GILL NETS
ZONE 4
July, '76- June, '77
N= 3188
ZONES 6,7
July, '76- June, '77
N= 2684
FREQUENCY, %
15.0
10.0
5.0
1.0
20.0
15.0
10.0
5.0
1.0
48
51
54
57
60
63
66
69
72
75
78
TOTAL LENGTH, CM.
2
wgm

LITERATURE CITED

Fabens, A.
1965. Properties and fitting of the von-Bertalanffy growth curve. *Growth*, 29: 265-289.

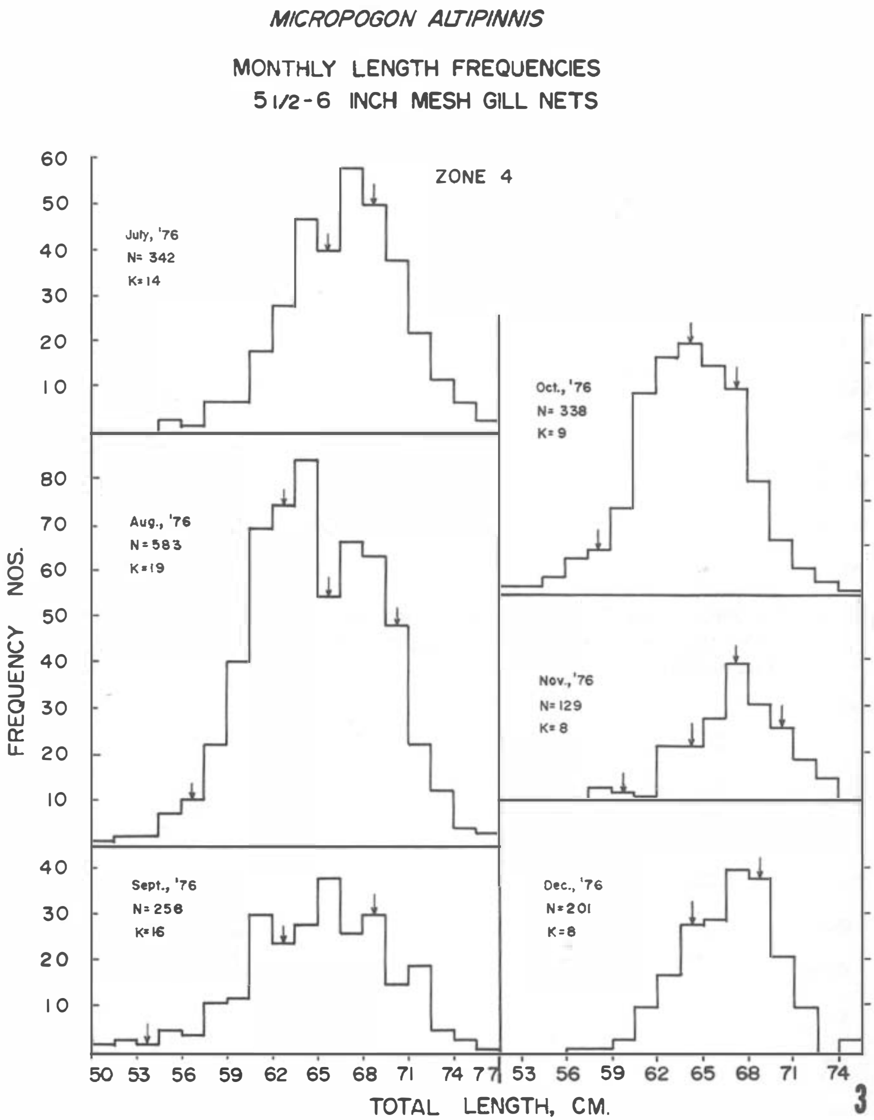
Hasselblad, V.
1966. Estimation of parameters for a mixture of normal distributions. *Technometrics*, 8: 431-444.

Munro, J. L., V. C. Gaut, R. Thompson, & P. H. Reeson
1973. The spawning seasons of Caribbean reef fishes. *J. Fish. Biol.*, 5: 69-84.

Tomlinson, P. K.
1971. Program name–NORMSEP. Programmed by Victor Hasselblad. *In* N. J. Abramson (comp.), *Computer programs for fish stock assessment.* FAO Fish. Tech.-Paper 101, 10 p.

Yong, M. Y. Y., & R. A. Skillman
1975. A computer program for analysis of polymodal frequency distributions (ENORMSEP), FORTRAN IV. *Fish. Bull., U. S.*, 73: 681.

Fig. 3. Monthly length frequency distributions for *Micropogon altipinnis* captured in 5.5-6 inch mesh gill nets, Zone 4, during the period July-December, 1976. Arrows indicate the estimated mean lengths for individual size groups.


MICROPOGON ALTIPINNIS
MONTHLY LENGTH FREQUENCIES
5 1/2-6 INCH MESH GILL NETS
ZONE 4
July, '76
N= 342
K=14
Aug., '76
N=583
K=19
Sept., '76
N=256
K=16
Oct., '76
N= 338
K= 9
Nov., '76
N= 129
K= 8
Dec., '76
N=201
K=8
FREQUENCY NOS.
TOTAL LENGTH, CM.
50 53 56 59 62 65 68 71 74 77
53 56 59 62 65 68 71 74

3

Fig. 4. Monthly length frequency distributions for *Micropogon altipinnis* captured in 5.5-6 inch mesh gill nets, Zone 6 (September, 1976 to March, 1977) and Zone 7 (January-April, 1977).

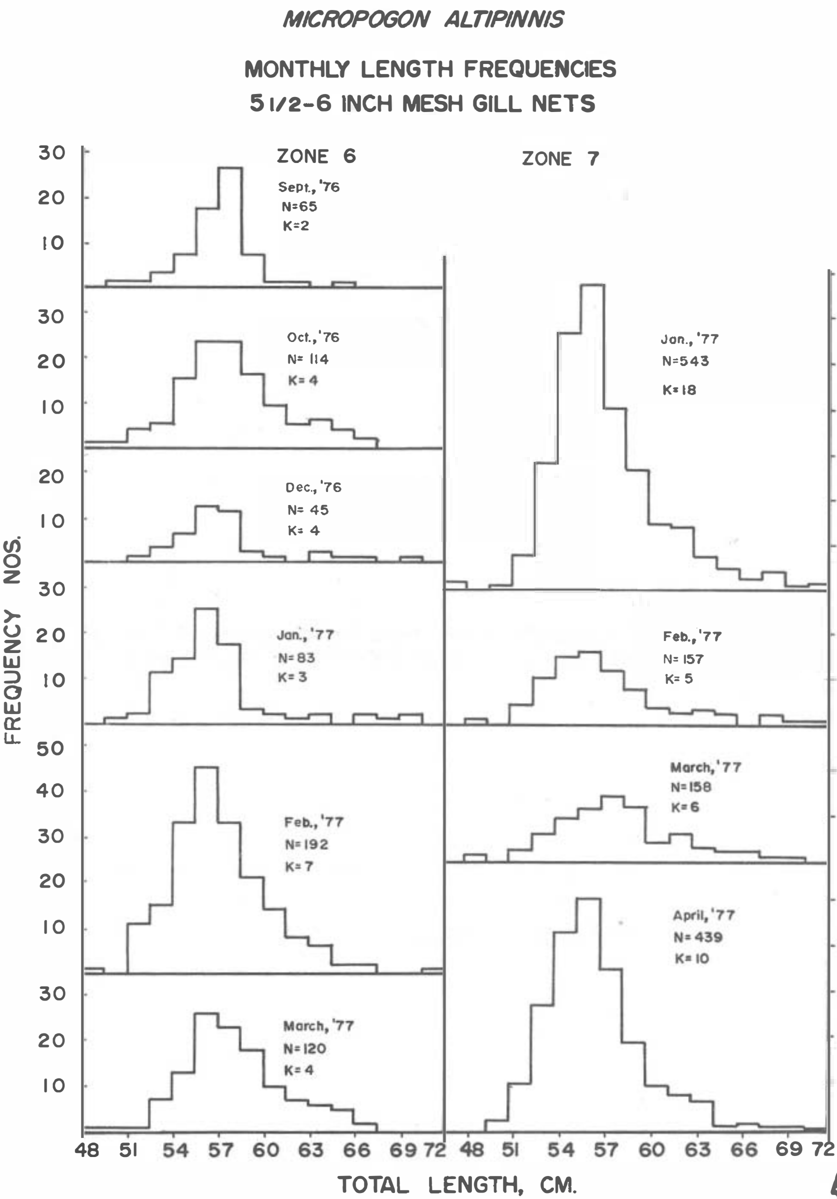

MICROPOGON ALTIPINNIS
MONTHLY LENGTH FREQUENCIES
5 1/2-6 INCH MESH GILL NETS
ZONE 6
ZONE 7
Sept., '76
N=65
K=2
Oct., '76
N= 114
K= 4
Dec., '76
N= 45
K= 4
Jan., '77
N=83
K=3
Feb., '77
N=192
K=7
March, '77
N=120
K=4
Jan., '77
N=543
K=18
Feb., '77
N=157
K=5
March, '77
N=158
K=6
April, '77
N=439
K=10
FREQUENCY NOS.
TOTAL LENGTH, CM.
48 51 54 57 60 63 66 69 72
4

Fig. 5. Predicted von-Bertalanffy growth curve for *Micropogon altipinnis* captured in 5.5-6 inch mesh gill nets, Zone 4, when $K = 1.53$, $L_\infty = 79.25$ cm and the length at $t_o = 0.5$ cm.

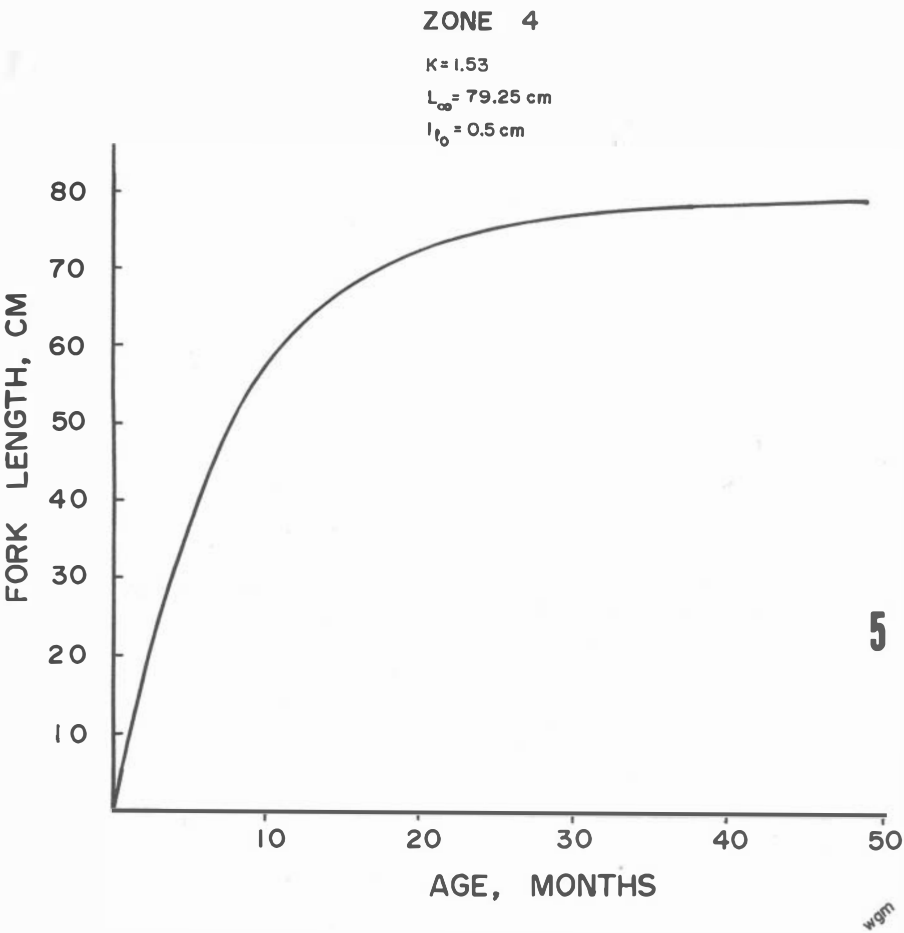
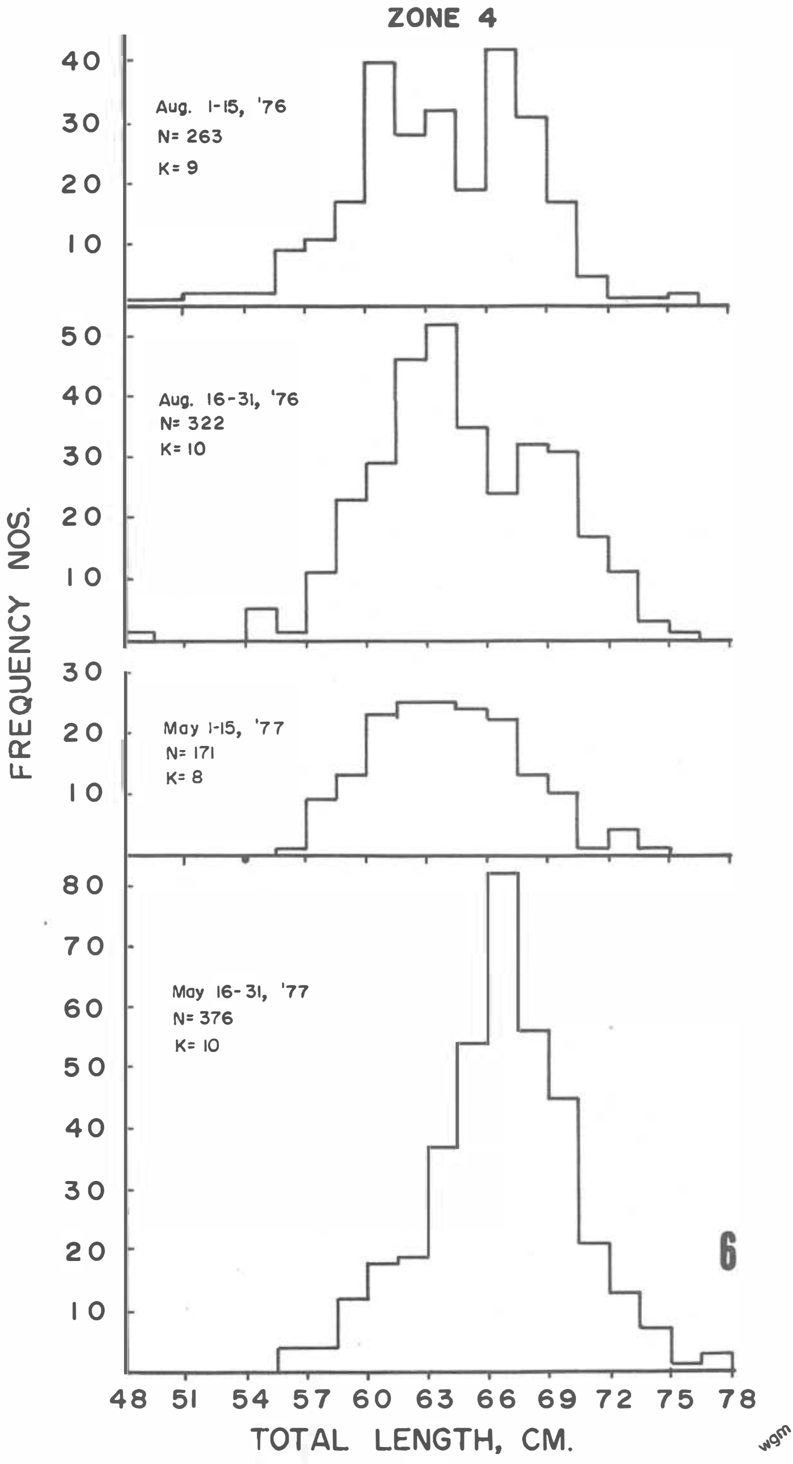

ZONE 4
K= 1.53
L∞= 79.25 cm
l_t0 = 0.5 cm
80
70
60
50
40
30
20
10
FORK LENGTH, CM
10
20
30
40
50
AGE, MONTHS
5
wgm

Fig. 6. Bi-monthly length frequencies for *Micropogon altipinnis* captured in 5.5-6 inch mesh gill nets, Zone 4, during August, 1976 and May, 1977.


ZONE 4
Aug. 1-15, '76
N= 263
K= 9
Aug. 16-31, '76
N= 322
K= 10
May 1-15, '77
N= 171
K= 8
May 16-31, '77
N= 376
K= 10
FREQUENCY NOS.
TOTAL LENGTH, CM.
48 51 54 57 60 63 66 69 72 75 78
6
wgm