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Evaluating fish stock changes from the fragmentary catch and effort data of the Angolan fisheries

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The procedure followed to evaluate in standard units the fishing effort of two different groups of purse-seiners fishing non-contemporaneously for the horse-mackerel *Trachurus trecae* (Cadenat) in Southern Angola is described in detail. Firstly, by comparing contemporaneous catches, differences in fishing ability within each group were evaluated as efficiency factors relative to the group mean efficiency. The efficiency factors of the two groups were then related by means of an empirical predictive equation of the efficiency factor given the purse-seiner gross metric tonnage, and expressed relative to the efficiency of an average 75 metric ton purse-seiner. The series catch-per-standard-purse-seiner-per-day in each month of the period 1962–71, although incomplete, shows seasonal and cyclic variations in horse-mackerel abundance, probably of an environmental nature. It is curious, however, that the period of 6 years of the cyclic variation is equal to the maximum age of the species in Angola; a somewhat similar coincidence was observed in the South-African maasbanker *Trachurus trachurus* L.

Introduction

The catch of the Angolan fisheries is too small (about 300 thousand metric tons per year of all species caught by all gears) to have an appreciable influence on the supporting stocks (De Campos Rosado, 1973). Since, however, some fisheries were established 20 or more years ago, before fishing at industrial level began in the Tropical Eastern Atlantic, the catch and effort data of the Angolan fisheries yield interesting information. For instance, the series catch-per-standard-bait-boat-per-day of yellowfin (*Thunnus albacares* Bonn.) and skipjack (*Katsuwonus pelamis* L.) tuna in Angola covers the years 1953 through 1969, and shows a gradual replacement of the former by the latter species, probably caused by the increasing fishing efforts of Japanese long-liners (De Campos Rosado, 1971). The series catch-per-standard-purse-seiner-per-day of the horse-mackerel *Trachurus trecae* (Cadenat), presented in this paper, covers, although incompletely, the period 1962–1971. It is, apparently, the only available information on the stock, whose catches of about 150 thousand metric tons per year supports the purse-seiner fishery of Southern Angola.

The catch and effort data of the Angola fisheries, do not, in general, discriminate unambiguously the species caught. The boats fishing in a given area are usually of very different sizes, and change from year to year as they move to and from different fishing grounds. Reliable records covering a period of 10 or more years are thus few and fragmentary. The abundance of the supporting stocks in standard units cannot be evaluated from such data in a straightforward way. The procedure followed to standardize the effort of the bait-boat tuna fishery is described in detail in the paper referred to above; briefly, it consists in relating in sequence the efficiencies of 15 bait-boats, by comparing the mean catches of individual boats in periods when some fished together. In the present paper I shall describe the procedure followed to deal with the horse-mackerel catch-and-effort data of two different groups of purse-seiners fishing in non-overlapping periods of time.

Treatment of the data and results

An example of the catch records of horse-mackerel is shown in Table 1, which gives the weight in metric tons of the monthly catch by each of 6 purse-seiners

Table 1. Metric tons, C, of horse-mackerel *Trachurus trecae* caught in g days by each individual purse-seiner of T gross metric tons, numbered from 1 to 6, in each month of 1966 off Baía dos Tigres. Totals and daily mean catches, in parentheses, for 1966

Purse-seiner		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	1966
1	g_1:	13	20	13	6	12	6	–	2	12	8	92
T_1 = 110·6	C_1:	243·0	379·5	393·0	207·0	273·0	262·0	–	73·0	389·0	264·6	2484·1 (27.0)
2	g_2:	9	–	6	4	10	13	8	3	8	5	66
T_2 = 96·5	C_2:	46·0	–	173·0	130·0	189·0	330·0	152·5	78·5	170·0	199·0	1468·0 (22·2)
3	g_3:	13	2	7	6	15	17	14	12	9	5	100
T_3 = 89·0	C_3:	130·0	9·0	199·0	117·0	271·0	537·0	271·5	234·5	251·5	214·0	2234·5 (22·3)
4	g_4:	15	19	9	–	–	–	–	–	3	4	50
T_4 = 28·4	C_4:	112·0	242·0	76·0	–	–	–	–	–	11·0	50·3	491·3 (9·8)
5	g_5:	–	12	9	4	10	14	10	8	8	3	78
T_6 = 47·8	C_5:	–	286·0	173·0	137·0	93·0	345·0	179·0	146·0	109·0	71·0	1539·8 (19·7)
6	g_6:	–	8	5	2	5	–	–	–	–	–	20
T_5 = 37·3	C_6:	–	108·5	75·0	51·0	65·0	–	–	–	–	–	299·5 (15·0)

fishing off Baía dos Tigres (Southern Angola) in 1966, the corresponding number of landings, the annual totals, and the daily mean catch for the year. The purse-seiners' gross metric tonnage are also given. The group is designated as Group A and the boats numbered from 1 to 6.

Differences in fishing ability among the 6 purse-seiners were discounted by means of efficiency factors (Shimada and Schaefer, 1956), computed by dividing the daily mean catch for the year of each purse-seiner by the daily mean catch of one boat chosen as a standard for comparable months. In order to use all the available data, purse-seiner 3 was chosen as the standard. Thus, the efficiency factor of the purse-seiner 1 was evaluated as 1·183, by dividing its mean catch (27·000 tons) by the mean catch of the purse-seiner 3 (22·826 tons) computed without taking its July catches into account; the efficiency factor of the purse-seiner 2 was evaluated as 0·979, by dividing its mean catch (22·242 metric tons) by the mean catch of the purse-seiner 3 (22·706 metric tons) computed without taking its February catch into account; and so on. The efficiency factors thus evaluated are shown in the third column of Table 2 (1). The efficiency factors of the same purse-seiners similarly evaluated for other periods are also given in Table 2 (1). To use all the available data, I chose as the standard in each period the purse-seiner with landings in the greatest number of months during that period, and it happened that in all four periods covering the years 1962–1971, the standard was a different purse-seiner. The question arose as to which of the 6 purse-seiners should Table 2 (1) be calibrated. It could be in respect to the purse-seiner whose efficiency factors varied least from period to period. However, the mean efficiency of the group provides a more reliable standard because errors tend to cancel each other out on averaging. Thus, denoting by E_i and E_j the efficiencies of any two purse-seiners i and j, and by $E_{ij} = E_i/E_j$ the efficiency factor of the former relative to the latter, the efficiency factor $E_{i\cdot}$ of the purse-seiner i relative to the

Table 2. Efficiency factors of Group A purse-seiners: (1) relative to the efficiency of individual purse-seiners, (2) relative to the group mean efficiency, and (3) relative to the efficiency of a 75 metric ton purse-seiner

Purse-seiner	Gross tonnage	(1) Relative to the efficiency of individual purse-seiner[1], E_{ij}				(2) Relative to the group mean efficiency, $E_{i\cdot}$				(3) Relative to the efficiency E_S of a 75 ton purse-seiner, E_{iS}				
		Periods				Periods				Periods				Mean
i	T_i	I	II	III	IV	I	II	III	IV	I	II	III	IV	E_{iS}
1	110·6	1·113	1·221	1·183	1·412	1·393	1·368	1·515	1·306	1·186	1·165	1·290	1·112	1·188
2	96·5	1	1·020	0·979	1·382	1·251	1·142	1·255	1·278	1·066	0·973	1·069	1·088	1·049
3	89·0	1·126	1·170	1	1·459	1·409	1·310	1·282	1·349	1·200	1·116	1·092	1·149	1·139
4	28·4	0·481	0·595	0·440	0·678	0·602	0·666	0·564	0·626	0·513	0·567	0·480	0·533	0·523
5	47·8	0·800	1	0·816	1·049	1·001	1·120	1·047	0·970	0·853	0·954	0·892	0·826	0·881
6	37·3	0·718	0·722	0·754	1	0·899	0·809	0·966	0·925	0·766	0·689	0·823	0·788	0·766

[1] The standard purse-seiner in each period is that whose efficiency factor is 1.

mean efficiency of the group is estimated as the arithmetic mean of its efficiency factors relative to all the others and to itself,

$$E_{i.} = \sum_{j=1}^{j=6} E_{ij}/6,$$

because

$$\sum_{j=1}^{j=6} E_{ji}/6 = E_i \sum_{j=1}^{j=6} (1/E_j)/6 = E_i/E_{..}$$

where $E_{..}$ is the mean efficiency of the group. These coefficients are given in Table 2 (2). To test whether the group mean efficiency constitutes a better standard than any individual efficiency, the results of 6 analyses of the variance of the efficiency factors E_{ij} measured in relation to the efficiency of each of the 6 purse-seiners ($j = 1, 2, \ldots 6$) were compared with the results obtained in the analysis of the variance of the efficiency factors $E_{i.}$. As shown in Table 3, in all the 6 analyses the mean squares attributable to the efficiency variation among periods are much larger, compared with the respective error mean squares, than the corresponding mean square in the $E_{i.}$ analysis. Actually, the only good individual standards are the purse-seiners 2 and 3, although they are worse than the group mean.

Similar results to these were obtained with another group of purse-seiners fishing off Porto Alexandre, 100 km north of Baía dos Tigres. This second group is denoted by Group B and the purse-seiners numbered from 7 to 13. Since their catch data refer to different years from those of Group A, only overlapping in 1965 and 1968, the relationship between the efficiency factors of Group A and Group B could not be evaluated directly by comparing their mean landings, as done for intra-group efficiency, but were established by means of a predictive equation of the efficiency factor $E_{i.}$ given the purse-seiners gross metric tonnage, T_i. It was first verified that the linear regression of $E_{i.}$ on T_i passed, in both groups, significantly above the origin, thus indicating that the rate of increase in efficiency decreases as the tonnage increases. The curve $E_{i.} = aT_i^b$ was then fitted by the method of least squares after the usual Log. Log transformation of the data. It is easily seen that changing the standard of measuring efficiencies does not affect the constant b in this formula but affects a, so that if the standard of Group A is k times smaller than the standard of Group B then the estimate of a in the former is k times larger than in the latter. Hence, the required relationship between the standard in Group A and the standard in Group B was evaluated as equal to 1·17029, by dividing the equation fitted to the data of Group A, $E_{i.} = 0{\cdot}11298\ T_i^{0.54218}$, by the equation fitted to the data of Group B, $E_{i.} = 0{\cdot}09654\ T_i^{0.54218}$, where 0·54218 is the common coefficient of regression, b, estimated by means of the analysis of the covariance Log $E_{i.}$ and Log T_i in the two groups. However, I found it more interesting, and useful for future work, to express the efficiency factors of all 13 purse-seiners relative to the efficiency E_S of a standard purse-seiner of T_S gross metric tons, by means of the easily derived formula

$$E_{iS} = (E_i/E_S) = (T_i/T_S)^{0.54218} \quad (1)$$

and choosing T_S = 75 metric tons, which is approxi-

Table 3. Analysis of the variance of the efficiency factors of Group A purse-seiners. Factors (E_{ij}) measured relative to the efficiency of each individual purse-seiner[1]

Source of variation	Degrees of freedom	Mean squares obtained when measuring efficiency with purse-seiner j: $j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$	$j = 6$
P.-seiners	4	0·16762**	0·27362**	0·20440**	0·46434**	0·41111**	0·49120**
Periods	3	0·01092*	0·01102	0·00984	0·16354**	0·03432**	0·04604**
Error	12	0·00230	0·00331	0·00304	0·01356	0·00456	0·00498

Factors ($E_{i.}$) measured relative to the group mean efficiency

Source of variation	Degrees of freedom	Mean square
P.-seiners	5	0·35189**
Periods	3	0·00157
Error	15	0·00467

[1] The standard purse-seiner efficiency factor (= 1) did not enter in the analysis.
* Significant.
** Highly significant.

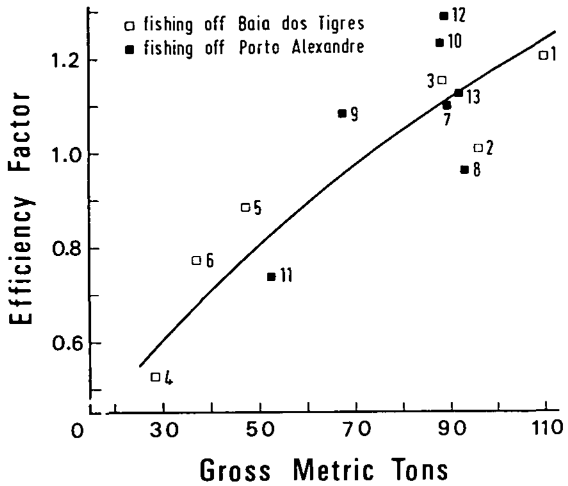

Figure 1. Relationship between the efficiency factor E_{is} and the gross metric tonnage T_i of purse-seiners fishing for horse-mackerel *Trachurus trecae* Cadenat in the southern littoral of Angola. The efficiency factors are expressed relative to the efficiency of an average 75 metric ton purse-seiner.

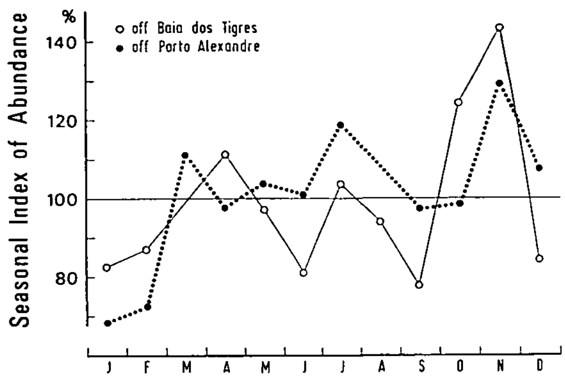

Figure 2. Seasonal indices of the abundance of horse-mackerel *Trachurus trecae* Cadenat off two fishing centres of Southern Angola. The indices were computed by averaging the abundance U in corresponding months, expressed as a percentage of the mean abundance in each year. The increased abundance in October–November is probably due to a massive spawning migration inshore.

mately the mean tonnage of the sampled purse-seiners and about the average tonnage of Angolan purse-seiners. The calculated regression line is shown in Figure 1 with the points ($\bar{E}_{is}$, T_i), $\bar{E}_{is}$ being the mean efficiency of the purse-seiner i in the four periods, as shown in Table 2 (3) for the purse-seiners of Group A.

The index of abundance U, catch-per-standard-unit-of-fishing-effort (metric tons caught by the 75 metric tons standard purse-seiner per day) in each month of the period 1962–71 off Baía dos Tigres and off Porto Alexandre was then computed with the formula (Shimada and Schaefer, 1956)

$$U = \sum_{i=1}^{i=k} C_i \Big/ \sum_{i=1}^{i=k} \hat{E}_{is}\, g_i$$

where C_i is the catch of purse-seiner i in g_i days weighted by the efficiency factor $\hat{E}_{is}$ calculated by formula (1). The U series was analysed into seasonal and long-term components, as represented in Figures 2 and 3. These variations of abundance are now being used as a working hypothesis for a more detailed study of the horse-mackerel stock of Southern Angola. It may be noted that the period of about six years of the cyclic variation shown in Figure 3 is equal to the maximum age of *Trachurus trecae*, as determined by the present writer from a succession of modal lengths (De Campos Rosado, 1972) and by Marécos (unpublished) in our laboratory, who, in examining over one thousand otoliths, has found none with more than six annual rings. A somewhat similar coincidence was observed in the South-African maasbanker (*Trachurus trachurus* L.) where Geldenhuys (1971) found a regular predominance of a modal group during a period of nine years, which is also the maximum number of annual rings of this species as reported by Letaconnoux (1951) and close to the maximum number observed by Polonskii (1965).

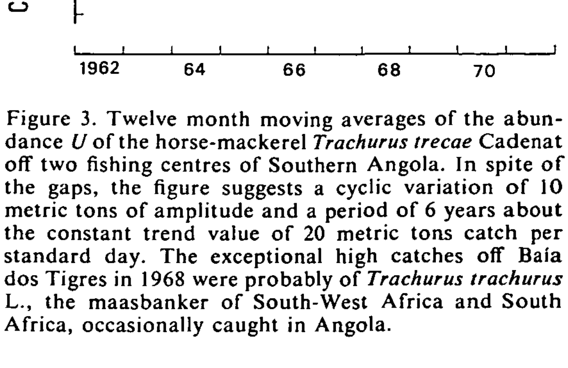

Figure 3. Twelve month moving averages of the abundance U of the horse-mackerel *Trachurus trecae* Cadenat off two fishing centres of Southern Angola. In spite of the gaps, the figure suggests a cyclic variation of 10 metric tons of amplitude and a period of 6 years about the constant trend value of 20 metric tons catch per standard day. The exceptional high catches off Baía dos Tigres in 1968 were probably of *Trachurus trachurus* L., the maasbanker of South-West Africa and South Africa, occasionally caught in Angola.

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References

De Campos Rosado, J. M. 1971. Long-term changes in abundance of yellowfin and skipjack off the coast of Angola. J. Cons. int. Explor. Mer, 34: 65–75.

De Campos Rosado, J. M. 1972. Estudos sobre a pescaria de carapau som artes de cerco em Angola. I. Estimativa do componente W_t do modelo de Beverton-Holt em *Trachurus trecae* Cadenat. Publ. mimeo. M.E. Bioceanol. Pescas, Angola. (5) 33 pp. (mimeo).

De Campos Rosado, J. M. 1973. The catch and effort of the Angolan bait-boat tuna fishery and its influence in reducing the supporting yellowfin population. J. Cons. int. Explor. Mer, 35: 52–60.

Geldenhuys, N. D. 1971. Growth and age composition of the South-African maasbanker *Trachurus trachurus* Linnaeus, 1950–1969. M.Sc. Thesis (Zoo.) Univer. Stellenbosch, 41 pp. (mimeo).

Letaconnoux, R. 1951. Contribution à l'étude des espèces du genre *Trachurus* et spécialement du *Trachurus trachurus*. (Linné 1758). Mem. Off. Scient. Techn. Pêches Marit., (15) 67 pp.

Polonskii, A. S. 1965. The horse-mackerel of the Eastern Atlantic and its fishery. Rÿb. Khoz., 41 (6): 8–10; and 41 (7): 13–15.

Shimada, B. M. & Schaefer, M. B. 1956. A study of changes in fishing effort, abundance, and yield for yellowfin and skipjack tuna in the Eastern Tropical Pacific Ocean. Bull. inter-Amer. Trop. Tuna Commn., 1: 351–469.