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SHORT NOTE

ALTERNATIVE METHODS FOR CALCULATING CATCH-PER-UNIT-EFFORT FOR SKIPJACK TUNA (*Katsuwonus pelamis*) CAUGHT IN THE SOUTHWESTERN ATLANTIC OCEAN

ANDRADE, H.A.[1]; PEREIRA, M.D.[2] & MAYER, F.P.[3]

[1] **UFSC - INE/CTC - C.P. 476 - 88010-970 - Florianópolis-SC - Brazil. E-mail: humber@inf.ufsc.br**
[2] **UNIVALI - CTTMar - Lab. Ocean. Fis. - C.P. 360 - 88302-202 - Itajaí-SC - Brazil. E-mail: marcalpereira@pop.com.br**
[3] **UNIVALI - CTTMar – Grupo de estudos Pesqueiros (GEP) - C.P. 360 - 88302-202 - Itajaí-SC - Brazil. E-mail: fernandomayer@gmail.com**

Fishery biologists have been pursuing methods to estimate index of abundance based on commercial catch-per-unit-effort (CPUE). However the relationship between CPUE and abundance may be weak because CPUE reflects changes of population abundance as well as catchability (Clark, 1985). In an attempt to “standardize” CPUE time series, statistical tools (*e.g.* generalized linear models) have been often used since the 1980’s (*e.g.* Pennington, 1983; Lo *et al*., 1992; Maunder & Punt, 2004). Those standardized values are expected to be less biased than CPUE when estimating how abundance changes across years, but there are no guarantees the standardized indexes reflect abundance (Hilborn & Walters, 1992; Quinn & Deriso, 1999).

Improvement of CPUE calculations is crucial when pursuing a reliable index of abundance. In fact the limitations of the standard way of calculating CPUE have been discussed (*e.g.* Clark, 1985; Hilborn & Walters, 1992; Quinn & Deriso, 1999) but few attempts have been made to solve them. Most of scientific papers deal with methods (sometimes fanciful statistical models) to analyze and “fix the wrong” CPUE data, but they do not attempt to improve CPUE data.

When fishermen aim at surface tuna schools (*e.g.* tuna pole-and-line fisheries) the calculation of useful CPUE is particularly problematic. Surveyed area or volume, or time spent by fishermen when “searching” for surface tuna schools should be accounted for in the effort calculations. Otherwise CPUE calculations are misleading because they will not decrease as the actual abundance diminishes. If so CPUE is hyper-stable (Clark, 1985).

While the importance of “search effort” is largely recognized, difficulties begin with the limitations of commercial logbooks and available databases like “Task II” of the International Commission for Conservation of Atlantic Tunas (ICCAT). There is not enough information to estimate the “search” component of the fishing effort in those datasets. Furthermore, logbooks often contain only information on one geographical position and total catch gathered each day. Lack of information about the number of fish schools fishermen sighted and the weight caught in each fishing operation, makes estimating reliable CPUE a hard task.

All problems mentioned above are present in the standard sampling programs used to monitor tuna fishery in the southwestern Atlantic ocean. In that region, annual skipjack tuna (*Katsuwonus pelamis*) yields rank first (~ 25.000 t) among tuna catches and most fish have been caught by Brazilian pole-and-line fleet. We have used the skipjack fishery as a case study for the investigations of alternative ways of calculating CPUE. For this purpose, we used data from traditional logbooks and industrial forms, as well as from interviews and on-board observer programs. All analyzed data were sampled and kindly provided by the “Grupo de Estudos Pesqueiros” (GEP/UNIVALI). Details on those research programs and sampling methods can be found elsewhere (Perez *et al*., 1998).

Our main objective was to assess how different CPUE time series calculated using alternative fishing effort would be. We were particularly interested in assessing if CPUE calculated using new information provided by on-board observer program would point to different fishery status scenarios if compared with the traditional method, using catch per fishing day.

The amount of “time spent at sea”, as reported in logbooks, carries some, but limited information about “search” effort. Actually few of the information we were looking for can be found in logbooks (*e.g.* number of fishing operations in each day). Therefore most of the data we analyzed (Table 1) was provided by interviews with skippers and on-board observer forms. Interviews were carried out across all the year, but on-board observer programs took place only in austral summer, which is the harvest season.

In all CPUE calculations the catch is in tons, but four alternative efforts were used:

i) Days at Sea (DS) – Number of days since the boat leave the harbor until it comes back;

ii) Fishing Sets (FS) – Number of times a school was found and fishermen released bait and tried to catch skipjack tuna;

iii) Fishing Days (FD) – Any day in which at least one fishing set was carried out; and

iv) Search Days (SD) – Any day in which fishermen were looking for tuna schools.

Some comments about some of the above effort measurements are warranted. At first we intended to use “search” as measured in hours or minutes. However detailed data were only available in few forms of on-board observer program. Hence we adopted “search days” measure described above. It is also important to stress that “fishing sets” is not equal to the number of schools found. The same school could be eventually fished twice a day. Therefore the number of fishing sets probably overestimate the number of schools.

In order to evaluate if alternative CPUE calculations showed different trends we confronted the results using correlation analysis, and comparative plots of the CPUE time series. Because logarithm transformations of the four CPUE calculations fit normal distributions ($p > 0.09$ in Shapiro-Wilk tests), and because scale of alternative calculations are different, we compared the standardized [z = (value – mean) / standard deviation] of the logarithm instead of the original CPUE values.

The time period December, 2002 – September, 2003, contains the largest data time series available (Table 1), hence that period was selected for the analysis. We have also analyzed how austral summer (first quarter) CPUE values changed across the years from 2000 to 2005.

Most of the CPUE calculations were between 0 and 12 tons per unit effort. The exception was the CPUE calculated using fishing days as effort (Figure 1). Most of coefficients were positive and significant (Figure 1 and Table 2), although correlations including the CPUE calculated with fishing sets as effort were weaker than all others.

All time series from December 2002 to September 2003 built using alternative CPUE calculations showed similar trends, being high from December to May but

Table 1 – Database entries per year and month. Number of Trips (NT); Days at Sea (DS) – Number of days since the boat leave the harbor until it comes back; Fishing Sets (FS) – Number of times some bait was released and the fishermen tried to catch skipjack; Fishing Days (FD) – Any day in which at least one fishing set was carried out. Search Days (SD) – Any day in which fishermen were looking for tuna schools. Catch (C) – weight caught (tons). Data source: Interviews with fishermen at harbor plus on-board observer program of GEP/ UNIVALI.

Year	Month	NT	DS	FS	FD	SD	C	Year	Month	NT	DS	FS	FD	SD	C
1999	12	2	19	45	11	11	70.9	2003	5	3	46	32	13	27	85.9
2000	1	3	28	51	13	17	128.8	2003	6	1	30	26	9	24	33.5
2000	2	2	31	25	9	23	118.8	2003	7	1	20	12	7	13	29.0
2000	3	2	24	19	8	18	73.5	2003	8	1	26	12	7	15	15.7
2001	1	1	16	16	5	12	44.5	2003	9	1	24	8	5	21	6.5
2002	1	1	17	15	7	17	16.0	2004	1	1	9	9	5	7	35.8
2002	2	4	57	60	25	54	93.41	2004	2	4	55	58	34	45	256.1
2002	3	2	35	21	11	35	59.43	2004	3	1	16	13	12	16	85.0
2002	12	1	14	15	6	8	11.0	2004	5	1	20	10	6	20	49.5
2003	1	6	82	106	35	67	213.3	2004	6	1	25	11	9	25	52.0
2003	2	10	149	162	86	126	372.5	2005	1	1	5	11	3	4	10.2
2003	3	10	155	113	71	134	365.8	2005	2	2	30	50	14	27	214.8
2003	4	9	115	88	52	94	370.3	2005	3	1	15	13	7	14	31.1

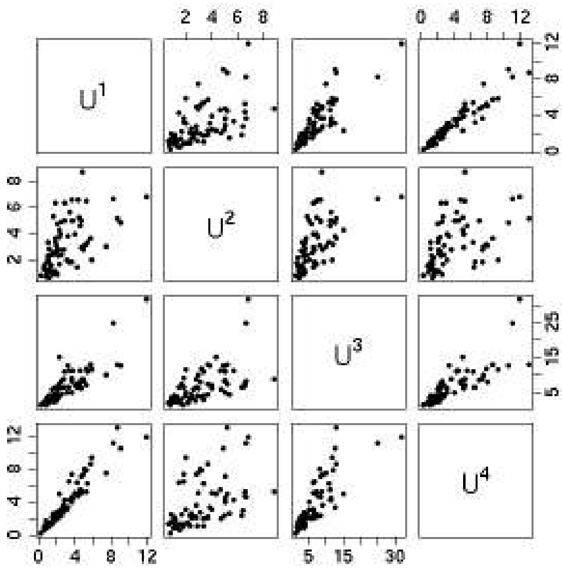

Figure 1 – Scatterplots of the four CPUE calculations. U^1 - tons/days at sea; U^2 - tons/fishing set; U^3 - tons/fishing day; U^4 - tons/search days.

Table 2 - Coefficients of correlation among the four CPUE calculations (upper corner) and the t-test probabilities (lower corner). U^1 - tons/days at sea; U^2 - tons/fishing set; U^3 - tons/fishing day; U^4 - tons/search days.

	U^1	U^2	U^3	U^4
U^1	1	0.561	0.845	0.947
U^2	3.02E-7	1	0.593	0.480
U^3	< 2.2E-16	4.07E-8	1	0.812
U^4	< 2.2E-16	2.03E-5	< 2.2E-16	1

decreasing towards austral winter, from June to September (Figure 2 A). All alternative summer CPUE calculations showed similar trend across the years (Figure 2 B). In spite of some oscillations, there was not overall evidence that CPUE have changed much across time. Such pattern was already described elsewhere (Andrade, 2007).

We were expecting that alternative calculations, like those including "search" in effort, would result in values of CPUE different from that calculated with the traditional "fishing days" as effort. However, for the Brazilian skipjack tuna fishery, all alternative CPUE series provided similar time trends. There are at least three possible explanations:

a) Differences among alternative CPUE calculations did not show up because abundance did not change too much across the years. Let consider the following simplistic example to make the argument clear. Suppose that if the abundance decrease, the number of schools decrease as well, the size of schools remain the same,

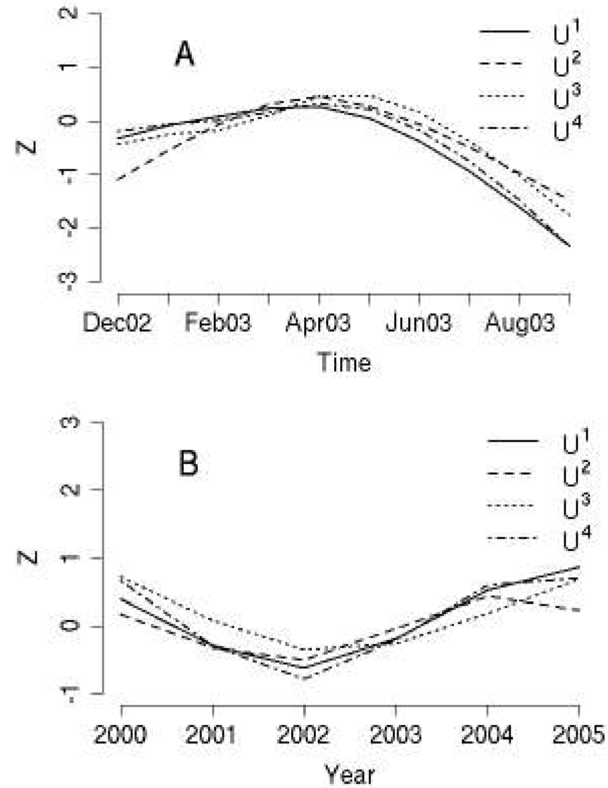

Figure 2 – Time trends of the alternative catch-per-unit-effort (CPUE). Score Z is the standardized log(CPUE) variable. (A) Ten month time series (December, 2002 through September, 2003); (B) Sequence of austral summers from 2000 through 2005. Lines stand for cubic smoothing splines. U^1 - tons/days at sea; U^2 - tons/fishing set; U^3 - tons/fishing day; U^4 - tons/search days.

and usually only one school is fished each day. Hence the CPUE as calculated using "search" effort should decrease because schools became rare. However the CPUE as calculated using "fishing days" would not decrease because the catch when schools of same size are found would be similar. In the above hypothetic fishery scene the abundance changes across the years, hence differences between the two CPUE values would be apparent. If the abundance is always close to the same value ("stability"), all alternative CPUE would just show similar time trends pointing for no changes. Therefore there is the possibility that alternative CPUE time series did not show differences just because the abundance did not change too much.

b) Available variables, like "search days" and "search days" for example, are too imprecise as effort measure. If one school is fished in one day and five schools are fished in another day, both will be considered a "fishing day". Hence that effort measurement does not reflect the difference of fishing one, two or eventually five schools. There are similar limitations with "search days" variable. No matter if fishermen survey just one hour or ten hours, that will be considered a "fishing day". Perhaps

there are not differences among time trends of alternative CPUE calculations because all available measurements of effort are too imprecise.
c) "Search" is not relevant for skipjack tuna fishery in the southwestern Atlantic ocean. Therefore CPUE calculations with "search days" and with "fishing days" are equally bad (or good) relative abundance indexes.

In summary, the first of the above issues (a) points that fishery scenario does not allow for conclusive comparisons among alternative CPUE calculations. Second issue (b) points the information on effort available nowadays is too limited. Finally, the ending issue (c) points that "search" effort is not important. Whatever the line of reasoning, if one takes into account the information available nowadays, there are no motivations to replace the traditional by one of the alternative CPUE calculations. In spite of criticisms, CPUE calculated with "fishing days" is still reasonable.

We would like to stress that the results we gathered might be considered in the light of the limited data we analyzed. Perhaps "search" effort will prove to be important in the future as more informative data is sampled. Hence, researches to gather detailed "search" effort measurements are encouraged. Studies on how improving calculations of abundance indexes remains an open and important scientific area.

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