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Short communication

A comparison of methods for estimating relative abundances in bottom longline fishery surveys

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Abstract

Longlines lose fishing power with soaking time due to bait losses and hooked fishes. Because logbook records and dockside interviews usually do not include detailed data on fishing power loss, relative densities in commercial fishing are estimated as the number or weight of fishes caught per hook and unit of time. To investigate the influence of the fishing power loss of bottom longlines on relative density estimates, data of 188 standardized hauls of 1000 hooks, baited with squid and soaked for 3 h in average were analyzed. The estimates given by the number of fish caught per 1000-hook-hour (CPUE) were compared to those from the partial removal instantaneous rates (λ) caused by each species, an index that requires detailed information that takes into account the progressive decrease in the number of baited hooks available to fish. It was found that, for relatively short hauls observed in commercial fishing operations in Southern Brazil, the patterns of bathymetric and latitudinal distribution of the three most numerous species in the catch did not differ significantly when calculated in either units. Nevertheless, high initial catch rates resulted in lower correlation between both measures. It was concluded that the analysis of CPUE from bottom longline commercial fishing catches can result in reliable information on the distribution and relative abundance of the target species in the fishery.

Keywords: Demersal fishes; Longline; Fishing power; Catch and effort

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1. Introduction

Longlines are passive stationary gears that keep fishing while fishes are attracted by the baits. The area of action of the longline depends on the types of target fishes and baits, the soaking time, and the direction and strength of the current (FAO, 1976; Engås and Løkkeborg, 1994). This area is variable and cannot be determined with any precision, thus longlines are not adequate to estimate absolute abundance (Gunderson, 1993). Despite this drawback, bottom longlines can be set over most types of habitats and may be useful to prospect the distribution and the relative abundance of fishes that inhabit irregular sea bottoms or are difficult to be caught with trawls (Hovgård and Lassen, 2000). Other fishing methods (e.g., gillnets and visual census) can be used in various habitats, but they also have problems (Jennings et al., 2001).

The most common measure of relative abundance in commercial longline fishing analysis is the catch per unit effort (CPUE) expressed as the number or weight of fish caught per number of soaked hooks (FAO, 1976; Skud, 1978; Løkkeborg and Pina, 1997). Implicitly or explicitly, the immersion time is considered, rather than the loss of fishing power during hauls. This is due to the difficulty of keeping detailed records of longline commercial fishing operations.

Longlines lose fishing power during soaking time because, as the number of hooked fishes increases, the number of available positions diminishes. Fishing power is also affected by the decreasing attractiveness of bait or its loss (Skud, 1978; Engås and Løkkeborg, 1994; Bjordal and Løkkeborg, 1996; Ward et al., 2004). Several methods to calculate or correct CPUE have been proposed and applied to scientific surveys (Somerton and Kikkawa, 1995; Kaimmer, 2004) that take into account the progressive loss of fishing power of longlines based on the exponential loss of fishing power formerly observed by Murphy (1960) and Rothschild (1967).

According to Hovgård and Lassen (2000), the instantaneous rate of bait removal by species (λ) proposed by Somerton and

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Kikkawa (1995) could be a more adequate measure of fish density than the quotient between catch and the number of hooks multiplied by the immersion time.

Around 1973, a dory-type fishery with hand-lines from small boats carried by larger vessels began over rocky bottoms of the outer shelf and continental slope off southern Brazil. After 1987, hand-lines were gradually replaced by different types of bottom longlines. By 1995, steel wire longlines were prevalent and the number of vessels expanded to 35 in 1997 (Peres and Haimovici, 1998; Ávila-da-Silva et al., 2001).

To assess the magnitude and distribution of the stocks affected by this fishery in 1996 and 1997 two bottom longline surveys were performed in the Southern Brazil Exclusive Economic Zone (EEZ) between latitudes 22°00′S and 34°40′S, at depths ranging from 100 to 500 m. These surveys were onboard a chartered bottom longline fishing vessel equipped with a steel groundline, the fishing gear used at that time by the fleet (Haimovici et al., 2004). Along these cruises a detailed record of the state of the hooks along recovery was kept.

The scope of this paper was to investigate if the distortion caused by the loss of fishing power could invalidate the comparisons of relative abundance of the main species between areas, seasons, and depth ranges in the Southern Brazil bottom longline fishery. To do so, we compared, for three different species, the series of CPUE measured in fish caught per 1000 hook-hour (1000 hh) with the corresponding series of instantaneous rate of bait removal.

2. Materials and methods

To investigate the influence of the fishing power loss of bottom longlines on the relative densities estimates, a data set of 188 standardized hauls of 1000 hooks was obtained in two seasonal surveys carried out between Chuí (34°40′S) and Cabo de São Tomé (22°00′S) in 1996 and 1997. Hauls were performed during day-time distributed along 18 profiles perpendicular to the coastline between the isobaths of 100 and 500 m, 50–55 nautical miles away from each other (Fig. 1). The groundline, was a 4.5 mm steel cable, 8000 m long. One meter long and 2 mm diameter monofilament polyamide secondary lines were attached with snappers to the groundline around 7 m from each other. The hooks were *Mustad Tuna Circle No. 13/0 Qual 39960 D*, with a gap of 32 mm. The hooks were baited with pieces of short-fin squid *Illex argentinus*. Due to the weight of the groundline, no anchorage was necessary.

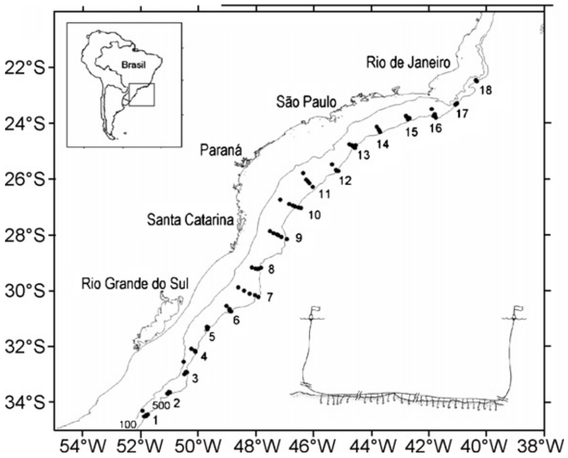

Fig. 1. Haul setting positions along 18 profiles perpendicular to the coast line at depth ranging from 100 to 500 m, in two seasonal longline surveys in winter–spring of 1996 and autumn 1997.

While setting the longline, latitude, longitude, depth, and time were recorded for each group of 100 hooks. During hauling operation, which started 1 h after the setting was finished, the time for each group of 100 hooks and the state of each hook as (1) with fish, indicating the species and size; (2) with bait (3) missing bait (4) missing hook were also recorded. Mean soaking time was around 3 h (Haimovici et al., 2004).

The catch per unit effort (CPUE) by species (i) was estimated for each fishing operation as the catch in number (C) divided by the product of the mean soaking time ($\bar{t}$, in hours) with the number of hooks set minus missing hooks (a), and multiplied by 1000. The mean soaking time indicates the overall average immersion time of the 10 groups of 100 hooks used per fishing operation. In sort, the CPUE by species and fishing operation was expressed as the number of fishes caught per 1000 hooks during 1 h (n/1000 hh):

$$\mathrm{CPUE}_i = \frac{C_i}{\bar{t} \times a} \times 1000$$

Another relative abundance index used was the partial removal rate of baits (λ) by species during the fishing operation. As proposed by Somerton and Kikkawa (1995) in Hovgård and Lassen (2000), the total instantaneous rate of bait loss (Λ) was estimated as:

$$\frac{\mathrm{d}B}{\mathrm{d}t} = -\Lambda B_0 \text{ which gives } \Lambda = \frac{-\ln(B_t/B_0)}{t}$$

B_t represents the number of baited hooks after time t and B_0 is the initial number of baited hooks.The total bait removal rate is the sum of its components:

$$\Lambda = \lambda_1 + \lambda_2 + \cdots + \lambda_n + \lambda_o$$

where $\lambda_1, \lambda_2, ..., \lambda_n$ is the bait removal rate caused by each one of the n species captured and λ_o the removal by fish, scavengers and mechanical process.The partial removal rate of species i was estimated for each fishing operation as:

$$\lambda_i = \frac{C_i}{B_0(1 - \mathrm{e}^{-\Lambda t})}$$

The influence of the fishing power decrease was evaluated by comparing the values of λ and CPUE for each of the three most abundant species separately: *Lopholatilus villarii, Urophycis mystacea* and *Polyprion americanus*. The data sets for each species included only the hauls where each one occurred.

The values calculated for these abundance indexes were standardized by species using the equations $\lambda_i \times (\lambda_i - \bar{\lambda}_i)/s_{\lambda_i}$ and $\mathrm{CPUE}_i \times (\mathrm{CPUE}_i - \overline{\mathrm{CPUE}}_i)/s_{\mathrm{cpue}_i}$, where $\bar{\lambda}_i$ and $\overline{\mathrm{CPUE}}_i$ are the means of λ and CPUE for species i in all fishing operations where it occurred and $s_{\lambda_i}$and s_{cpue_i} are their standard deviations.

Table 1
Regression analysis of the standardized catch per unit effort (CPUE) variation in function of the standardized partial instantaneous rate by species

Species	r and b	Std. error	t	p-Value ($\times 10^{-16}$)	CL 95%		CL 99%	
					+CL	−CL	+CL	−CL
Lopholatilus villarii	0.971	0.025	38.81	<2	1.020	0.921	1.037	0.905
Polyprion americanus	0.950	0.048	19.79	<2	1.047	0.853	1.080	0.821
Urophycis mystacea	0.906	0.039	23.40	<2	0.983	0.830	1.008	0.805

r: correlation coefficient; b: slope; t-test calculated value; p-value: significance level of t; CI 95% and CI 99%: upper (+) and lower (−) confidence limits for 95% and 99%.

The equivalence between both standardized relative abundance indexes (CPUE'_i and λ'_i) were tested by correlation and regression analysis, observing the correlation (r) and determination (r^2) coefficients, the t-test statistic for the slope (b), and the 95% and 99% confidence limits (Zar, 1998). The relation between the standardized residuals from the linear regression $\mathrm{CPUE}'_i \sim \lambda'_i$ with depth, latitude and mean soaking time was described by the deviance analyses of a generalized linear model

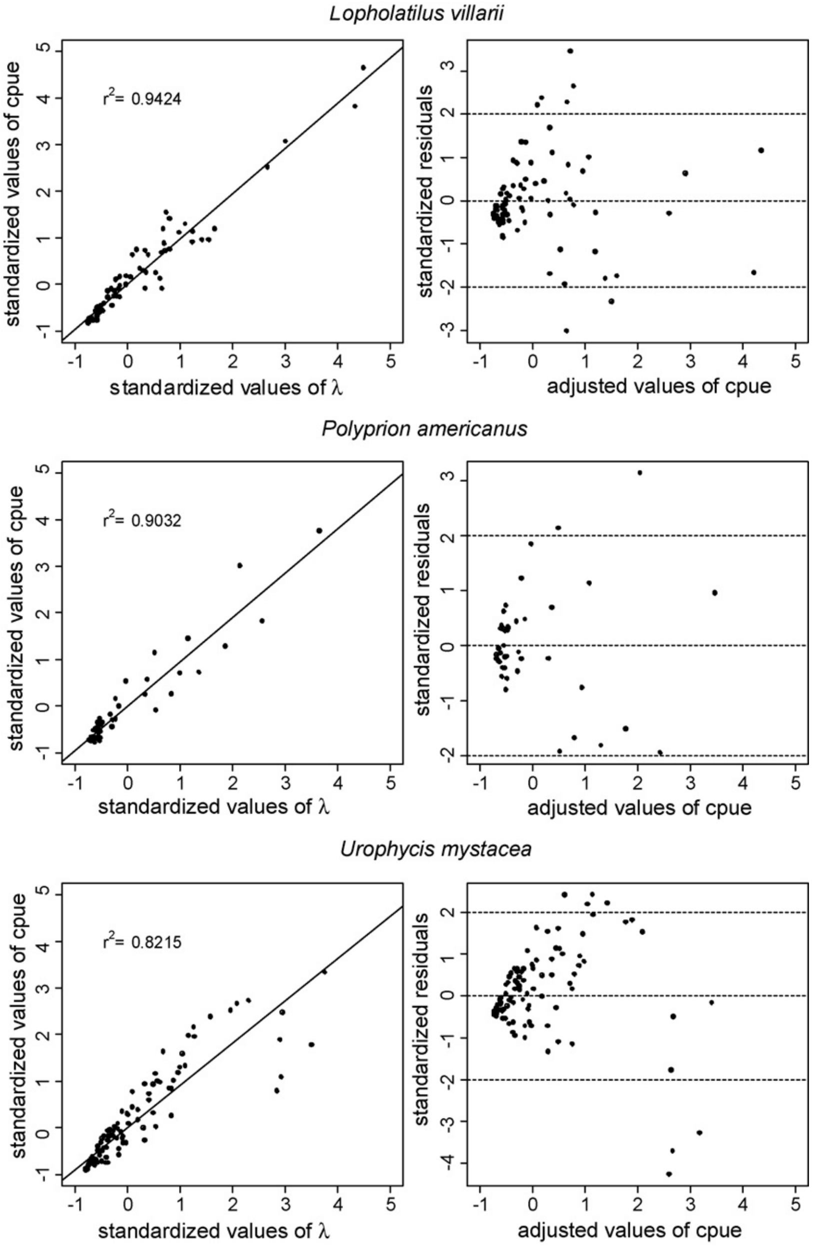

Fig. 2. Linear regression of standardized CPUE against standardized λ for *L. villarii*, *P. americanus* and *U. mystacea* and their standardized the residuals scatter plots.

with identity link function and Gaussian variance function. The variables order in the model was given by their significance in the Akaike information criteria (Venables and Ripley, 1997).

Possible differences in density estimates due to the use of CPUE_i or λ_i were verified by comparing the mean CPUE_i and λ_i values by profile in the survey carried out in winter–spring ’96. The relative population number, RPN (Gulland, 1969; Sigler and Zenger, 1989), was used to estimate the relative abundance by region (south and southeast) and survey (winter–spring ’96 and autumn ’97). RPN was calculated by using CPUE_i and λ_i mean values. In both cases, by depth stratum (100–149, 150–199, 200–399, 400–510 m) and section, defined as a three profile group (1–3, 4–6, etc.), weighed by the respective sector area.

3. Results

Data from 94 hauls with catches of *Lopholatilus villarii*, 44 with *Polyprion americanus*, and 121 with *Urophycis mystacea* were selected. The correlations obtained between the values of CPUE'_i and λ'_i by species were highly significant ($p < 2 \times 10^{-16}$). The values and significance levels by species of the angular coefficient of the linear regression (*b*), and of the coefficient of the linear correlation (*r*) can be observed in Table 1. It can be noticed that, for standardized data, the values of both *b* and *r* are equivalent and that perfect equivalence between the standardized values of λ' and CPUE' would be obtained for regression coefficient *b* equal to 1. The linear regression analysis of the variation of CPUE'_i in function of λ'_i showed high coefficient of determination (r^2) for all three species (Fig. 2).

For *L. villarii* and *P. americanus*, *b* estimates included the unit at a 95%, confidence limit. The highest departure was observed for *U. mystacea*, where the unit was within the 99% confidence limits of estimated *b*. The hauls that resulted in a larger amount of negative residuals for this species were among the ones with a higher rate of catches (Fig. 2).

The analysis of the variation of standardized residuals of $\text{CPUE}'_i \sim \lambda'_i$ regression due the depth, latitude and mean soak time showed different results for each species. For *P. americanus*, none of the explanatory variables under analysis had a significant effect on the deviations ($p > 0.5$). The depth variation showed a more important effect on the *L. villarii* deviations, but, even so, it was little or of no significance ($p \cong 0.03$). For the deviations of the abundance estimates of *U. mystacea*, latitude had great impact ($p < 0.000$); estimates given by λ were larger in southernmost positions where the hauls with higher catches were located (Table 2).

Mean relative densities by profile obtained in the survey carried out in winter–spring 1996, estimated through the standardized values of the λ and CPUE, showed that, for the three selected species, the patterns were similar and that the differences were compatible with previous analysis (Fig. 3). This similarity in the results was also observed when comparing estimates of the relative population number for the South and Southeast regions in the surveys carried out in winter–spring 1996 and autumn 1997 (Fig. 4).

4. Discussion

The results of our comparisons showed that, for the most caught species and the soaking time of the bottom longlines utilized in the fishery in Southern Brazil, the bias due to bait loss and saturation was not large enough to distort the distribution and abundance patterns of these species as evidenced by the high correlation between λ and CPUE (Fig. 2). The relative abundances in both units differed little when they were integrated by profiles and even less when they were integrated by regions and time periods (Figs. 3 and 4). However, in a small number of hauls with a high number of *U. mystacea*, catch-per-hook-and-time underestimates the relative abundance by over 50% when compared with λ. This is not unexpected as

Table 2
Analysis of deviance for the generalized linear models, fitted with gaussian variance function and identity link function, to $\text{CPUE}'_i \sim \lambda'_i$ regression standardized residuals for *L. villarii*, *P. americanus* and *U. mystacea* in function of depth, latitude and soaking time

	d.f.	Dev.	Resid. d.f.	Resid. dev.	*F*	*p*-Value
L. villarii						
Null			93	93.000		
Depth	1	4.802	92	88.198	5.127	0.026
Soaking time	1	3.707	91	84.491	3.958	0.050
Latitude	1	0.204	90	84.288	0.217	0.642
P. americanus						
Null			43	43.000		
Latitude	1	0.436	42	42.564	0.414	0.524
Depth	1	0.364	41	42.200	0.345	0.560
Soaking time	1	0.003	40	42.197	0.003	0.956
U. mystacea						
Null			120	120.000		
Latitude	1	15.618	119	104.382	19.434	<0.000
Depth	1	5.300	118	99.082	6.595	0.012
Soaking time	1	5.056	117	94.026	6.292	0.014

d.f.: degrees of freedom; Dev: deviance; Resid. dz: residual degrees of freedom; Resid. Dev.: residual deviance; *F*: *F*-statistics; *p*-value: significance level.

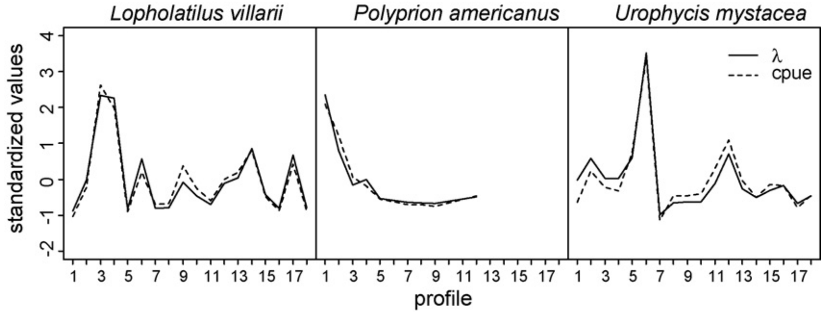

Fig. 3. Comparison of the estimates of relative density of *L. villarii, P. americanus* and *U. mystacea* measured by the mean CPUE (no./1000 h) per profile (traced line) and by the mean instantaneous and partial bait removal rate (λ) per profile (continuous line) in the survey carried out in winter–spring 1996 with longlines, aboard the fishing boat Margus II.

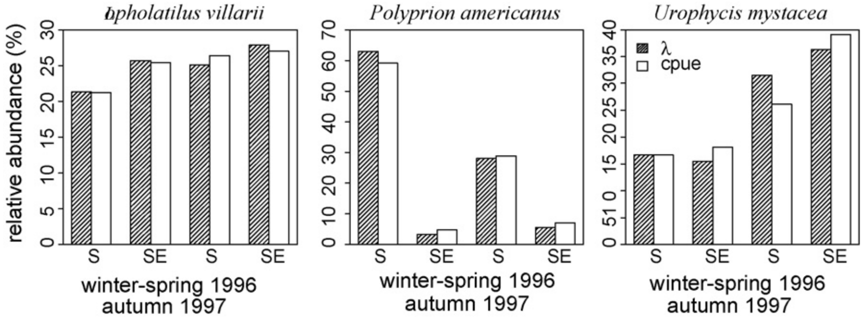

Fig. 4. Comparison of the relative numeric abundances calculated on the basis of CPUE (no./1000 hh) (white columns) and the instantaneous and partial bait removal rate (λ) (shady columns) of *L. villarii, P. americanus* and *U. mystacea*, according the region (*S* = profiles 1–9, S.E. = profiles 10–18), in the surveys carried out in winter–spring 1996 and autumn 1997 with longlines aboard the fishing boat Margus II.

the smaller *U. mystacea* is numerically more abundant than the larger and most valuable *L. villarii* and *P. americanus*.

The high correlation between both density estimators per species in our survey with commercial fishing gear can be explained by the short-time between setting and hauling the longline. Additionally commercial longliners avoid fishing in areas where the lower valued *U. mystacea* or scavengers are abundant. This way of fishing is adopted to optimize the working time of the fisherman and minimize the loss of baits by scavengers and small fish.

It was concluded that CPUE data from relatively short soak times, as observed in Southern Brazil, can provide reliable information on distribution and relative abundance of the target fishes. In this Brazilian case, the usage of commercial fishing CPUE was an important tool for fishing monitoring and assessment. In the years following the survey, the stock of *L. villarii* was reduced to half of its abundance at the beginning of the 1990’s (Ávila-da-Silva and Haimovici, 2005), and for the stock of *P american*us the cpue decreased 10-fold after intense fishing (Haimovici and Peres, 2005) and had its fishing and commercialization suspended for 10 years since 2005.

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