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Short communication

Using the turtle excluder device (TED) in the pink shrimp trawling fishery off southern Brazil

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ABSTRACT. The use of the turtle excluder device (TED) has been mandatory in Brazil since 1994. In spite of the importance of sea turtle bycatch reduction, TED effectiveness to maintain target species capture had never been evaluated in shrimp fisheries off southern Brazil. For this purpose, a test was carried out in November 2013 with the TED installed with two different configurations, top or bottom opening under the supervision of a technician of the National Oceanic and Atmospheric Administration (NOAA). Absolute catch and fishery yields were simultaneously monitored in 10 fishing hauls of a double-rig trawler by an onboard observer in one net equipped with a TED and the other without a TED. Although a Bayesian hypothesis test demonstrated no significant differences through the simultaneous comparison of absolute capture considering the use and non-use of the TED, the credibility interval of posterior beta distributions intercepted almost its minimum limit which weakens the hypothesis of equality. In terms of orientation, the model mounted with the top opening showed no differences in absolute catches of the target species in respect to control.

Keywords: sea turtles, turtle excluder device, trawl fishery, incidental catch, southern Brazil.

Utilizando el dispositivo excluidor de tortugas (TED) en la pesquería de arrastre de camarón rosa en el sur de Brasil

RESUMEN. El uso del dispositivo excluidor de tortuga (TED) es obligatorio en Brasil desde 1994. A pesar de la importancia de la reducción de la captura incidental de tortugas marinas, la eficacia del TED para mantener la captura de las especies objetivo nunca había sido evaluado en la pesquería de camarón frente a la costa sur de Brasil. Por este motivo, se realizó una prueba en noviembre de 2013, con un diseño de TED usando dos vías de evacuación (arriba-abajo), bajo la supervisión de un técnico de la National Oceanic and Atmospheric Administration (NOAA). Tanto la captura absoluta como los rendimientos de pesca fueron simultáneamente monitoreados en 10 lances de pesca a bordo de un barco arrastrero por un observador, usando una red equipada con TED y el otro sin TED. Aunque una prueba de hipótesis bayesiana demostró que no existen diferencias significativas mediante la comparación simultánea considerando la captura absoluta del uso y no uso del TED, el intervalo de credibilidad de las distribuciones beta posteriores interceptaron cerca de su límite mínimo lo cual debilita la hipótesis de igualdad. En términos de orientación, el modelo montado con la abertura hacia arriba no mostró diferencias en las capturas absolutas de las especies objetivo respecto al control.

Palabras clave: tortugas marinas, dispositivo excluidor de tortugas, pesquería de arrastre, captura incidental, sur de Brasil.

In the 1970s the reduction in sea turtle populations mobilized scientists of the National Marine Fisheries Service (NMFS) to study the feasibility of modifying shrimp trawls in order to develop a way for sea turtles to escape as soon as they entered the net, without reducing shrimp catch, which became known as the turtle excluder device (TED) (Skaggs, 1990). The TED is a grid installed at an inclination of 55-35° and in-

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serted in the trawl directly in front of the codend, with an opening on the bottom or top panel to allow a turtle to escape. When turtles and other large animals enter the trawl, they bump into the grid bars and slide through the escape opening. Shrimp and other small animals pass through the grid bars into the codend. Since TED was first introduced in the late 80's, research and development has continued to improve TED for both turtle exclusion and shrimp retention (NOAA, 2014).

In the late 1980s, the US government signed a public law that allowed the imports of shrimp from extractive fishing of foreign countries, being held constant inspections of the use of TED by the US government for the renewal of the export authorization. At that time the American market was important for many Brazilian companies, and therefore the National Council of Fisheries and Aquiculture (CONEPE) supported the Ordinance N°36 published by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) in April 1994. TED's first normative forced to catch the pink shrimp in the Brazilian coast, only industrial vessels with fishing licenses. Three years later, in 1997 the mandatory use was extended to the whole shrimp trawl fleet independent of the target species, excluding fishing vessels up to 11 m in length. Technical characteristics of the TED were altered in 2004 through Ordinance N°31, developed by Ministry of Environment, which remains in effect, maintaining the obligatory use defined in 1997 for all shrimp vessel larger than 11 m. However, TEDs have not been tested in Brazilians' commercial fishing before implementation, resulting in a low level of acceptance, and due to the poor enforcement, was also poorly used.

The use of TED, apart from the ecological importance of avoiding the capture of sea turtles, has been tested and perfected in order to prevent the entry of undesirable products in the codend without loss of the target species. Double-rig trawling for pink shrimp (*Farfantepenaeus brasiliensis* and *F. paulensis*) catches also large quantities of bony fish, which are mostly discarded (Vianna & Almeida, 2005). In this sense, the present experiment aimed to compare the performance on the catches and catch per unit of effort (CPUE) of the pink shrimp obtained in the simultaneous operation of one net equipped with a TED and the other with any selective device.

The test was conducted during a pink shrimp fishing trip onboard a 21 m steel hull industrial double-rig trawler in November 2013. This study was carried on as a pilot test in order to verify the impact of the use of the TED in shrimp and fish catches in four consecutive days in a traditional shrimp trawling ground between 26º13'-27º07'S and 48º06'-48º24'W.

One net was equipped with a TED and the other without the device. The TED used was composed of a metal grid with of 130 cm long and 110 cm wide with 10 cm spacing between the bars. The device was attached to a modified panel in angle of approximately 60º with an escapement opening at the end of the grid. Additionally, two PVC floats of 7.2 cm diameter and 22.2 cm long were installed in the upper side of the TED.

In the test two models of TED were mounted under supervision of Jack Forrester from the National Oceanic and Atmospheric Administration (NOAA) performed during a visit to Itajaí in September 2013. Technical specifications of these models comply with Ordinance Nº31. All materials used in the assembly of these TED's were from the US. The test was conducted under two treatments:

Model 1. A TED with a double flap opening aiming downwards: installed on the trawl to allow the organisms to escape below the net, *i.e.*, escape opening has 176 cm long and 53 cm wide and is located at net bottom. Another feature is the use of dual covers, consisting of two identical panels of equal dimensions, which are overlapped and allow the escape through the space between the panels (Fig. 1a).

Model 2. A TED with an escape opening located in top of the net and simple coverage: in this case the escape of organisms is carried out through the top of the net since its opening is located on top. Unlike Model 1, the opening escape is 201 cm long per 61 cm wide, being covered by a simple panel, *i.e.*, only one panel was used to cover the opening in order to prevent loss of target species (Fig. 1b).

At the end of each haul the catch of both nets were maintained on deck to be sorted (Fig. 1c). The catches of pink shrimp and retained fauna, characterized as various fishes, were separated and weighted with a hand dynamometer. Geographical information of the fishing operations and respective catches were recorded, including observations on the presence of debris, large size fish, sea turtles and other aspects related to the operation of each trawl.

An onboard observer was previously trained for turtle identification in a specific program held by the National Sea Turtle Conservation Program (TAMAR) that included biological information collection, post-shipment handling, marking, photographic documentation and correct release at sea. The observer was also authorized to collect the turtles if they were caught dead. The experiment was properly registered at the Chico Mendes Institute for Biodiversity Conservation (ICMBio) database and permission was issued in Authorization and Information on Biodiversity System (SISBIO).

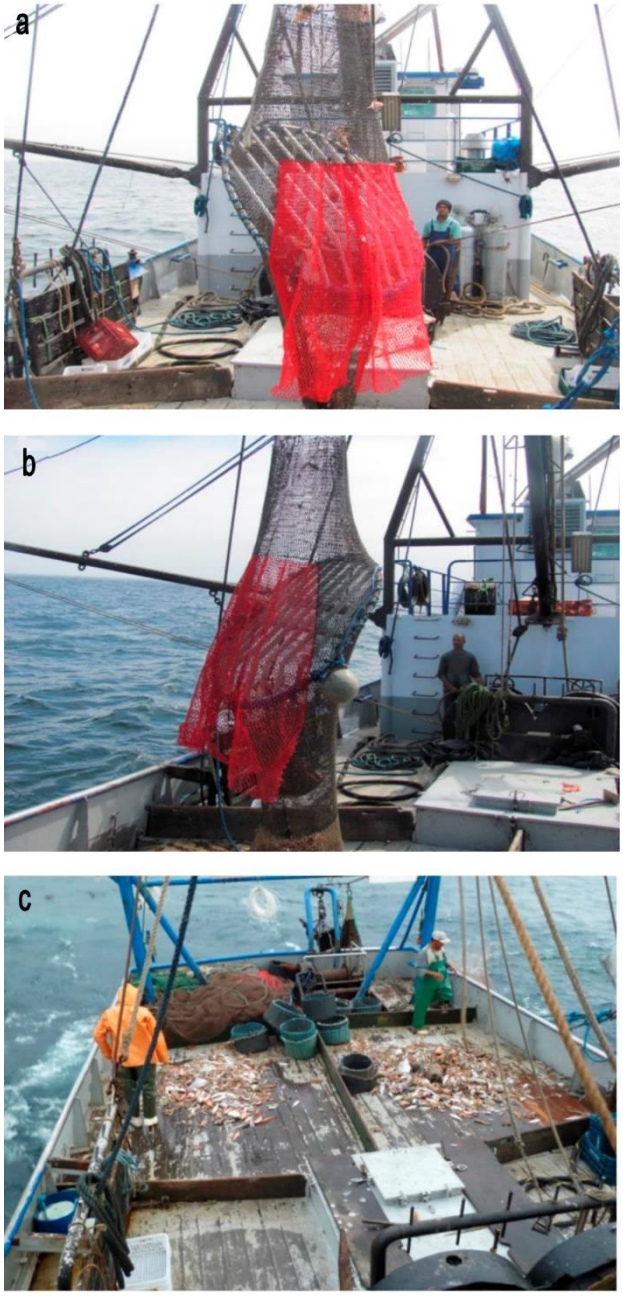

Figure 1. a) Model 1. TED mounted with the escape opening on the downside, b) Model 2. TED mounted with escape opening located in the top of the net, c) Capture of the equipped net with TED (left) and without TED (right) sorted on deck.

A hypothesis test based on the Bayesian method was conducted to verify the influence of TED over the target (pink shrimp) and other retained species (various fishes) in monitored trawls on a typical double-rig trawler off southern Brazil. This test is adapted from Student's *t* test, to identify the effect of binary exploratory variable (*i.e.*, fishing haul with and without TED) over a continuous variable (*i.e.* capture in kg; CPUE, in kg/trawling hour).

Linear models were fitted to catch (kg) and yield (kg/per trawling hour) for the target species and various fishes depending on the use and non-use of TED. Bayesian estimates of parameters were performed by Monte Carlo method via Markov Chains (MCMC) (Gelman *et al*., 1995; Carlin & Louis, 2000; Ellison, 2004). Uninformative *prioris* were used for all parameters.

In the first four hauls the TED was set as defined in Model 1. In these hauls, catches of both shrimp and various fishes in the net equipped with a TED were lower in relation to the net without a TED. By comparing the production of hauls 1, 2 and 3, it was found that the difference in shrimp and fish production in both nets was continuously around 50% higher in net without the equipment. On the fourth haul, despite the net without a TED still produced more, the difference between the nets was lower (Table 1).

In the next six hauls the TED was set as defined in Model 2. A lower difference in the shrimp production was observed for these hauls between the TED and non TED equipped trawls. In hauls 5 and 6 there was an increase in shrimp production in the net equipped with TED and exactly the same production of fish for both nets. For the sixth haul, the net without TED was exchanged for another net due to damages. Adjustments in the footrope's chains were also performed of in both nets. On the seventh haul the TED was installed in another net, resulting in a production of shrimp identical in both nets, while the amount of fish was lower in the net equipped with the device. In the hauls 8, 9 and 10, the difference in shrimp production was smaller between the nets equipped with and without TED; however the difference for fish remained higher. The last haul was peculiar because the difference of fish catch was higher in the net with the TED producing 4 kg more than the other net (Table 1).

Shrimp production was lower in the net equipped with TED (131.5 kg) than in the net without the device (159 kg), presenting a difference of 27.5 kg (17.3% less - Table 1). Fish production was also lower in the net equipped with TED (144.5 kg) than in the net without the device (194.5 kg), a difference of 50 kg (25.7%) in favor of the unequipped net (Table 1). The average production values were higher for both pink shrimp and various fishes in the net without the TED; however, this difference was smaller for pink shrimp (Figs. 2a and 2c). None turtle was captured in the net without TED (control).

In terms of yields (CPUE), posterior estimates of beta parameter (β), which represent the difference

Table 1. Summary of the differences in catches obtained in each fishing operation monitored in net without TED and the net equipped with TED, for the target species (Shrimp, Shr) and retained species (Fishes, Fis) expressed in kilograms per trawling hours (CPUE).

Hall number	Net without TED				Net with TED				Difference in production	
	Shr (kg)	Fis (kg)	CPUE Shr	CPUE Fis	Shr (kg)	Fis (kg)	CPUE Shr	CPUE Fis	Shr (kg)	Fis (kg)
1	18.0	18.0	3.86	3.86	11.0	10.0	2.36	2.14	7.0	8.0
2	18.5	13.5	3.58	2.61	10.0	8.5	1.94	1.65	8.5	5.0
3	18.0	24.0	3.38	4.50	9.0	15.5	1.69	2.91	9.0	8.5
4	15.5	12.0	3.00	2.32	12.5	11.0	2.42	2.13	3.0	1.0
5	10.0	25.0	1.82	4.55	13.0	25.0	2.36	4.55	-3.0	0.0
6	14.0	9.0	2.67	1.71	16.0	9.0	3.05	1.71	-2.0	0.0
7	20.0	28.0	2.93	4.10	20.0	17.0	2.93	2.49	0.0	11.0
8	19.0	18.0	3.45	3.27	17.5	9.5	3.18	1.73	1.5	8.5
9	14.0	30.0	2.58	5.54	11.5	18.0	2.12	3.32	2.5	12.0
10	12.0	17.0	2.40	3.40	11.0	21.0	2.20	4.20	1.0	4.0
Total	159.0	194.5			131.5	144.5			27.5	58.0

between the average yield on hauls without a TED and the average yield of hauls with a TED, in both cases (pink shrimp and various fishes, Figs. 2b and 2d, respectively) reject the null hypothesis of equality between the yields in the two treatments, favoring the alternative hypothesis (Table 2; Fig. 3). In the case of absolute catches, both for pink shrimp and various fishes, the posterior distribution of beta (β) cut the scalar 0 (zero), which favors the null hypothesis (equality between two treatments).

However, the credibility interval of 95% intercepts the scalar zero almost at its minimum limit, which weakens the hypothesis of equality (Table 2; Fig. 3). On the other hand, the average difference in absolute shrimp capture between treatments was zero for model 2 while in model 1 catches were higher in the net without TED (Table 2).

An effective TED should reduce bycatch, but maintain fishing profitability, safety and ease of operation (Robins-Troeger *et al.*, 1994). In this study, catches from both target and accessory species tended to be higher in the net without TED. Between TED models used, the model equipped with top-opening escape door presented the same absolute captures, in average, of the net without a TED with almost the same reduction rate of accessory species. Similar results were found in Australia in which the reduction of the catch showed no significant prawn catch loss (1.38%) during a scientific experiment with the Australian TED (AusTED). However, commercial fisherman testing the AusTED in north Queensland waters have reported prawn losses varying between 4 and 50% by nets equipped with the AusTED system, which could be linked to a lack of standardization of unmodified nets by commercial fishers (Robins-Troeger *et al.*, 1994). This variability could also be related to different trawling locations that may influence prawns catch rates because of differences in bottom type and abundance of debris (Robins-Troeger *et al.*, 1994). Although this preliminary test has shown that the levels of capture of the target species can be maintained equal in the equipped with TED and the other with any selective device, more tests must be conducted in a wider range of trawling grounds and a higher number of trawls (*i.e.*, 30 trawl for each TED Model), due to the high variability and adjustments to improve TED's efficiency if necessary.

Results obtained for the absolute catches with TED model 2 demonstrated that this configuration can achieve shrimp loss values as similar as obtained elsewhere in the world (Kendall, 1990; Skaggs, 1990; Renaud *et al.*, 1993; Broadhurst, 2000; Gallaway *et al.*, 2008). Such results nevertheless corroborate North American experiments using top-opening escape door, where shrimp loss has achieved minimal levels. Besides maintaining target species catch levels, top-opening escape door favors turtles to escape due to a tendency to swim upward when captured (NOAA, 2014).

This study represented the first attempt to evaluate the TED efficiency to maintain good yields capture of the main target species (including pink shrimp and some fish species) in south Brazil. However, because of TED model 2 was tested in only six hauls, research should continue in order to improve shrimp and valuable bycatch capture.

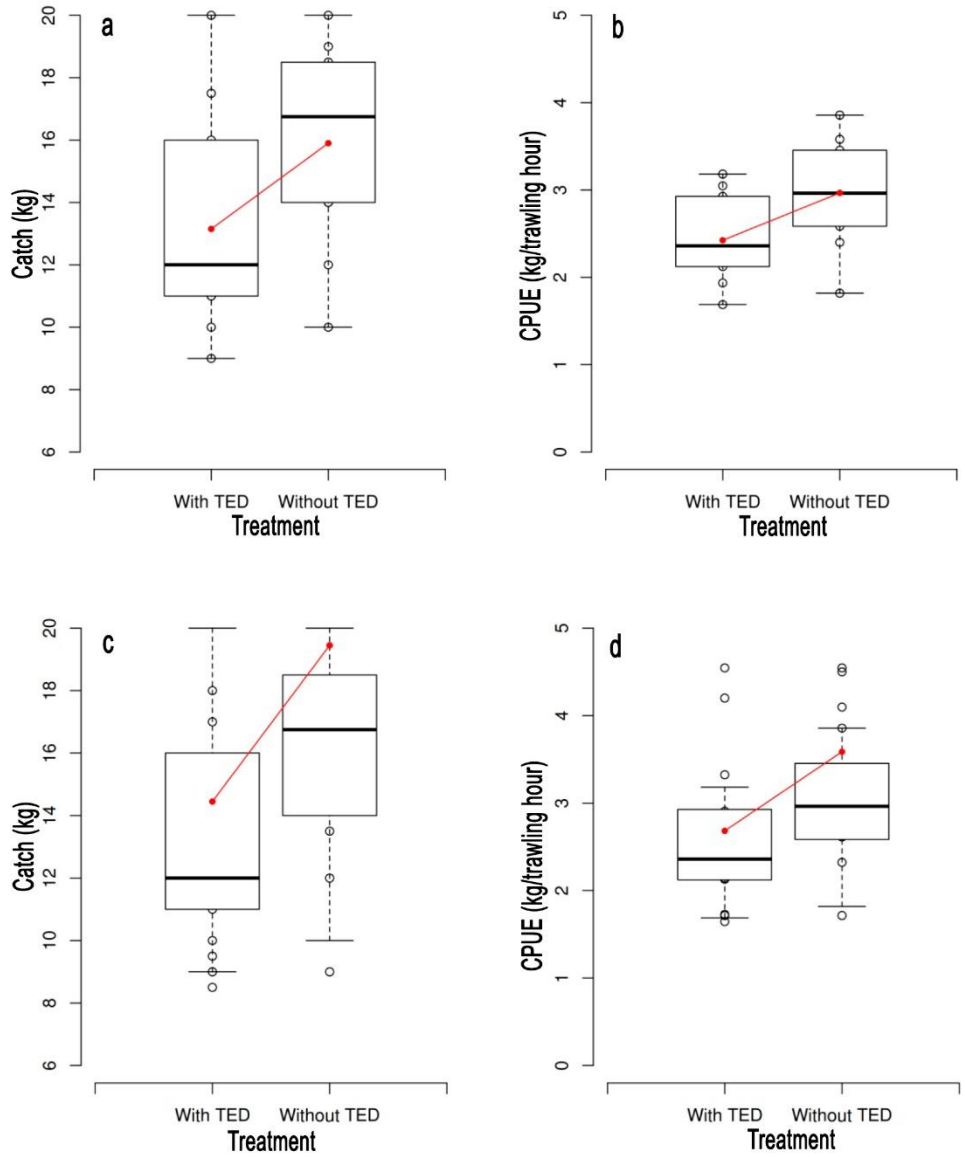

Figure 2. Boxplots representing pink shrimp catch (kg) and CPUE (kg/trawling hour) of the net equipped with TED and the net without TED for the pink shrimp (a, b) and various fishes (c, d). The bold line represents the median, box delimitate the first and third quartile, and dotted lines indicate lower and upper extremes. Outliers were represented by the open circles. The red line exhibited the mean values compared.

Table 2. Summary of the linear models used to test the equality of the means of each dependent variable due to the use/non-use of turtle excluder device (TED). α - intercept or average of the response variable at the reference level (hauls equipped with TED); β - slope or difference between the average of the response variable at the reference level and the average of the following response variable (hauls without TED). CI 2.5 e 97.5% - correspond to the upper and lower limits of the credibility interval of 95% to the posterior of β.

Model	Description	α	β	CI of β 2.5%	CI of β 97.5%
1	Pink shrimp catch	13.159	2.729	-0.624	6.092
2	Pink shrimp CPUE	2.425	0.542	0.006	1.08
3	Various fishes catch	14.43	5.027	-1.069	11.12
4	Various fishes CPUE	2.679	0.909	-0.16	1.994

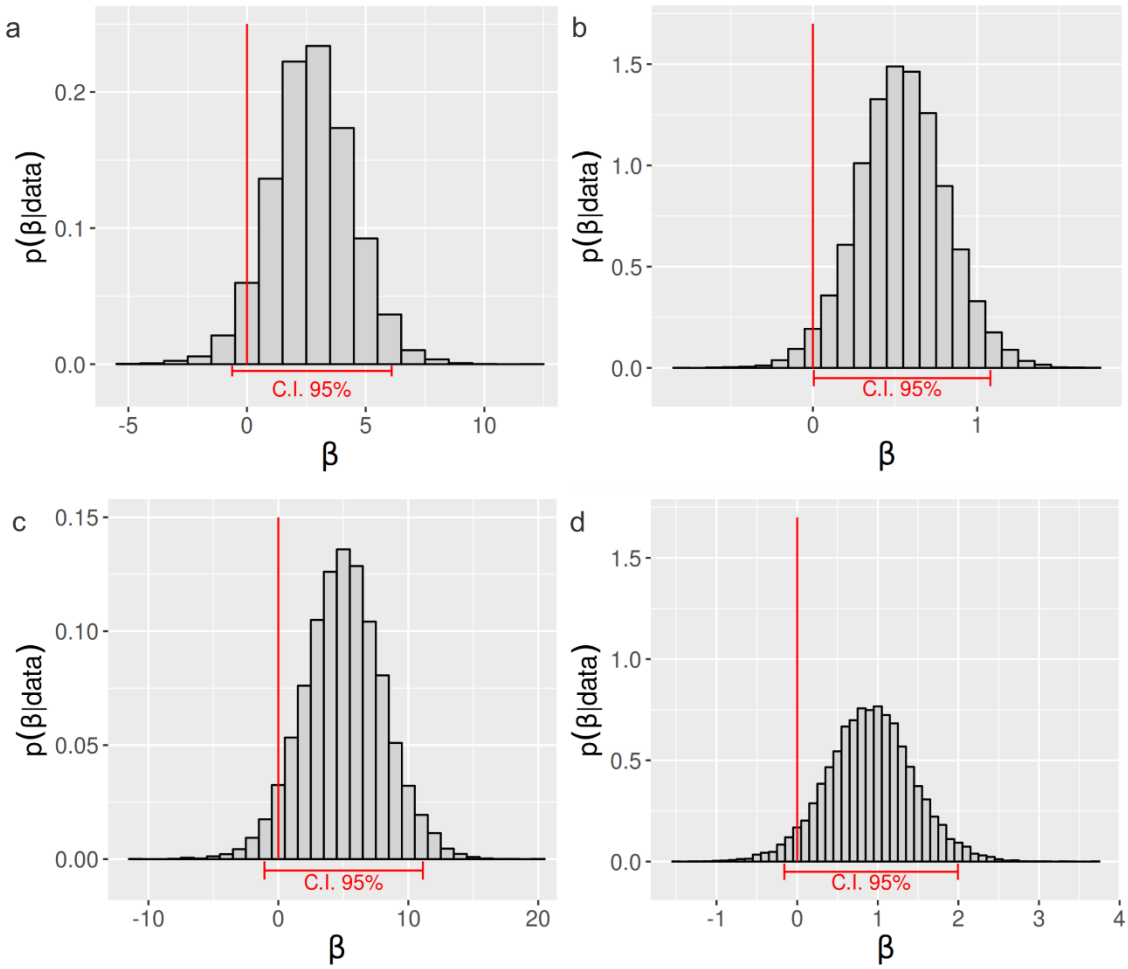

Figure 3. Posterior probability distribution of the parameter β for each model analyzed. CI represented the credibility interval of 95% of data for: a) Pink shrimp capture model, b) pink shrimp CPUE model, c) fishes capture model, and d) fishes CPUE model. The vertical red line represents the scalar zero.

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