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Fishing biology of lumptail searobin, *Prionotus stephanophrys* Lockington, 1880 from the multi-purpose fishing fleet during 2017 and 2018 in Ecuador

Biología pesquera de la gallineta, *Prionotus stephanophrys* Lockington, 1880, procedentes de la flota polivalente durante el 2017 y 2018 en Ecuador

Authors

[1]*Sara España-Mindiolaza*

[2]*Willan Revelo-Ramírez*

[1]**Gabriela Vergara*

[1]Universidad de Guayaquil, Facultad de Ciencias Naturales, Avenida Juan Tanca Marengo y Avenida Raúl Gómez Lince, Guayaquil, Ecuador.

[2]Instituto Nacional de Investigaciones en Acuicultura y Pesca, Letamendi 102 y la Ría, Guayaquil, Ecuador.

*Autor de correspondencia.

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Abstract

The lumptail searobin (*Prionotus stephanophrys* Lockington 1881) is one of the most captured species as part of the bycatch in hake fishing operations; therefore, this research analyzed the size-weight relationship, gonadosomatic index, and size at sexual maturity of 622 individuals incidentally captured by the polyvalent fishing fleet between 2017 and 2018 in the Ecuadorian coast, where it was observed that the most frequent lengths were 27-28 cm TL for both sexes, with an average length for females of 27.73 ± 2.88 cm LT and for males of 26.78 ± 2.51 cm LT; however, in general, no significant differences were found in size structure in combined years (P>0.05). Additionally, the estimated size at sexual maturity was 20.22 cm; therefore, it is considered that all incidentally captured individuals are above sexual maturity, with only 3.86% below it. The total length-total weight relationship showed for the species a negative allometric growth; meanwhile, the gonadosomatic index established that the reproductive season corresponds from march to november, and from april to may is resting season. The highest incidental capture of individuals, especially females, coincided with the peak of reproductive intensity, with a sex ratio F:M of 1.5:1.

Keywords: lumptail searobin; *Prionotus stephanophrys*; bycatch; gonadosomatic index; sexual maturity.

Resumen

La gallineta (*Prionotus stephanophrys* Lockington 1881) es una de las especies más capturadas como parte de la fauna acompañante dentro de las faenas de pesca de la flota merlucera; por lo tanto, la presente investigación analizó la relación talla-peso, índice gonadosomático y talla media de madurez sexual de 622 individuos capturados incidentalmente por la flota polivalente en la costa ecuatoriana entre el 2017 y 2018, donde se observó que las tallas más frecuentes oscilaron entre 25-30 cm LT para ambos sexos, con una talla promedio para hembras de 27,73 ± 2,88 cm LT y para machos de 26,78 ± 2,51 cm LT; sin embargo, de manera general, no se encontraron diferencias significativas en la estructura de tallas en años combinados (P >0,05). Adicionalmente, la talla media de madurez sexual estimada fue de 20,22 cm de LT; por lo tanto, se consideró que todos los individuos capturados incidentalmente se encontraron por encima de la madurez sexual, con únicamente el 3,86% por debajo de esta. La relación longitud total-peso total mostró para la especie un crecimiento alométrico negativo; mientras que, el índice gonadosomático estableció que la época reproductiva correspondió de marzo a noviembre y de abril a mayo como de reposo. La mayor captura incidental de individuos, sobre todo de hembras coincide con la mayor intensidad reproductiva, con una proporción sexual H:M de 1,5:1.

Palabras clave: gallineta; *Prionotus stephanophrys*; fauna acompañante; índice gonadosomático; madurez sexual.

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Introduction

Trawling fishing is considered in many countries as a practice with high environmental impact (Eayrs, 2007; Amoroso et al., 2018; Abdulqader et al., 2020; Mendo et al., 2022), because, among other effects, it alters the benthic habitat and its communities (Pranovi, 2000; Simpson and Watling, 2006; Victorero et al., 2018), as well as incidental capture and bycatch of non-target species (Gilman et al., 2020). The high rate of incidental capture in hake fishing is the result of low selectivity in the fishing techniques, where it is estimated that between 45,5 and 55 % of all bycatch worldwide are produced by hake fishing (Amoroso et al., 2018; Pérez-Roda et al., 2019). It may be pointed out that bycatch is composed by live and dead individuals (Blanco et al., 2023) in different stages of sexual maturyity (Pérez-Roda et al., 2019), which has long-term consequences in sexual proportion, size distribution (Zhou et al., 2010), recruitment and sustainability of fishing resources, associated with chang changes in the trophic structure (Hall et al., 2000; Baum y Worm, 2009).

In Ecuador, it has been reported that approximately 30 to 50% of all capture by shrimp trawling is bycatch, where the lumptail searobin (*Prionotus stephanophrys* Lockington, 1880) is one of the most representative species both in net weight and number of individual captures (Quijije, 2018), and in similar numbers by hake fishing operations (Samamé y Molina, 2000; Paredes-Bulnes y Rodríguez, 2004). *Prionotus stephanophrys*, is distributed aling the Pacific Coast, from southern California (EE. UU.) to Ilo (Peru) (Chirichigno y Velez, 1998), and inhabits the continental shellup to 240 m of depth (Schmitter-Soto and Castro-Aguirre, 1994). It mainly eats planktonic crustaceans, with a preference for euphasiids (Herdson and Martínez, 1985), and shares its habitat with the hake (*Merluccius gayi*).

Research in fishing focuses in the target species or incidental bycatch of threatened species or in critical danger, without consideration for species with no ceconomic or conservational importance *P. stephanophrys* is not considered to be a target species, being instead classified as bycatch , and is mainly used to make fish flour, if not simply discarded. Nonetheless, it is possible that this species supports intrinsic trophic pelagic chains, thus studying it becomes a priority. Considering the lack of knowledge about the biological criteria of species considered as bycathc, it is necessary to produce information for future assessment in fishing that would produce sustainable regulations in the industry; likewise, to reduce the discarding rate through efficient resource exploitation.Therefore, this study determined the size-weight relation, size structure, gonadosomatic index, and sexual maturity size of the lumptail searobin (*P. stephanophrys*).

Materials and methods

The biological data of *P. stephanophrys* came from the records of fishing observers on board of 43 vessels that constitute the multipurpose industrial fleet that targets hake (M. gayi), and covers the periods January-August, October-November of the 2017, and January-August 2018 (closed season in September). The data provided by the Public Aquaculture and Fisheries Research Institute (IPIAP) included information on total length (TL), total weight (TP), gonadal weight (PG), sex, sexual maturity and gonadosomatic index (GIS).

The capture area of the multipurpose industrial fleet is concentrated in the Gulf of Guayaquil between points 2°32.445' S and 80°54.221' W and 3°15.505' S and 80°36.207' W (figure 1). Trawling was carried out at depths between 64 and 207 m with a bottom trawl (wings: 6"; body: 4.25"; codend: 3.5"), with an average of 8 to 10 sets per day per vessel. , lasting between 01h30 and 02h38.

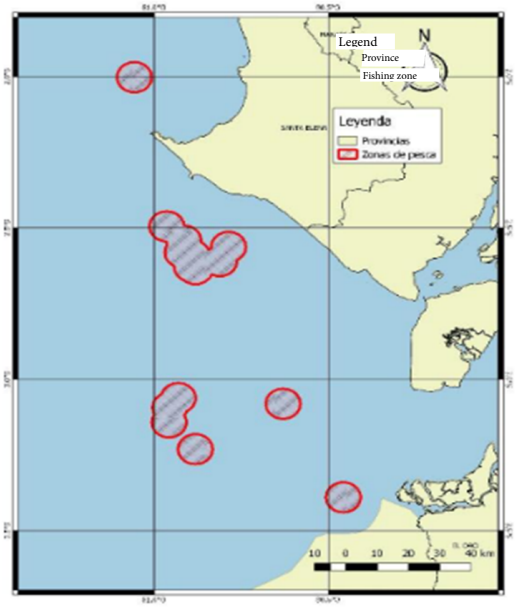

Figure 1. Capture area of the multipurpose industrial fleet during the 2017-2018 period.

The size structure of captured individuals between 2017 and 2018 was measured using absolute frequency histograms, applying Sturges' rule to establish size class intervals

(Salgado-Ugarte and Saito-Quezada, 2020). Subsequently, the length between females and males were compared applying the Mann Whitney U test (Kolmogorov-Smirnov with Lilliefors correction, P<0.01) in the R program. In addition, the type of growth for females, males and combined sexes was established through the total length-total weight (LT-PT) relation for the years 2017 and 2018 using Ricker's potential equation (1977).

$$PT=a*(LT)^b$$

where "a" represents the intercept or origin and "b" the type of growth; considering that, if b= 3 the growth was isometric, b> 3 the growth was positive allometric and b< 3 the growth was negative allometric (Froese, 2006). The gonadosomatic index (GIS) of females and males was estimated by applying the Vazzoler (1996) equation.

$$IGS=(PG/PT)*100$$

IGS values were represented by the median of each month. In the months where data did not exist, an interpolation was generated by a sixth degree polynomial, given that this had the highest coefficient of determination (♀: r2= 0.80; ♂: r2= 0.73). The mean size at maturity was estimated with the equation proposed by Gislason et al. (2008).

$$L\infty= 0.64\ (\pm0.15)\ L\infty 0.95(\pm0.05)$$

where, L∞ corresponds to the asymptotic length; the numerical value 0.64 was the proportion of sexual maturity in relation to asymptotic size; the expression L∞ (0.95(±0.05) represents an exponential relationship in which L∞ is raised to a power of 0.95.

Results and discussion

Six hundred twenty-two lumptail searobin (*P. stephanophrys*) were analized, of which 368 were females and 254 males (figure 2). In 2017, between 11 (july) and 59 (january) individuals were captured incidentally.Meanwhile, in 2018, between 9 (february) and 104 (march) individuals were captured. In general, during the study period, there was higher female capture than male, in a proportion F:M of 1,5:1. In this context, the variations in incidental capture of *P. stephanophrys* could be closely tied with fishing efforts on target species (hake) and the operability of the fleet; nonetheless, this hypothesis cannot be asserted due to a lack of open-acces information.Other possible explanations for the fluctuation in the number of incidentally captured individuals are changes in the water (temperature) and food availability; thus, the fish are forced to move within water columns. Consequently, the time and depth of fishing sets can be determining factor for the number of captured individuals.

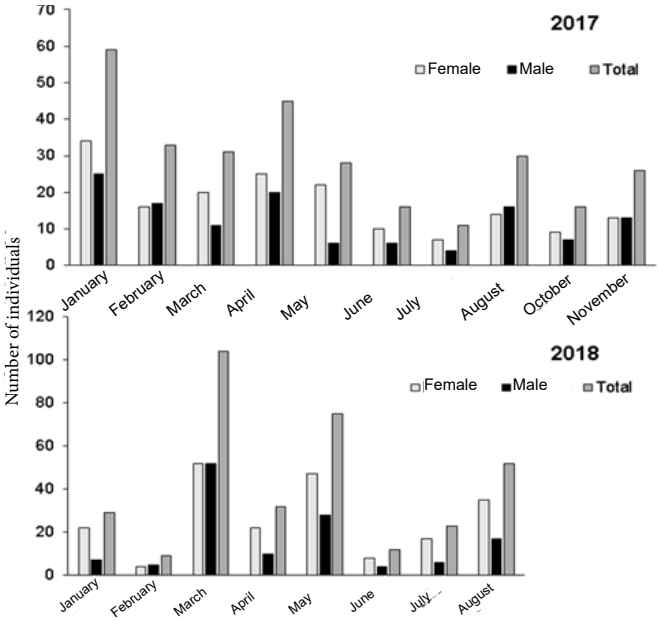

Figure 2. Number of *P. stephanophrys* individuals as part of the multipurpose fleet bycatch between 2017 and 2018.

The size structure of incidentally captured individuals ranged from 21 to 36 cm LT in both years; this differed from the data obtained by Herrera et al. (2010) in the gulf of Guayaquil, where the range was between 22 to 39 cm LT for females and 21 to 38 cm LT for males. This difference can be associated to data obtention (explotartory fishing vessel during june 2007). In 2017, the highest quantity of incidentally captured individuals within the 27-28 cm LT range for both sexes was observed. Meanwhile, in 2018 there was a difference in size between sexes, whereby size in males did not change from the previous year (27-28 cm TL), while females had a 25-26 cm LT range. In general, the lowest capture of individuals fell in the 33-34 cm and 35-36 cm TL ranges.

The average size for females was 27.73 ± 2.88 cm TL and 26.78 ± 2.51 cm LT for males. The size of capture individuals did not show significant differentes between sexes in combined years (P>0.05); nonetheless, when analyzing each year independently, there were significant differences (2017: P<0.01; 2018: P<0.001), with a greater annual size average in females (2017: 27.4 ± 2.74 cm LT; 2018: 27.7 ± 2.71 cm LT) (table 1). Pérez-Huaripata and Castañeda-Condori (2018) reported sizes from 6 to 35 cm LT for this species, and an average size of 23.4 cm LT in females and 21.7 cm LT in males. The notable difference in the size ranges and medians in both studies is due to the data coming exclusively from the multipurpose fleet, which used 90 mm traling nets, which allowed individuals of smaller size to escape; meanquile, the data from Pérez-Huaripata y Castañeda-Condori (2018) comes from a bycatch assessment vesself of *M. gayi*, which operates with different net sizes.

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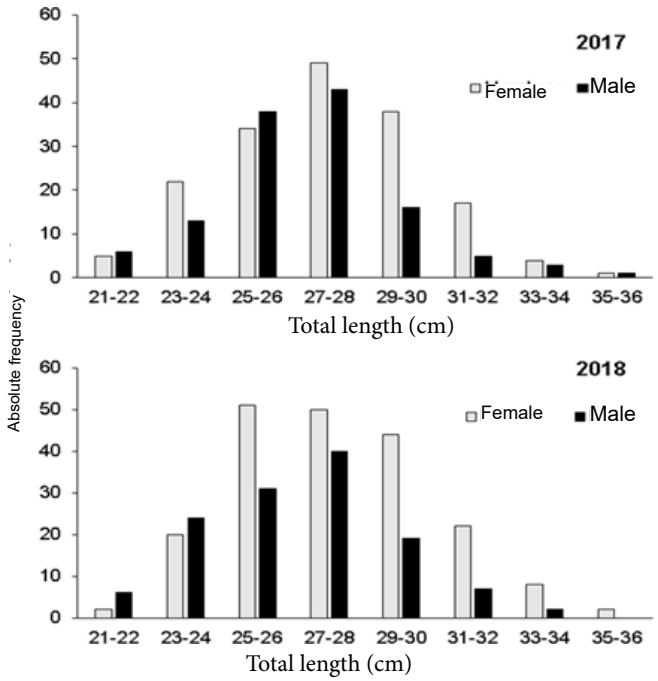

Figure 3. Size structure of male and female lumptail searobin (*P. stephanophrys*) captured by multipurpose fleets between 2017 and 2018 in Ecuador.

Table 1. Descriptive statistics for size (cm TL) in *P. stephanophrys* males and females captured by the multipurpose fleet between 2017 and 2018 in Ecuador.

Year	Sex	Average size (cm)	Standard deviation	Standard error
2017	Female	27.40	2.74	0.21
	Male	26.80	2.42	0.21
2018	Female	27.70	2.71	0.19
	Male	26.40	2.58	0.22
Combined years	Female	27.73	2.88	0.15
	Male	26.78	2.51	0.15

The LT-PT relation in females, males and combined sexes in both years presented values of b < 3 (b = 2.57-2.82), which indicated negative allometric growth. However, the b value and significance observed in males during 2018 (b= 2.82; p= 0.08) corresponded to isometric growth; this could be associated with several factors, including the general condition of the population and gonadal development of males (Rahman et al., 2015) during 2018, as well as the methodology applied (sample size and size ranges captured). Consequently, it should be considered that what was observed in 2018 did not represent the general growth of the species (table 2); considering also that the slope did not present significant differences between females and males.

Table 2. LT - TP ratio of female, males and combined sex of P. stephanophrys obtained from the multipurpose fleet during 2017 and 2018 in Ecuador. Females (H), Males (M), Combined (C).

Year	Sexo	n	LT range (cm)	a	b	r^2	t-calculated	p-value	Growth
2017	H	170	21 - 35	0.04	2.60	0.87	-5.19	< 0.001 *	Allometry (-)
	M	125	22 - 35	0.05	2.57	0.87	-4.98	< 0.001 *	Allometry (-)
	C	295	21 - 35	0.04	2.61	0.87	-6.71	< 0.001 *	Allometrya (-)
2018	H	198	22 - 36	0.04	2.62	0.81	-4.31	< 0.001 *	Allometry (-)
	M	129	21 - 34	0.02	2.82	0.86	-1.75	0.08	Isometry
	C	327	21 - 36	0.03	2.75	0.84	-3.80	< 0.001 *	Alometría (-)

Represents significancy.

However, in the combined data (years and sex) it was shown that the lumptail searobin had a negative allometric growth (t= -7.09, P<0.001) with values of b= 2.67 and r^2 = 0.85 (figure 4). Herdson and Martínez (1985) determined a value of b= 2.67, although the 244 individuals analyzed by the authors were in a range between 16 and 21 cm TL. Even given the difference in the size ranges, the value of the length-weight exponent (b) was the same, which could be a result of the stability of the environmental conditions of the ecosystem, or that P. stephanophrys presented biological and stable morpho-physiological conditions (Rahman et al., 2015).

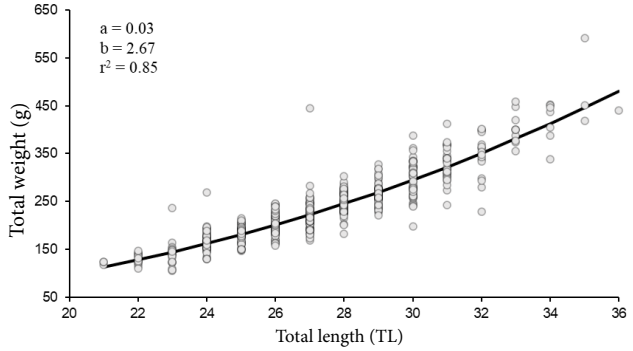

Figure 4. LT-PT relation curve for combined data (years and sex) of lumptail searobin (P. stephanophrys) obtained from the multipurpose fleet in Ecuador.

The type of allometric growth of negative *P. stephanophrys* differed from that recorded in Peru (Pérez-Huaripata and Castañeda-Condori, 2018) and Mexico (Schmitter-Soto and Castro-Aguirre, 1991), as well as in other species of the genus *Prionotus*, such is the case of *P. nudigula* in Mar de Plata, Argentina (Volpedo and Thompson, 1998) and *P. ruscarius* on the coasts of Jalisco and Colima, Mexico (Lucano-Ramírez et al., 2005) who determined isometric growth , that is, the weight increased proportionally with the length. The negative allometric growth of *P. stephanophrys* observed in Ecuador was possibly due to food supply and competition and/or trophic pressure with *M. gayi*. In this context, it has been determined that around 65% of the diet of P. stephanophrys was made up of euphausiids (Samamé and Fernández-Ramírez, 2000), there is an overlap in trophic niche with *M. gayi* (Alamo and Espinoza, 1997), and it is also one of its main predators (Castillo-Rojas et al., 2000).

The fishing area could also influence the results obtained in this study, since the hake capture areas in Peru were more coastal, and with high abundances of euphausiids (Orosco and Ayón, 2016), reducing trophic competition and, consequently, the Relative growth in height and weight was isometric. Meanwhile, the multipurpose fleet in Ecuador was concentrated mainly in the external estuary of the Gulf of Guayaquil, which has oceanic influence, where there was a lower abundance of euphausiids (Jiménez and Bonilla, 1980), which could be the reason that prevented P. stephanophrys to gain weight in the same ratio at which it grew. Additionally, another factor to consider was the level of exploitation of the hake resource, since fishing could reduce interspecific competition and predation..

In 2017, February had the maximum IGS value (IGS= 5.30) and the minimum in May (IGS= 0.88); while, in 2018, January presented the maximum value (IGS= 3.46) and August the minimum (IGS= 0.52). Paredes-Bulnes and Rodríguez (2004) confirmed the above with macroscopic analysis of the gonads from December to March 2001, determining that 73.4% of the individuals examined were mature during this period. Similarly, Wasiw (2012) in his study carried out during January-February 2003 determined that, of 23 females examined, 69.6% were in the mature stage and the rest were spawning. This could indicate that the highest reproduction intensity for *P. stephanophrys* in Ecuador occurs from November to March; while, taking into account the IGS values observed in April and May, they could be considered months of rest. The IGS values of this study were comparable with those obtained by Samamé and Fernández-Ramírez (2000) in Peru; This could be a result of oceanic conditions, governed by the influence of currents (Humboldt current) and water masses with similar thermohaline characteristics, which determined the availability of food and the metabolic processes of organisms (Morgan et al., 2010), factors closely associated with growth and reproduction.

The IGS variation coincided between females and males during 2017; However, for the year 2018 the variation was inverse, noting that the months where the IGS increased in females, it decreased in males (figure 5). Although reproductive periods were highly variable in marine species and depended on intrinsic and extrinsic variables at different time scales (Lowerre-Barbieri et al., 2011), reproductive asynchrony, observed in the IGS values obtained in 2018, could be considered as an atypical behavior and it would be important to analyze whether this trend is maintained in the long term, since it could affect reproductive success, larval survival and recruitment. Such effects have been observed in target species (Cushing, 1973; Wieland, 2000; Anderson et al., 2008); However, there are no studies on species considered companion fauna.

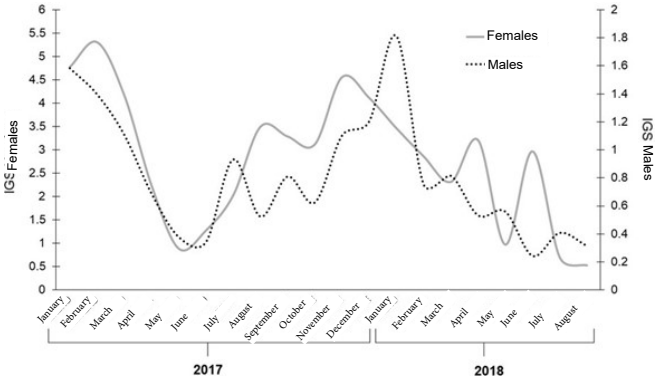

Figure 5. Gonadosomatic index (GIS) of female and male P. stephanophrys obtained from the multipurpose fleet during 2017 and 2018 in Ecuador.

The highest number of captured individuals was recorded in January 2017 and March 2018, this coincided with the months where the highest IGS values were obtained, which indicated that individuals were likely to be captured during the season of greatest reproductive intensity. It can be infered that, if the species is not protected during the most intense months, the recruitment rate will decrease, observing lower abundances of P. stephanophrys in the long term. Additionally, the increase in catches could indicate a greater effort by the trawl fleet, which would have an effect on the size structure and the average size at sexual maturity.

The estimated mean size at maturity for P. stephanophrys was 20.22 cm TL for both sexes, which coincided with the L50 reported in Peru by Samamé and Fernández-Ramírez (2000) based on the observation of the gonads. However, the lack of reproductive studies of this species in Ecuador prevented discussion of possible changes in size at first maturity during the transition from trawling to current multipurpose fishing or changes at a temporal level. Furthermore, it should be noted that the average size at maturity estimated in this research was carried out by indirect methods, and it was necessary to complement it with the analysis of gonadal maturity.

Although this is not a target species, it is likely that in the long term a decrease in size at sexual maturity will be observed,

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a behavior observed in other species in response to high mortalities induced by fishing, both in Ecuador (Suarez-Torres et al., 2022), as well as worldwide (Marshall and Browman, 2007; Rochet and Marty, 2016), especially considering the degree of exploitation exerted on *M. gayi*, and the proportion and composition of the bycatch.

Conclusion

The largest bycatch of *P. stephanophrys* was recorded in a size range of 25-30 cm LT, being above the calculated sexual maturity size (20.22 cm LT), presenting negative allometric growth. Furthermore, the reproductive season based on IGS values is established from November to March for both years; However, there is greater pressure on females during the months of greatest reproductive intensity, since a sexual ratio of 1.5:1 was estimated.

Conflict of interest

The authors declare that they have no conflicts of interest in this publication in any of its phases.

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Authors contribution

Authors	Contribution
Sara España-Mindiola	Research design; literature review; analysis and interpretation of data.
Willan Revelo-Ramírez	Databases.
Gabriela Vergara	Data interpretation, preparation and edition of the manuscript, style correction.