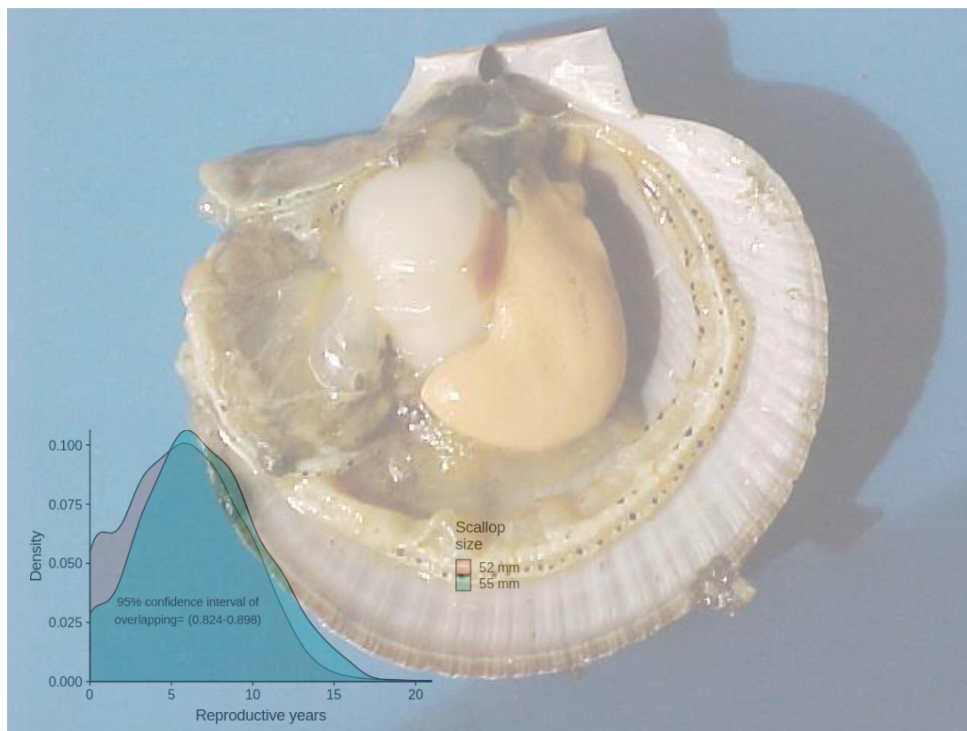


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On the possible effects of changes in harvest strategy of the patagonian scallop (*Zygochlamys patagonica*) on its reproductive potential



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Mar del Plata, abril 2022

ON THE POSSIBLE EFFECTS OF CHANGES IN HARVEST STRATEGY OF THE PATAGONIAN SCALLOP (*Zygochlamys patagonica*) ON ITS REPRODUCTIVE POTENTIAL

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ABSTRACT. The objective of this work is to analyze, by using mathematical models and published data, the possible effect of the reduction of legal size of catch from 55 mm to 52 mm on the reproductive potential of the Patagonian Scallop (*Zygochlamys patagonica*). By using reported data of size at first maturity and growth rate, the experienced reproductive cycles before harvest was simulated for each size class (i.e. 55 mm and 52 mm). Results show that individuals of 52 mm experienced, on average, 1 reproductive event less than individuals of 55 mm (i.e. a reduction from 7 to 6 events). The overlap of reproductive events distributions (that may be an estimation of the total decrease in reproductive events beside the differences in the mean), was 88%. Taking together, these results suggest that the reduction of legal size of catch from 55 mm to 52 mm has a relatively small effect on the number of reproductive cycles experienced before harvest. A more accurate estimation of the effect of legal size changes on recruitment potential, nevertheless, is strongly limited by actual available data. This limitation also includes the lack of knowledge about the importance of Reproductive Reserves and fished areas as sources of larval production (and ultimately recruitment).

RESUMEN. Sobre los posibles efectos de los cambios en la estrategia de captura de la vieira patagónica (*Zygochlamys patagonica*) sobre su potencial reproductivo. El objetivo de este trabajo es analizar, utilizando modelos matemáticos y datos publicados, el posible efecto de la reducción de la talla legal de captura de 55 mm a 52 mm sobre el potencial reproductivo de la vieira patagónica (*Zygochlamys patagonica*). Mediante el uso de los datos de tamaño en la primera madurez y tasa de crecimiento de publicaciones previas, se simuló los ciclos reproductivos experimentados antes de la captura para cada clase de tamaño (es decir, 55 mm y 52 mm). Los resultados muestran que los individuos de 52 mm experimentaron, en promedio, 1 evento reproductivo menos que los individuos de 55 mm (es decir, una reducción de 7 a 6 eventos). La superposición de las distribuciones de eventos reproductivos (que puede ser una estimación de la disminución total de eventos reproductivos además de las diferencias en la media), fue del 88%. En conjunto, estos resultados sugieren que la reducción del tamaño comercial de la captura de 55 mm a 52 mm tiene un efecto relativamente pequeño en el número de ciclos reproductivos experimentados antes de la captura. Sin embargo, una estimación más precisa del efecto de los cambios de tamaño comercial en el potencial de reclutamiento está fuertemente limitada por los datos reales disponibles. Esta limitación también incluye la falta de conocimiento sobre la importancia de las Reservas Reproductivas y las áreas de pesca como fuentes de producción de larvas (y, en última instancia, reclutamiento).

Key words: Reproductive Potential, reproductive reserves, size of catch, *Zygochlamys patagonica*.

Palabras clave: Potencial reproductivo, reservas reproductivas, tamaño de captura, *Zygochlamys patagonica*.

INTRODUCTION

Fisheries must be managed with the goal of sustaining healthy marine ecosystems and the fisheries they support (Pikitch et al. 2004). One now common strategy, to both minimize the impact of fishing on the environment and maximize sustainability, is to spatially manage fisheries, zoning distribution into unfished reproductive reserves (or closures) and zones with limited fishing effort (Pauly et al. 2002). Beside zoning strategies, another useful tool is to adjust legal minimum landing size in relation to size at maturity. This strategy is grounded in the leme “Let fish grow

and reproduce”; stating that individuals of exploited populations should be allowed to realize their growth potential and reproduce before being caught (Froese et al. 2008, 2016).

The Patagonian scallop (*Zygochlamys patagonica*) bottom otter trawl fishery in Argentine Sea is regulated by the Argentine Government through the Consejo Federal Pesquero (CFP). The spatial management of this fishery is based both on zonation and on establishment of minimum landing size, and implies the determination of (i) closures, and (ii) areas where the fishing is allowed. At each management unit (MU), location of allowed

areas (as well as total allowable catches; TACs), are set in accordance with the proportion of commercial sized scallop relative to total available scallop. Specifically, the CFP Resolutions N° 4/2008 and 9/2016 state that it is forbidden to catch in areas that contain $\geq 50\%$ of juvenile scallop (i.e. in areas where the biomass of scallops < 55 mm, the minimum commercial size, is higher than the biomass of scallops ≥ 55 mm). Nonetheless, CFP Resolution N° 4/2018, that regulate the establishment of closures and TACs in the subareas of MU B (BI, BII and BIII), modified the minimum commercial size, changing it from 55 mm to 52 mm. This reduction of minimum commercial size applies only for this MU, but implies a clear management strategy modification.

The reduction of commercial size may have negative effects on the sustainability of the fishery. This is due because it may imply a reduction of reproductive events before adults scallops are removed. As the average size at maturity was estimated in 36 mm (Campodónico et al. 2008), and given the growth rate described by Lomovasky et al. (2008), the minimum commercial size of 55 mm established in the CFP Resolution N° 4/2008 is supposed to ensure at least 3 reproductive events (see 1st Surveillance report 2019). Thus, reducing the harvest size would potentially imply a significant decrease in the reproductive input.

In order to anticipate these possible detrimental effects on the sustainability of the fishery, it is necessary to evaluate if the change in harvest strategy would significantly affect the reproductive events of the scallop stock. To estimate the number of reproductive events (or cycles) that individuals experienced until reaching a given size, in turn, both the age-at-maturity and the age-at-the-given-size are needed. Both values, nevertheless, need to be estimated by taking into account the natural variability of individual growth rates instead of using fixed mean values. Thus, although smaller individuals are definitely expected to have experienced (on average) less reproductive events than larger individuals, the existence of a statistically or biologically significant difference in reproduction between two different sizes will rely on both (i) the net differences in size and (ii) the variability in growth and maturity rates.

The objective of this work is to analyze, by using mathematical models and published data, the possible effect of a decrease in the size-at-first-capture on the reproductive potential of the Patagonian Scallop (*Z. patagonica*). The main hypothesis is that the change in harvest strategy (i.e. the reduction of legal size of catch from 55 mm to 52 mm) will significantly affect the number of reproductive events.

METHODS

By using reported data from Lomovasky et al. (2011), the mean age expected for female individuals of 55 mm and 52 mm shell length, as well as its associated standard deviation, were estimated. Then, assuming that, for a given adult shell size, age of individuals are normally distributed, those parameters were used to simulate the age (in years) of 1000 hypothetical scallops of 55 mm and 1000 hypothetical scallops of 52 mm. For each hypothetical scallop, age at maturity was simulated by using data published in Campodónico et al. (2008). The mean size at maturity of female scallop was, as reported in Campodónico et al. (2008), 36.31 mm. The associated standard deviation was estimated (by digitizing data reported at Campodónico et al. (2008)), as 3.52 mm. This estimation of standard deviation was done by applying the “empirical rule” (i.e. for a normal distribution, 68% of data falls within the first standard deviation from the mean, 95% fall within two standard deviations and 99.7% fall within

three standard deviations; see Altman and Bland (1995)). Size at maturity (in years) was then assigned for each hypothetical scallop by randomly sampling a normal distribution with mean 36.31 mm and standard deviation of 3.52 mm. Obtained size values were rounded to the nearest mm. The age at maturity was then estimated as explained above (by using means and standard deviations of age per size class estimated after digitizing data reported in Lomovasky et al. (2011)). Then, for each hypothetical scallop, the number of experienced reproductive cycles after reaching size at first capture (i.e. either 55 mm or 52 mm) was estimated as the difference between age at first capture and age at maturity. Thus, this procedure resulted in 1000 simulated data of experienced reproductive cycles for each size class (i.e. 1000 values of experienced reproductive cycles for scallops sized 55 mm and 1000 for scallops sized 52 mm; see Fig. 1). This procedure was repeated 100 times. Each time, the mean experienced reproductive cycles for each size class, and the overlap of the distributions were recorded. The simulation was done in R 3.5.1 (R Core Team 2016), using the best available data (i.e. reported data at Campodónico et al. (2008) and Lomovasky et al. (2011)) to estimate used parameters. Estimations are, thus, tied to the imitations of those works in terms of sample size.

RESULTS AND INTERPRETATIONS

Mean reproductive cycles experienced before capture was 7 years for scallops of 55 mm and 6 years for scallops of 52 mm, indicating that the reduction in the size at the first capture from 55 mm to 52 mm can reduce the mean number of experienced reproductive cycles in 1 year (see Fig. 1). The mean overlap of the distributions was 88% (95% confidence interval of overlapping: 0.824-0.898; see Fig. 2).

As expected, individuals of 52 mm experienced less reproductive events than individuals of 55 mm. These results suggest that reducing the harvest size from 55 mm to 52 mm will reduce the number of expected reproductive events before harvest in 1 (i.e. from 7 to 6 events; a 14% reduction). The overlap of reproductive events distributions (non-overlap of the distribution may be an estimation of the total decrease in reproductive events beside the differences in the mean), nevertheless, was relatively high, suggesting a relatively small difference.

The relevant question, nevertheless, may be if this reduction of reproductive events, expected at fished areas, will imply a reduction on recruitment. The actual management of the Patagonian scallop fishery, however, also included fixed non-take areas, known as Reproductive Reserves (RR). The rationale behind this design is that RR are acting as reproductive hotspots. After the first assessment of the MSC and following the objective to maintain stock sustainability, on March 12, 2009, the Consejo Federal Pesquero Resolution No 5/2009 creates non-take areas as RR for the Patagonian scallop. This resolution was modified on August 16, 2012 by the Resolution No 15/2012, to better match with the distribution of the scallop beds, in the geographic definition and denomination of the Management Units (MU). There are 12 RR, encompassing a total area of 730 km². This area is nearly 5.3 % of the estimated total bed area (i.e. 13745 km²). Specifically, the RR area encompass 6.1% of the bed area at MU B. There are, in addition, several areas avoided by the trawling fishing fleet, due to objects on the ocean bottom that would hang or snag nets and fishing gears, that may act as small natural RR. Actual knowledge of the system, nevertheless, do not guarantee that RR are the main source of larvae and, in order to ensure sustainability, the location of RR should be regularly reevaluated

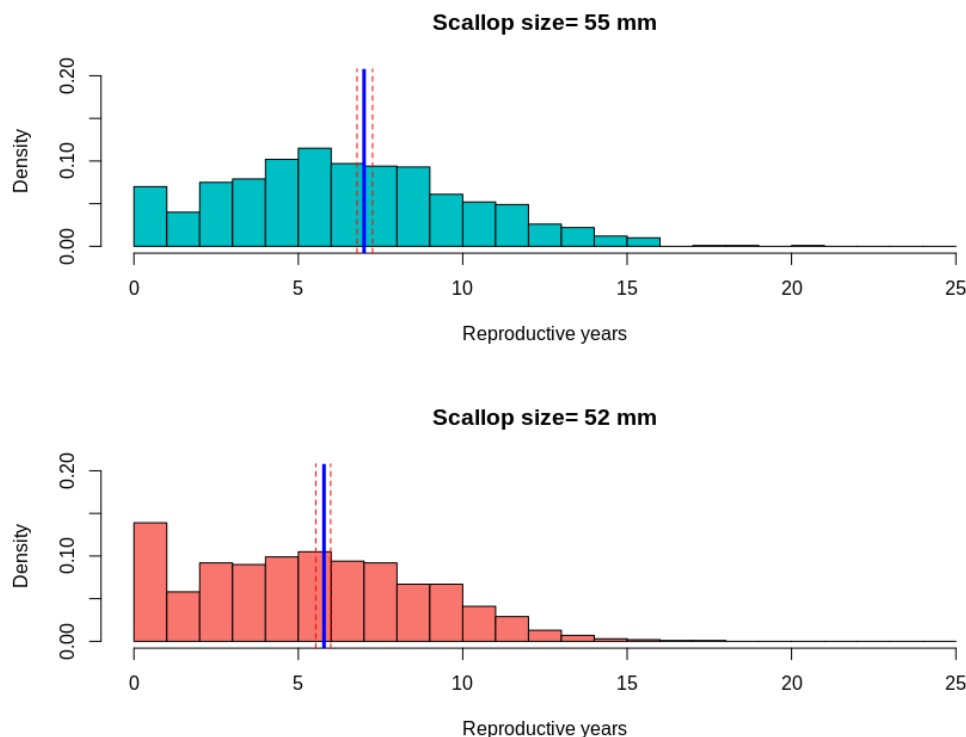


Fig. 1. Frequency distribution of the number of reproductive years (i.e. the difference between age at capture and age at maturity) for 1000 hypothetical scallops sized 55 mm and 1000 hypothetical scallops sized 52 mm. Blue solid lines represent the arithmetic mean of the distribution and dashed red lines represent the 95% confidence interval of the arithmetic mean after 100 repetitions of the procedure.

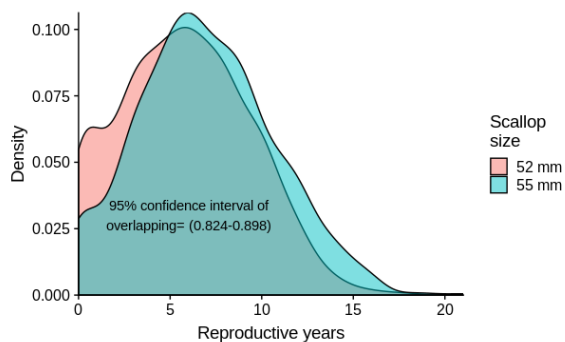


Fig. 2. Density distribution of the number of reproductive years (i.e. the difference between age at capture and age at maturity) for 1000 hypothetical scallops sized 55 mm and 1000 hypothetical scallops sized 52 mm. The reported 95% confidence interval of the overlapping was calculated after 100 repetitions of the procedure.

(e.g. each 2 or 3 years). Ideal design, in addition, should benefit from increased knowledge about biological factors, (as spatial larval production, larval stage duration and dispersal potential), as well as a more accurate notion of the genetic structure of the population and increased information about physical forces. Finally, a more robust estimation of both (i) the variability in size at first maturity and (ii) the variability in individual growth rates, should drive to a more accurate determination of the minimum commercial size in order to ensure sustainability of the fishery.

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