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Research Article

Changes in the distribution density of locate, *Thaisella chocolata* (Duclos, 1832) (Gastropoda, Thaididae) as an indicator for predicting their reproductive events

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ABSTRACT. For a population of locate, *Thaisella chocolata*, in La Rinconada, Chile, on a grid of 39 stations distributed along three 910 m-long transects at depths of 5 to 18.5 m, Moran and Morisita indices were used to evaluate whether density variations along the depth distribution are related to the stratification of larger sizes at the beginning of their reproductive process. Results indicate that before, during, and after forming reproductive aggregations, there is a *T. chocolata* increase in density in the shallow stratum (5 to 13 m). This finding is corroborated by the Moran index, which showed a greater autocorrelation in January-May, September-October, and January 2010, and by the Morisita index; thus, it is validated as a potentially easy-to-use indicator for assessing the reproductive process of this species. This index could also alert fishermen to the prevalence of reproductive aggregations in an area and that these aggregations should not be exploited as is currently the case to ensure the reproductive success of this species.

Keywords: *Thaisella chocolata*; aggregations; reproductive behavior; aggregation indicator; Moran index; Morisita index

INTRODUCTION

The snail, *Thaisella chocolata*, commonly called "locate," is a carnivorous mollusk distributed from Paita, Peru, to the Region of Valparaíso, Chile (Osorio 1979). Historically, locate has been a benthic resource of economic importance for the northern Chilean artisanal fishery. It is concentrated in shallow waters (Retamales & González 1982), including rocky areas in the intertidal zone (Miranda 1967). However, due to intensive exploitation at the beginning of its fishery in 1978, after having reached maximum landings in 1986 of 8244 t (Avendaño et al. 1996) which exceeded the recommended technical levels, the vulnerable fraction in the shallow zone was strongly reduced, restricting the fishery to the Arica and Parinacota, Tarapacá and Antofagasta regions. Since 1988, the abundance of the resource in the Atacama and Coquimbo regions has not supported a commercial catch (SUBPESCA 1995). Its fishery, centered in the Tarapacá and Antofagasta regions, currently harvests 17 t (SERNAPESCA 2021).

Bathymetrically, *T. chocolata* is distributed between 5 and 40 m on rocky or shell substrates and coarse sand (Avendaño et al. 1996, 1997, 1998, Andrade et al. 1997). It is a carnivorous species that feeds mainly on the bivalves *Aulacomya atra* on rocky bottoms or *Transennella pannosa* and *Tagelus dombeii* on sandy bottoms (Avendaño et al. 1997, 1998, 2008). It is also considered a scavenger (Andrade et al. 1997). This resource is a gonochoric species with internal fertilization, for which the adults concentrate during the breeding season, forming groups known as "maicillo" (Retamales & González 1982, Avendaño et al. 1997, 1998), as with other species of this genus (Bertness

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1977, Palmer 1983). Before and after reproductive aggregations, other lesser magnitude feeding aggregations have been observed (Avendaño et al. 1996, 1997, 1998).

This reproductive strategy seriously affects the species' survival because fishermen largely resort to them for their extraction (Andrade et al. 1997, Avendaño et al. 1997, 1998, Cantillánez & Avendaño 2013), seriously affecting their reproductive success.

Aggregations have been observed to occur throughout the year at variable intensities; however, it has been possible to detect at least two reproductive periods of annual importance (Avendaño et al. 1996, 1997, 1998, 2008, Andrade et al. 1997). These periods vary in extent according to location, given natural fluctuations in oceanographic conditions acting on their reproduction (Cantillánez & Avendaño 2013).

The variations in density that occur along the snails' depth distribution may be related to a certain level of stratification in the distribution of larger sizes at the beginning of the reproductive processes. Correlating the increase in the density of specimens of reproductive size in the shallower depths where the snails are distributed could serve as an easy-to-use quantitative indicator to interpret the reproductive behavior of the species, which could be used to educate fishermen and ultimately protect the snails' reproduction. If this indicator is validated, the strong extractive pressure on the resource in shallow waters (mostly specimens over the minimum legal size of 55 mm, required in Chile) should be seen as a threat to the reproductive process of the species, as the resource is extracted from these aggregations. The object of this study is to evaluate aggregations in the distribution of *T. chocolata* in the protected marine area of La Rinconada (Antofagasta) using the Moran (Legendre & Legendre 1998) and Morisita (1962) indices.

MATERIALS AND METHODS

Study

The study takes place between December 2008 to January 2010, in the marine ecosystem La Rinconada Marine Reserve, Antofagasta (23°28'S, 70°30'W), which represents one of the most ecologically important coastal sectors in Chile, home to one of the largest shoals of *Argopecten purpuratus* in the country, which through the D.S. N°522, was declared the first Marine Reserve in 1997 (Avendaño & Cantillánez 1997, 2008). Although it was created to protect *A. purpuratus* from overfishing to which it was subjected, this measure has also contributed to reducing the exploitation of other species of commercial interest, such as *A. atra*, *T. dombeii*, *T. panossa*, and the carnivorous snail *T. chocolata* (Ortiz et al. 2009). According to the last population survey of *T. chocolata* in this reserve, the species covered a surface area of 206 ha between 5 and 22 m depth, with an average density of 1.106 ind m^{-2} (standard deviation, SD = 1.18) and an estimated abundance of 2,277,254 individuals (Cantillánez et al. 2011).

Aggregation indexes

A representative area with snails present at depths ranging from 5 to 20 m in depth was selected within this distribution zone (Fig. 1). Between January 2009 and January 2010, monthly variations in the spatial distribution of the resource were determined by installing, according to the methodology of Legendre & Legendre (1998), three transects (A, B, and C), spaced 70 m apart, and with stations established along each, also every 70 m, adjusting their orientation to the local bathymetry. These were georeferenced with a Garmin GPS map 76CSx, and their depth was determined with a Beuchat CX 2000 Comex dive computer. Each line was weighted with lead along its length and equipped with cement anchors at its ends. These transects were extended for 910 m, with 13 stations distributed 70 m apart, thus obtaining a grid of 13 stations per transect, distributed at depths between 5 and 18.5 m (Fig. 1). The geographic coordinates and depths of the sampling stations are shown (Table 1). The specimens' density was determined monthly at each station using a 1 m^2 quadrat. The organisms in each quadrat were collected separately in properly labeled bags and taken on board. Subsequently, they were measured with a Mitutoyo digital meter with 0.1 mm precision, weighed on a Rite Weight field scale of 0.1 g precision, and their sex was determined by direct observation. Data obtained were tabulated to determine the frequency by the individuals' size according to the distribution depth.

Density values were transformed to log (n+1). Then, a Euclidean distance matrix of 39×39 was generated. The respective lags were obtained by ranking the Euclidean distances, establishing eight lags equidistant from each other at 100 m.

The Moran's index (I_t) was calculated according to Legendre & Legendre (1998):

$$I_t = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(x_{it}-\bar{x}_t\right)\left(x_{jt}-\bar{x}_t\right)}{\sum_{i=1}^{n}\left(x_{it}-\bar{x}_t\right)^2}$$

Monthly global correlograms and partial correlograms were constructed for each month in which the highest Moran's index was recorded (January, May and

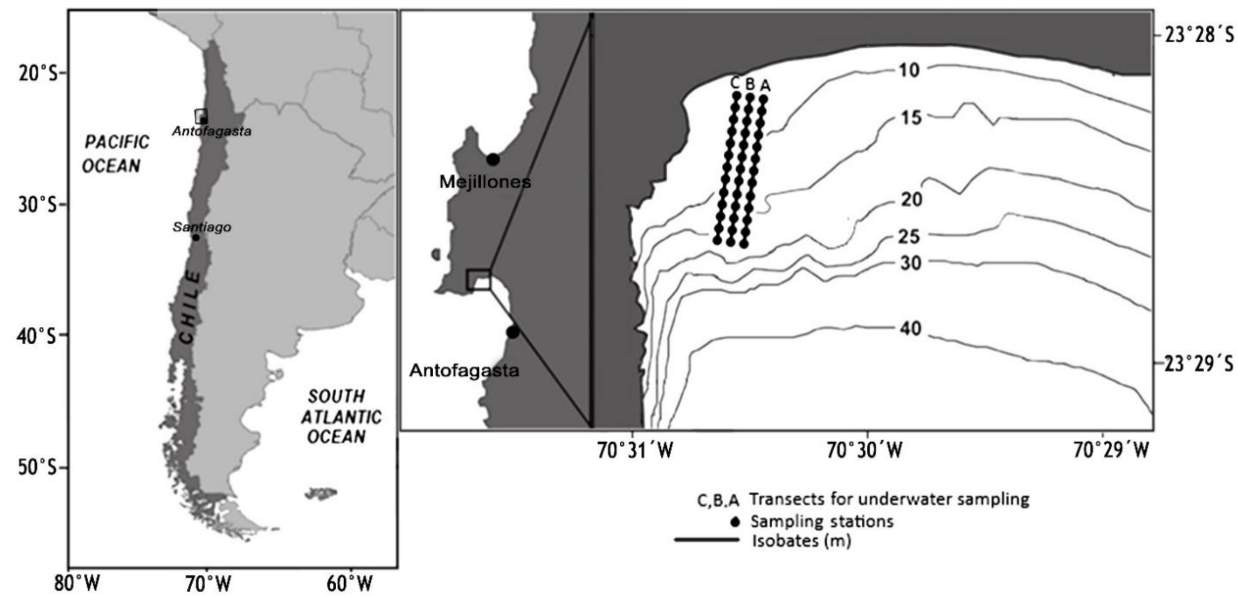

Figure 1. Location of the transects (A, B, C) with their respective 13 sampling stations used to monitor *Thaisella chocolata* at La Rinconada, Antofagasta.

Table 1. Geographic coordinates and depth of the sampling stations (Ide) in the three diving transects (A, B, C) of the La Rinconada, Antofagasta.

Ide A	Coordinates	Depth (m)	Ide B	Coordinates	Depth (m)	Ide C	Coordinates	Depth (m)
A1	23°28'30.7''S 70°30'36.4''W	18.5	B1	23°28'30.7''S 70°30'38.9''W	18.5	C1	23°28'30.7''S 70°30'41.5''W	17.0
A2	23°28'28.4''S 70°30'36.1''W	15.7	B2	23°28'28.5''S 70°30'38.6''W	15.7	C2	23°28'28.5''S 70°3041.2''W	15.0
A3	23°28'26.2''S 70°30'35.8''W	13.5	B3	23°28'26.2''S 70°30'38.3''W	13.5	C3	23°28'26.2''S 70°30'40.8''W	13.0
A4	23°28'23.9''S 70°30'35.5''W	12.0	B4	23°28'23.9''S 70°30'38.0''W	12.0	C4	23°28'24.0''S 70°30'40.4''W	11.7
A5	23°28'21.7''S 70°30'35.2''W	11.1	B5	23°28'21.6''S 70°30'37.7''W	11.1	C5	23°28'21.7''S 70°30'40.1''W	11.0
A6	23°28'19.4''S 70°30'34.2''W	10.0	B6	23°28'19.5''S 70°30'37.4''W	9.8	C6	23°28'19.5''S 70°30'38.9''W	11.0
A7	23°28'17.1''S 70°30'34.5''W	8.9	B7	23°28'17.1''S 70°30'37.1''W	10.0	C7	23°28'17.3''S 70°30'39.4''W	10.0
A8	23°28'14.9''S 70°30'34.2''W	8.2	B8	23°28'14.9''S 70°30'36.8''W	8.0	C8	23°28'15.0''S 70°30'39.0''W	9.0
A9	23°28'12.6''S 70°30'33.9''W	7.6	B9	23°28'12.7''S 70°30'36.4''W	8.2	C9	23°28'12.8''S 70°30'38.7''W	8.0
A10	23°28'10.4''S 70°3033.6''W	7.1	B10	23°28'10.4''S 70°30'36.1''W	7.2	C10	23°28'10.5''S 70°30'38.4''W	7.0
A11	23°28'08.1''S 70°30'33.4''W	6.7	B11	23°28'08.1''S 70°30'35.8''W	7.0	C11	23°28'08.3''S 70°30'38.0''W	7.5
A12	23°28'05.9''S 70°30'33.3''W	6.5	B12	23°28'05.9''S 70°30'35.6''W	6.8	C12	23°28'06.1''S 70°30'37.7''W	6.5
A13	23°28'03.6''S 70°30'32.7''W	5.3	B13	23°28'03.8''S 70°30'35.3''W	6.3	C13	23°28'03.9''S 70°30'37.4''W	6.0

September 2009, and January 2010). The calculations were executed using the routine implemented in the Ape Library (APE) package of the R program (Version 2.10.1, Copyright© 2009, The R Foundation for Statistical Computation).

Subsequently, the distribution model was characterized by applying the Morisita (1962) dispersion index to strengthen the study. This index was developed to evaluate how the distribution model presented by the population, in its original form, responds to the function:

$$I_d = n\left[\frac{\sum x^2 - \sum x}{(\sum x)^2 - \sum x}\right]$$

where I_d: Morisita index of dispersion, n: sample size (number of observations), $\sum x$ = sum of counts, $\sum x^2$ = quadratic sum of the counts.

Among the benefits of this index is its relative independence from population density, but it can be affected by the sample size. Morisita (1962) demonstrated that the null hypothesis of random distribution could be tested using: $\chi^2 = I_d (\sum x - 1) + n - \sum x$ with n-1 degrees of freedom Smith-Gill (1975) improves the Morisita index by generating a standardized index, which transforms the values of the original index to an absolute scale that varies between -1 and +1. Through a simulation model, Myers (1978) shows that the Morisita standardized index is one of the best measures of dispersion since it is independent of the density of the population under study, as well as the size of the sample.

The calculation of the standardized index requires computing the original index according to the first equation and then estimating a uniformity index (Mu) and an aggregation index (Mc) according to the following equations:

$$M_u = \frac{X^2_{0.975} - n + \sum x_i}{(\sum x_i) - 1} \quad (1)$$

where Mu: uniformity Index, $X^2_{0.975}$ value of the χ^2 statistic (if a confidence of 5% is estimated = 0.975) with -1 degrees of freedom.

$$M_c = \frac{X^2_{0.025} - n + \sum x_i}{(\sum x_i) - 1} \quad (2)$$

where Mc: aggregation index, $X^2_{0.025} =$ value of the χ^2 statistic (if a confidence of 5% is estimated = 0.025) with -1 degrees of freedom.

The standardized Morisita Ip index is then calculated according to the following decision rule:

If $I_d \geq$ Mc > 1.0 $\quad I_p = 0.5 + 0.5 \times \left[\frac{I_d - M_c}{n - M_c}\right]$

If Mc> Ip ≥ 1.0 $\quad I_p = 0.5 \times \left[\frac{I_d - 1}{M_u - 1}\right]$

If 1.0> Ip > Mu $\quad I_p = -0.5 \times \left[\frac{I_d - 1}{M_u - 1}\right]$

If 1.0> Mu > Ip $\quad I_p = -0.5 + 0.5 \times \left[\frac{I_d - M_u}{M_u}\right]$

The Morisita standardized dispersion index varies between -1.0 and +1.0, with confidence limits at +0.5 and -0.5, with $\alpha = 0.05$.

Random patterns give a value of 0 for Id. Values above zero represent aggregate distributions, and negative values correspond to a uniform distribution pattern.

Parallel to the immersion carried out to collect the transect samples, an observation was made by diving over an extension of 500 m, in the range of 1 to 15 m depth, during December 2008 and January 2010. The objective was to detect and quantify the presence of aggregations of the resource (feeding and reproductive). Each time these were present within the sampled areas, a subsample of 25 specimens was taken, considering those of smaller and larger sizes, and measured at their maximum length.

RESULTS

At this site, the average density of *T. chocolata* varied in the deep stratum (13 to 18.5 m) between 0.08 and 0.83 ind m^{-2} and between 2.41 and 4.63 ind m^{-2} at the surface (5 to 13 m). Table 2 shows the average density by stratum (deep and shallow), while Table 3 shows the average size and weight of males and females obtained by stratum and from the aggregations found.

Aggregation index

The results from the Moran index of spatial autocorrelation indicate how related the density values of locates are to each other based on the location of the measured quadrats.

This index fluctuated between 0.04 ± 0.027 in August and December and 0.25 ± 0.027 in January 2009 and January 2010 (Fig. 2). Although the values were relatively low, they were significant, which may be explained by the arrangement of the quadrats, which captured the greatest abundances of locate in the shallowest stratum. According to this Moran index, locate densities are spatially autocorrelated during practically every month of the year. However, this autocorrelation is greater from January to May and in September and October, which shows a change in the degree of spatial aggregation in these two periods. In the partial correlograms of these months (Fig. 3), it is

Table 2. *Thaisella chocolata* density (mean ± standard deviation) in the deep stratum and shallow stratum during the study period of one year, carried out in the sector of La Rinconada, Antofagasta.

Sampling date	Deep stratum	Shallow stratum
	Density (ind m^{-2})	Density (ind m^{-2})
01/16/09	0.08 ± 0.29	2.59 ± 2.87
03/04/09	0.17 ± 0.39	2.48 ± 4.33
04/06/09	0.33 ± 0.78	2.41 ± 1.60
05/09/09	0.58 ± 1.16	3.52 ± 2.19
05/30/09	0.75 ± 1.48	2.85 ± 2.55
07/10/09	0.75 ± 1.14	3.37 ± 4.14
08/19/09	0.50 ± 1.00	3.26 ± 3.17
09/30/09	0.17 ± 0.39	4.63 ± 5.02
10/30/09	0.17 ± 0.58	4.26 ± 5.83
11/27/09	0.83 ± 2.04	4.00 ± 5.62
12/26/09	0.75 ± 0.97	3.26 ± 3.21
01/09/10	0.17 ± 0.39	3.44 ± 4.49

possible to observe high autocorrelations between the first distances, that is, between the densities of *T. chocolata* located at 110 m, which begin to decrease at greater distances, corresponding to greater depths concordant with the bathymetric disposition of the profiles.

The results from the Morisita and standardized Morisita indexes are shown (Table 4), where it can be noted that the specimens of *T. chocolata* were aggregated throughout the study. Uniform resource distributions were recorded in the deep stratum in March, April, September, and December 2009, as well as in January 2010 (Table 2).

Aggregations

Different location aggregations were observed in the 5 to 13 m depth strip. In December 2008, at 5 m, a significant reproductive aggregation in copulation and laying was recorded, covering an approximate surface of 50 m^2 and reducing its intensity until January 2009. In March, small feeding aggregations at 6 m depth were observed in front of the sector's beach; however, only traces were found in April. The presence of stranded specimens next to the mass of capsules with eggs indicates that this aggregation could have been reproductive but would have been affected by a storm surge that occurred. In August, in the shallow sector adjacent to the rocky sector of the reserve, there were copulating and laying aggregations that extended until September. In December 2009, at the 5 m contour, a large feeding aggregation appeared again, occupying an approximate surface of 100 m^2 in January 2010, becoming a reproductive aggregation with the specimens copulating and laying egg capsules.

DISCUSSION

In the present study, it was possible to observe that a higher density of larger organisms occurred in the shallow stratum before, during, and after the formation of reproductive aggregations. Although the reproductive aggregations were recorded in December, January, August, September 2009, and January 2010, the presence of feeding aggregations indicates that in this place, reproductive aggregations could have been formed in March, April, and December of 2009, with the most important being those recorded during December and January, as was observed in 2008-2009 and 2009-2010. Although the results obtained through the Moran spatial autocorrelation index indicated that the densities of *T. chocolata* are spatially autocorrelated during practically all months of the year, this autocorrelation is greatest in the months of January-May, September-October 2009, and January 2010, showing a change in the degree of spatial aggregation of the resource during these periods coinciding with periods before and after which reproductive aggregations were recorded. Results also show a correlation in the densities of *T. chocolata* found in the shallow stratum at the first stations sampled within the first 110 m along the transects, which are close to the area where reproductive aggregations are found. These autocorrelations decrease at greater distances, corresponding to greater depths, which suggests the existence of spatial aggregation at shallow depths, mainly during the months between January-May, September-October 2009, and January 2010. These periods occur before, during, and after the development of reproductive aggregations in this sector.

The Morisita index also shows that locate is mainly distributed in an aggregate pattern, indicating that their density increases in the shallow stratum before, during, and after the formation of reproductive aggregations (5 to 13 m). This density increase at shallow levels, independent of the presence of reproductive aggregations, could indicate the beginning of reproductive activity for *T. chocolata*.

These results, however, are mismatched to the current regulations for this resource during the study period, which defines a fishery regime based on a minimum extraction size of 55 mm and establishing a biological closure during two periods: a) between March 1 and June 30, and b) between September 1 and December 31: closures that do not coincide with the events recorded in this study. Consequently, landings

Table 3. Average size and weight of *Thaisella chocolata* males and females by stratum and from aggregations at La Rinconada, Antofagasta.

Date	Shallow stratum				Deep stratum				Aggregation			
	Female		Male		Female		Male		Female		Male	
	Size (mm)	Weight (g)	Size (mm)	Weight (g)	Size (mm)	Weight (g)	Size (mm)	Weight (g)	Size (mm)	Weight (g)	Size (mm)	Weight (g)
12/01/08									64.46	68.58	65.13	78.19
01/16/09	60.94	75.83	68.68	122.36	61.95	86.25	55.96	60.11	58.47	75.72	56.28	69.03
03/04/09	66.85	107.64	62.31	99.55	32.85	11.05	0.00	0.00	64.47	107.37	64.48	101.38
04/06/09	66.83	79.58	64.63	88.04	66.18	59.54	62.75	50.75	69.84	132.91	73.77	132.86
05/09/09	67.10	92.50	69.02	101.79	68.90	61.63	68.44	72.65				
05/30/09	68.14	103.45	71.82	115.14	69.39	78.34	64.03	58.15				
07/10/09	75.01	112.77	62.50	73.15	59.48	53.08	61.76	46.63				
08/19/09	74.91	107.56	75.77	128.62	67.49	84.78	72.83	101.98	64.77	75.72	69.89	87.07
09/30/09	65.22	80.23	71.71	106.60	57.88	47.65	56.97	51.55				
10/30/09	56.62	51.38	68.02	89.21	58.38	43.33	64.14	68.46				
11/27/09	63.95	90.90	63.09	78.53	60.52	47.99	54.59	36.88				
12/26/09	72.95	118.25	64.13	104.68	74.51	104.41	65.00	83.20	69.55	101.07	65.83	90.88
01/09/10	69.88	109.33	63.32	84.08	60.49	54.40	57.53	43.73	67.62	100.18	58.76	58.56

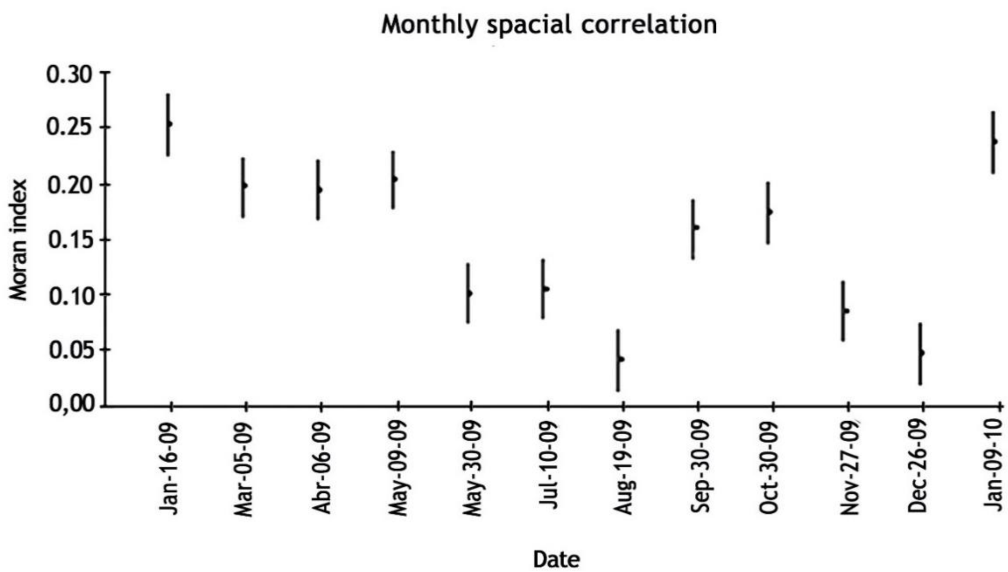

Figure 2. Moran's correlogram shows the monthly global autocorrelations in locate (*Thaisella chocolata*) densities at La Rinconada, Antofagasta.

are concentrated in the summer (January and February) and winter (July and August). The few studies of the reproductive cycle of the resource, which so far support the biological closures, show periods of permanent reproduction throughout the year; however, large reproductive aggregations are observed only in certain periods. The results obtained by Cantillánez et al. (2011) in the population of the marine reserve indicated that the gonadal development of the population is asynchronous, with specimens found in different stages of maturation throughout the year, and where mature individuals are stratified between 5 and 13 m depth, and for most of the year form aggregations at a depth of 5 m. These authors determined periods of greatest maturity in July, August, and November-January, showing that the most important aggregations near the end would not coincide with the closed seasons established in the regulations in effect during the study.

As has already been pointed out, the overfishing of these larger specimens from aggregations (SUBPESCA 1995), which represent the fraction with the population's greatest reproductive capacity, affects the species' reproductive success. Consequently, the reproductive aggregations outside the closed seasons make them more vulnerable to extraction, affecting their reproductive success because their reproductive strategy consists of mainly adult specimens (as shown by this work) aggregating in shallow waters, which

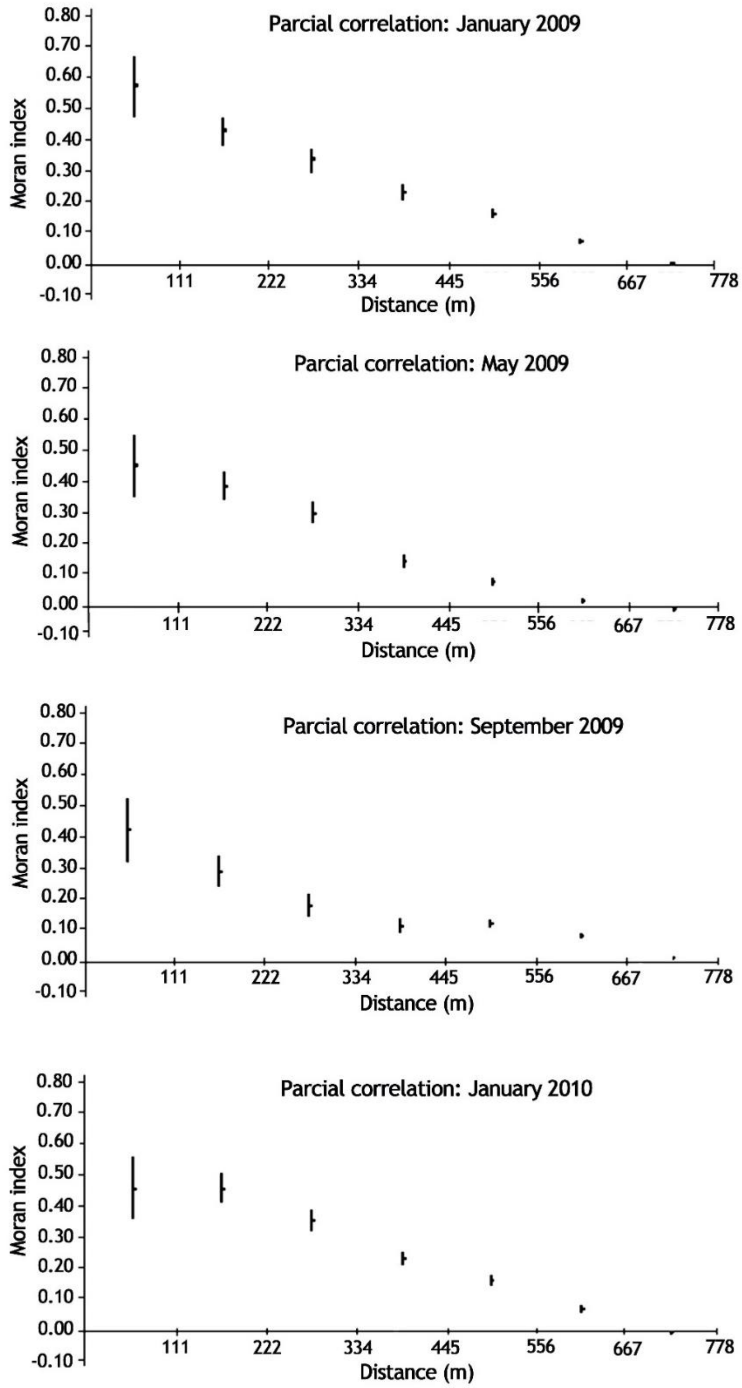

Figure 3. Moran's correlogram shows partial autocorrelations indices in months of high global autocorrelation of *Thaisella chocolata* densities in La Rinconada, Antofagasta.

directly impacts their survival when extracted (Andrade et al. 1997, Avendaño et al. 1997, 1998), an even more serious factor in sand habitats because their extraction leaves them without the anchoring that the aggregation provides for the masses of capsules with eggs, which, when detached, end up being beached by waves. Additionally, contributing to this is the long time it takes for their larvae to settle (Romero et al. 2004). These could be one of the main causes of uncertainty in the recruitment process and its relationship with local reproductive processes, which has induced an imbalance in the dynamics of the snails' ecosystem.

Aggregations have been observed throughout the year from the Tarapacá region to the Coquimbo region,

Table 4. Morisita index (Id) and standardized Morisita index (Ip), obtained in the shallow and deep strata between January 2009 and 2010 at the La Rinconada (Antofagasta) for *Thaisella chocolata*, on each date and stratum (D: deep; S: shallow) the form of aggregation (A) or uniform distribution (U), and random distribution (n/c) resulting from the analysis is indicated.

Date	Stratum	Ip	Id	Decision
01/16/09	D	n/c	n/c	n/c
	S	0.51147865	1.82236025	A
03/04/09	D	0	-0.069	U
	S	0.54535861	3.578019	A
04/06/09	D	-0.62639198	4	U
	S	-0.06707672	1.02548077	U
05/09/09	D	0.53314659	3.42857143	A
	S	-0.38880518	1.10055991	U
05/30/09	D	0.56754887	3.6666667	A
	S	0.504455891	1.43950786	A
07/10/09	D	0.55679287	2	A
	S	0.51946893	2.18241758	A
08/19/09	D	0.50090744	3.2	A
	S	0.50850669	1.62225705	A
09/30/09	D	-0.06959911	0	U
	S	0.51549293	1.93006452	A
10/30/09	D	n/c	n/c	n/c
	S	0.52805787	2.59084668	A
11/27/09	D	0.6866485	5.86666667	A
	S	0.52805787	2.6728972	A
12/26/09	D	-0.18559762	1.3333333	U
	S	0.5089165	1.64341693	A
01/09/10	D	-0.06959911	0	U
	S	0.52323148	2.37307153	A

in greater or lesser intensity; however, it has been possible to detect at least two reproductive periods of annual importance (Avendaño et al. 1996, 1997, 1998, 2008, Andrade et al. 1997). These periods, however, vary in their extension according to their location, which is explainable by the natural fluctuations in oceanographic conditions in the sectors studied (Cantillánez & Avendaño 2013).

Finally, it can be concluded that before, during, and after the reproductive aggregation's formation, there is an increase in the density of locates in the shallow stratum (5 to 13 m). It is corroborated by the results of Moran's spatial autocorrelation index, which shows a greater autocorrelation in January-May, September-October, and January 2010. Demonstrating a change in the degree of spatial aggregation of the resource during these periods, which results from the Morisita index, would further support, which could validate as an indicator of the reproductive process of this species, and consequently used to modify the closure period that governed the population during the study, to better align with the periods of more extensive reproductive aggregations that occur in the different localities where this resource is distributed. However, these periods are not rigid and are prone to variations from one year to another. Although there was an increase in the density of the largest specimens in the shallow stratum before the occurrence of reproductive aggregations, the best indicator of this process is the aggregation itself.

Consequently, it is necessary to raise awareness among fishermen so they refrain from extracting the resources while these events occur, especially during periods of greatest activity as recorded at each extraction site. In the case of La Rinconada, these are August-September and December-February. This indicator, on the other hand, may serve to alert fishermen that reproductive aggregations will occur, which should not be disturbed to ensure the reproductive success of this species, thus contributing to the recovery of its natural shoals. The current ban that governs the resource from December 2009 (Exempt Decree N°1965, of the Ministry of Economy, Development and Reconstruction) has been established for the coast between Arica-Parinacota region

(18°28'42"S) to Antofagasta region (25°17'00"S) from March 1 to October 31 of each year, leaving the resource exposed to extraction during the most important reproductive events, which occur between December-February as indicated in this work.

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