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Article

Spatial distribution of *Cyclograpsus cinereus* Dana 1851 in rocky shores of Antofagasta (23º27′ S, Chile).

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Abstract: The decapod fauna in intertidal rocky shore in continental Chile has high species diversity mainly in northern and central Chile due high productivity of these coast due influence of cold Humboldt stream. One of the abundant species in these ecosystems is decapod *Cyclograpsus cinereus* Dana, 1851. The aim of the present study was determine the spatial distribution pattern of *C. cinereus* along rocky shore in Antofagasta bay, north of Chile between spring and summer 2018-2020. Data was obtained counting individuals from random quadrants in intertidal zones, to the obtained data was applied the variance mean ratio for determine if the specimens have random, aggregate or uniform distribution, that are associated to Poisson, negative binomial or positive binomial distributions respectively. Data obtained revealed the existence of associated distribution with respective negative binomial distribution pattern in 16 observations, and uniform distribution for 3 observations. The sites corresponds to rocky shores in urban zones, and in a protected zone, and the density does not have significant differences for both kind of sites. The observed data about aggregated pattern agree with observations for decapods for rocky shore in central and southern Chile, specifically in interpretative probabilistic models.

Keywords: *Cyclograpsus cinereus*; spatial distribution; intertidal; rocky shore; negative binomial distribution.

1. Introduction

The intertidal decapods in continental Chilean coast is characterized by their high species diversity mainly in central and northern Chile (18-33ºS), due the strong influence of cold Humboldt stream that is associated with continuous upwelling processes, that can support high productivity and in consequence high species diversity [1, 2]. In this scenario, in decapods species in northern and central Chile there are many widespread species that can inhabits from Peruvian to central Chilean coast [2, 3, 4].

In rocky shores there are many environmental heterogeneity due the irregular characteristics of substrate, that has creeks, or presence of rounded rocks that allow the presence of microenvironments that can sustain high invertebrate species richness such as was observed in first studies for central Chilean rocky shore [5, 6], and in recent studies along continental Chilean territory [7]. The ecological importance of these species is their role of detritivores (vegetal and animal dead matter) as well as prey for littoral rocky fishes, sea birds or other large crabs [5, 6, 8]. Within the species reported are decapods such as Grapsid crabs that inhabits in creeks, whereas under rounded rocks, inhabits small crabs such as *Cyclograpsus cinereus* Dana, 1851, *Petrolisthes granulosus* (Guerin, 1835) or *P. violaceous* (Guerin, 1830) [2, 5, 6, 7].

The species *C. cinereus* is widespread along continental Chilean and Peruvian coast [2, 5, 7, 9], and Chilean oceanic islands [2, 10, 11]. This species inhabits mainly under rounded rocks, being an important component in rocky shores in continental Chile, alternating its dominance with porcellanid crabs based on evidence in central Chile [2, 5, 6]. The literature reports mentioned that this species is gregarious under low tidal and during high tidal the specimens are spreaded, the individuals are detritivores, and prey on littoral fishes [5,6].

The aim of the present study is do a characterization of spatial distribution of decapod *C. cynereus* in different sites in rocky shore of Antofagasta bay, with the aim of determine the presence of probabilistics models that can explain the specimens distribution for each site. The hypothesis would be that *C. cinereus* would have a defined probabilistic pattern in its spatial distribution in rocky shores in Antofagasta bay.

2. Materials and Methods

Study site: the sites corresponds to different rocky beaches with rounded rocks, along Antofagasta town , located in the homonymous bay [12], these sites included two sites in a protected zone destined as littoral fisheries resources management in according to Chilean laws (El Lenguado 1 and El Lenguado 2), that are sites where it is not possible do any aquatic resources extraction and culture the sites are located at south of Antofagasta with a very narrow coastal plain and granitic and basaltic rocky shores (Table 1, Fig. 1). The other five sites located within the town (Playa Blanca, Las Almejas, Trocadero and Jardines del Norte), that corresponds to basaltic rocky shores in a wide coastal plain. The sites were visited in September, December and February 2018-2020 under low tide (Table 1, Figure 1).

Table 1. Geographical location of sites considered in the present study.

Site	Geographical location
Jardines del Norte	23°34’48.4’’S; 70°23’36.4’’W
Trocadero	23°34’57.2’’S; 70°23’40.5’’W
Las Almejas	23°40'13.8"S; 70°24'35.5"W
Playa Blanca	23°40'34.5"S; 70°24'50.7"W
El Lenguado 1	23°46’09.5’’S; 70°28’22.2’’W
El Lenguado 2	23°46’21.7’’S; 70°28’26.1’’W

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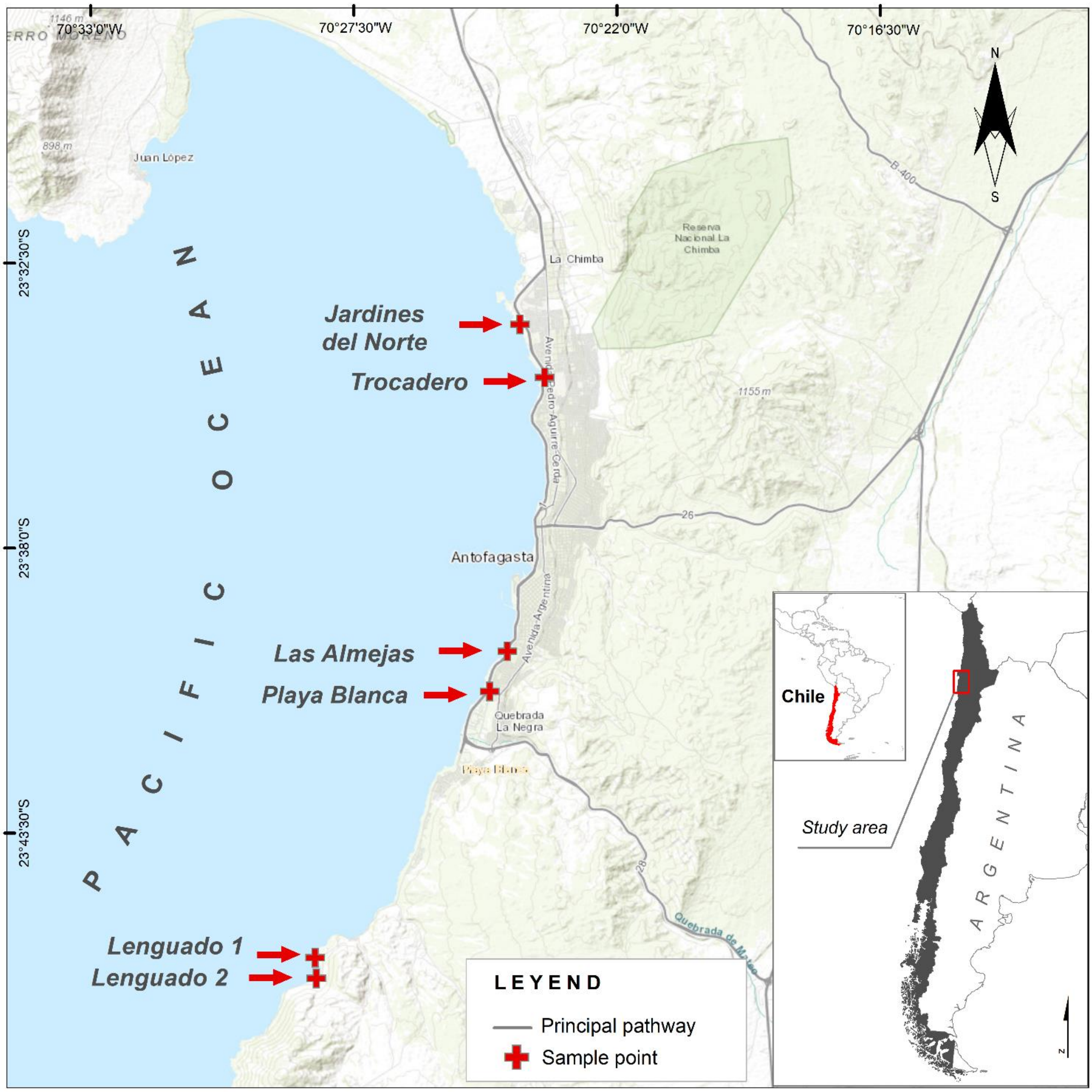

Fig. 1. Map of sited included in the present study.

Data collection: the first species identification was done in situ were based on literature descriptions [3, 6, 9]. Random quadrants (10*10 cm) were released in studied sites (n = 90) during low tide, it was considering this size of quadrant on the basis of the fast movements of studied specie [6], and this size of quadrant would be more adequate for fast movement species [13, 14]. Data were recorded manually in a field copybook.

Data analysis: in a first step, it was compared the *C. cinereus* abundances for each site, and for two groups of sites (protected and human altered sites), homocedasticity and normality were determined for data, and due the absence of both conditions it was done a non-parametric tests [15] using software Python [16], it was verified normal distribution and variance homogeneity and due the absence of both conditions, a Kruskall-Wallis using Pandas, Numpy, Matplotlib and Seaborns libraries [17,18, 19, 20] and Dunnets multiple comparison test using bioinfokit library [21].

To each specie counting data, was obtained in first instance a variance mean ratio, first for determine if the specie has random if the value is 1, uniform if the value is lower than 1, or aggregated distribution, if the value is upper than 1, [22, 23, 24]. Once determined the spatial pattern, random, uniform or aggregated, it determined if the species have Poisson, binomial or negative binomial distribution respectively, the analysis was done manually using Excel software and literature descriptions [22, 23, 24].

3. Results

The results denoted a density variable between 0.96 ind/grid (Trocadero, February 2020), and 2.64 ind/grid (Las Almejas, September 2018; Table 2). The results of Kruskall-Wallis test revealed the existence of significant differences for studied sites (…), and the Dunnets multiple comparison test revealed that the groups with maximum and minimum abundances reported marked differences with remaining groups (Table 3). The results of variance/mean ratio revealed that many sites has value upper than 1.0, that imply the potential association to negative binomial distribution, except with Playa Blanca (06th February 2020, 28th December 2019), Trocadero (28th December 2019), and Playa Blanca (17th September 2019) where it was reported a variance mean ratio value lower than 1.0, that would be associated to positive binomial distribution (Table 1), the presence of negative binomial distribution and positive binomial distribution patterns associated respectively to variance/mean ratio upper than 1.0 and lower than 1.0 are significant for each cases ($P < 0.01$; Figure 2).

Table 2. *C. cinereus* mean density (ind/grid 10*10 cm), variance (Var) and variance mean ratio for studied sites.

Sampling date	Site	Mean	Var	Var/Mean ratio
07-02-2020	Jardines del Norte	0.35	0.52	1.49
06-02-2020	Playa Blanca	1.02	0.79	0.77
06-02-2020	Las Almejas	2.17	2.35	1.08
05-02-2020	El Lenguado 2	1.47	1.55	1.05
05-02-2020	El Lenguado 1	1.62	6.19	3.82
28-12-2019	Playa Blanca	2.56	2.05	0.80
28-12-2019	Las Almejas	1.30	1.74	1.34
28-12-2019	Trocadero	1.78	1.03	0.58
27-12-2019	El Lenguado 1	1.28	1.24	0.97
27-12-2019	El Lenguado 2	1.13	1.31	1.15
17-09-2019	Playa Blanca	0.72	2.18	3.02
17-09-2019	Las Almejas	0.72	2.18	3.02
07-02-2019	Trocadero 1	0.96	1.30	1.36
07-02-2019	Trocadero 2	1.19	2.72	2.29
07-02-2019	Las Almejas	1.04	1.17	1.12
07-02-2019	Playa Blanca	1.19	2.72	2.29
07-02-2019	El Lenguado 1	0.92	1.42	1.54
29-12-2018	Las Almejas	0.19	0.31	1.65
21-09-2018	Las Almejas	2.64	5.22	1.97

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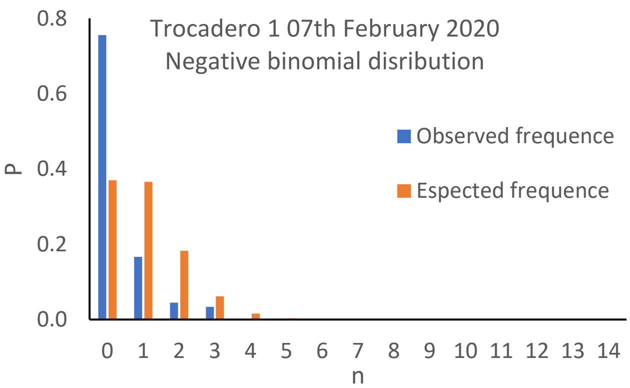
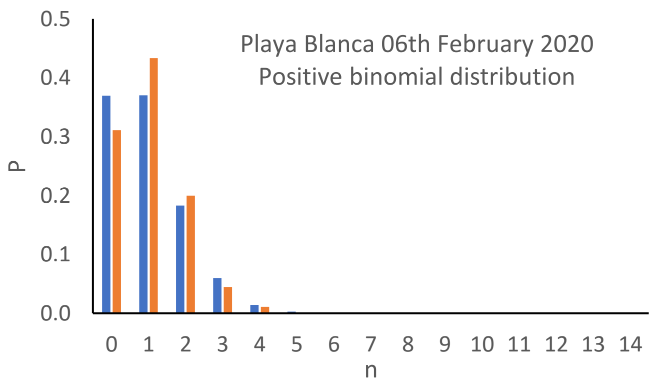
Table 3. "P" values for Dunnets multiple comparison tests for *C. cinereus* densities for studied sites ("P" values lower than 0.05 denotes significant differences).

	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B
A	0.000	1.000	0.000	0.032	0.134	0.001	1.000	0.000	1.000	0.006	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
B	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.001	0.000	0.002	
C	0.194	0.000	1.000	0.474	0.130	1.000	0.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000		
D	0.000	1.000	0.018	1.000	1.000	0.373	0.987	0.060	1.000	1.000	0.000	0.000	0.002	0.000	0.000			
E	0.101	0.000	1.000	0.846	0.247	1.000	0.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000				
F	0.047	0.000	1.000	1.000	0.491	1.000	0.000	1.000	0.000	1.000	1.000	1.000	1.000					
G	0.009	0.000	1.000	1.000	1.000	1.000	0.000	1.000	0.000	1.000	0.850	0.850						
H	1.000	0.000	0.148	0.000	0.000	0.006	0.000	0.048	0.000	0.001	1.000							
I	1.000	0.000	0.148	0.000	0.000	0.006	0.000	0.048	0.000	0.001								
J	0.000	0.061	1.000	1.000	1.000	1.000	0.000	1.000	0.541									
K	0.000	1.000	0.004	1.000	1.000	0.117	1.000	0.016										
L	0.000	0.001	1.000	1.000	1.000	1.000	0.000											
M	0.000	1.000	0.000	0.000	0.001	0.000												
N	0.000	0.010	1.000	1.000	1.000													
O	0.000	0.945	1.000	1.000														
P	0.000	0.279	1.000															
Q	0.001	0.000																
R	0.000																	

A = Las Almejas: 21-09-17; B = Las Almejas: 29-12-17; C = El Lenguado I: 07-12-2018; D = Playa Blanca: 07-02-2019; E = Las Almejas: 07-02-2019; F = Trocadero I: 07-02-2019; G = Trocadero II: 07-02-2019; H = Playa Blanca: 17-09-2019; I = Las Almejas: 17-09-2019; J = El Lenguado I: 27-12-2019; K = El Lenguado II: 27-12-2019; L = Trocadero II: 28-12-2019; M = Playa Blanca: 28-12-2019; N = Las Almejas: 28-12-2019; O = El Lenguado II: 05-02-2020; P = El Lenguado I: 05-02-2020; Q = Playa Blanca: 06-02-2020 ; R = Las Almejas: 06-02-2020; S = Trocadero II: 06-02-2020.





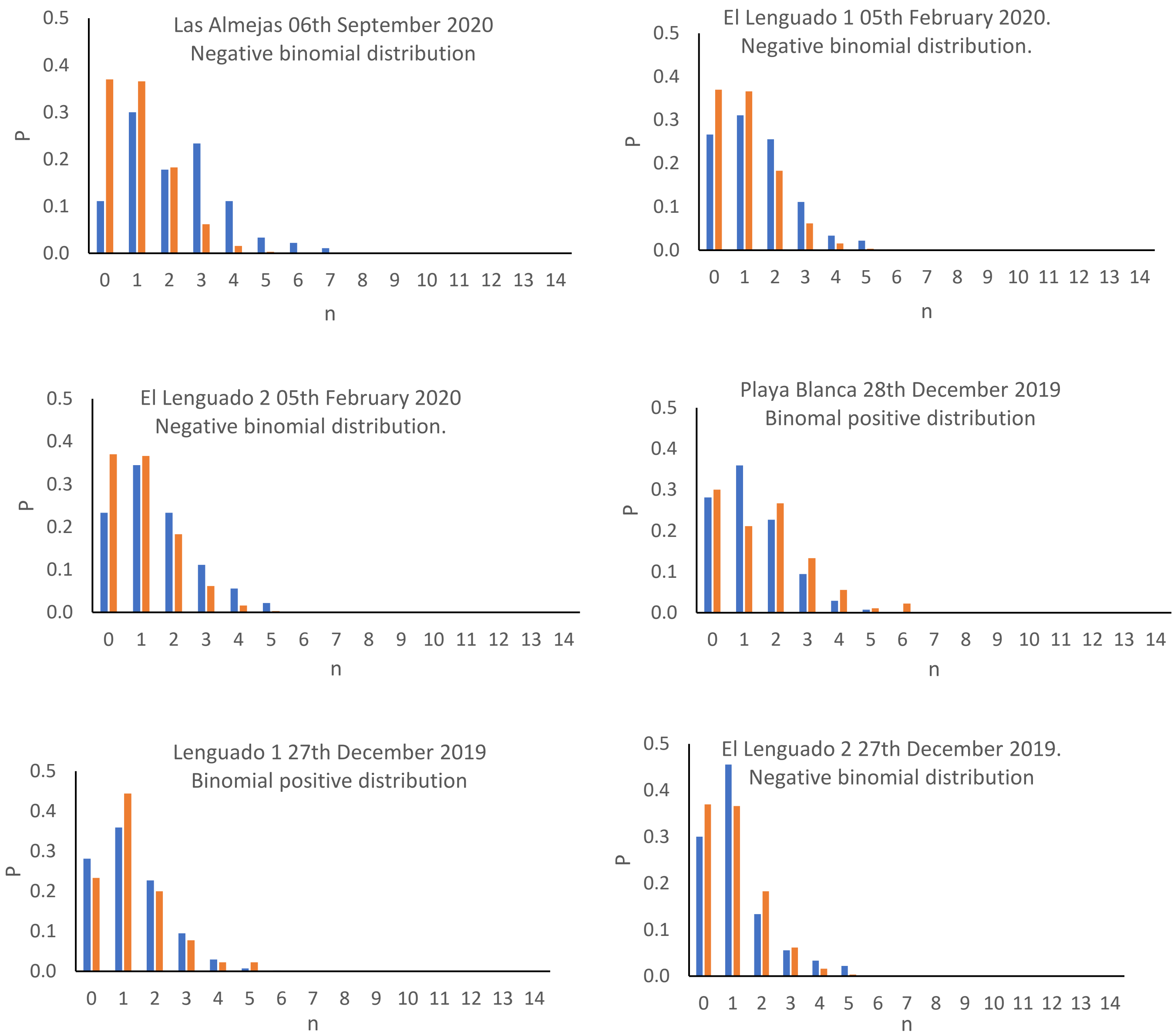


Fig. 2. Distribution patterns observed for *C. cinereus* populations for studied sites.

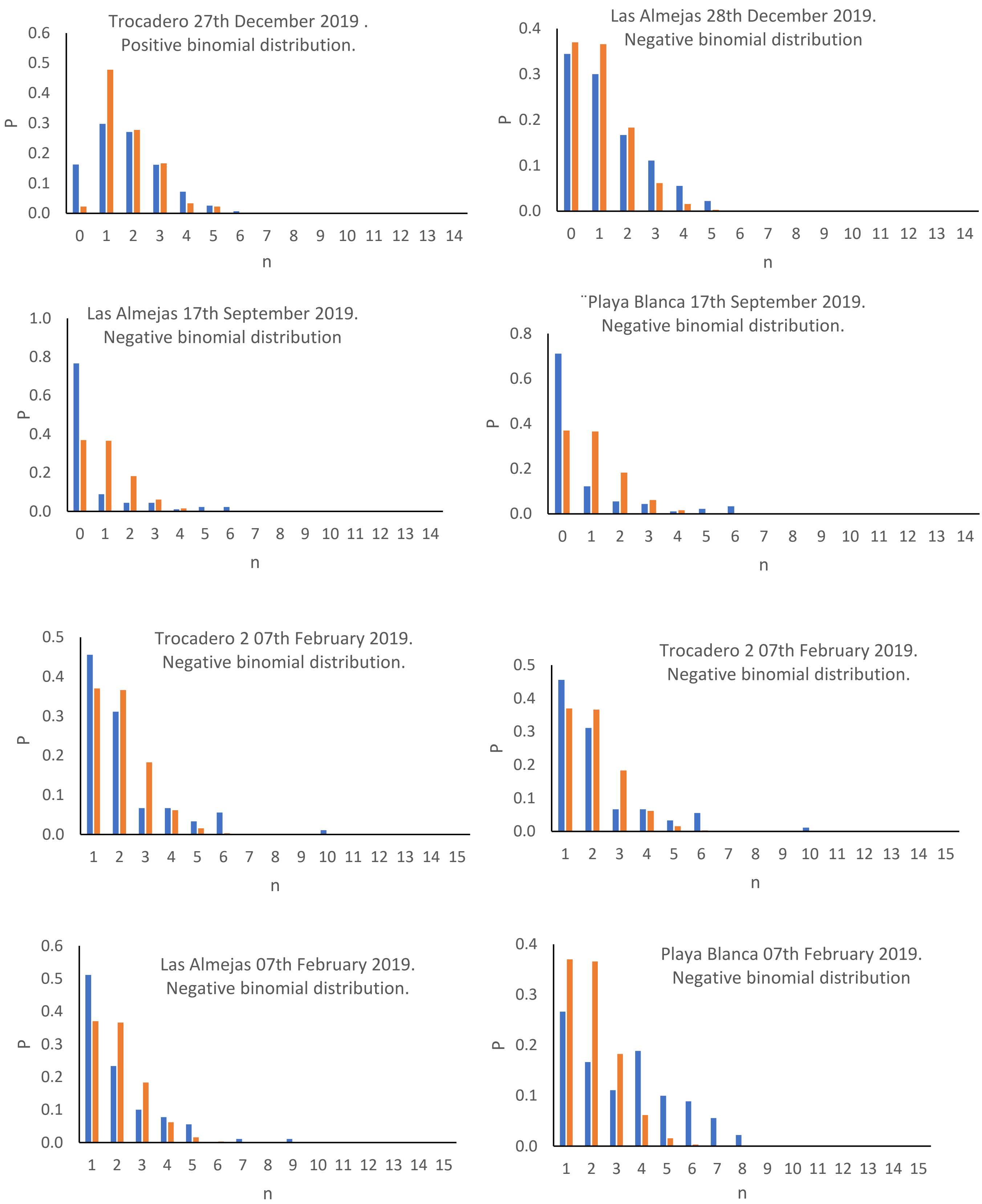


Fig. 2 (Continuation). Distribution patterns observed for *C. cinereus* populations for studied sites.

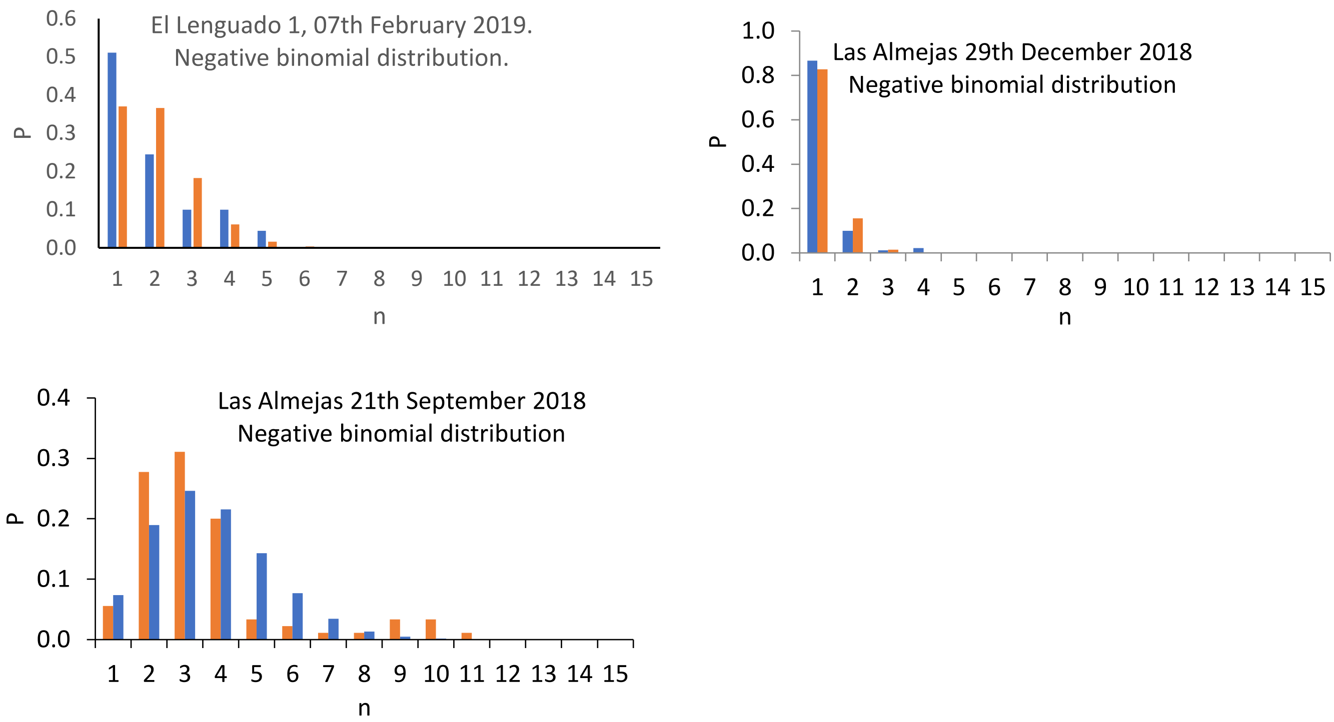


Fig. 2 (Continuation). Distribution patterns observed for *C. cinereus* populations for studied sites.

4. Discussion.

The exposed results revealed that presence of *C. cinereus* in sites included in the present study agree with classic literature on biogeography of this species in continental Chilean coast (2, 3, 7). The presence of negative binomial distribution in many of studied sites would agree with first literature descriptions for this species for rocky shores in central Chile that mentioned that this species join groups that alive under rounded rocks in intertidal zone (6), similar pattern was reported for *Petrolisthes granulosus* in central Chile (5), it remarks that both species can coexists along continental Chilean rocky shore (2, 5, 6, 7), nevertheless, these references did not mention density quantitative data.

The use of spatial distribution probabilistic models for marine crustaceans in continental Chile was reported for intertidal rocky shore in central Patagonia, these results remark the aggregated pattern associated to negative binomial distribution (23). This association of aggregated pattern and negative binomial distribution has been reported by classic literature about benthic fauna (25), as well as applied entomological studies (22). This pattern was reported for inland water crustaceans in Chilean Patagonia (24, 26), for intertidal invertebrates in northern Patagonian coast (27), and the gastropod *Echinolittorina peruviana* in Antofagasta rocky shore (12). The existence of uniform distribution in four of 19 samples probably would be to interspecific interactions, probably competence with other species that share ecological niche (5, 6, 7).

The presence of negative binomial distribution associated to aggregated distribution is a survival strategy for an efficient use of trophic resources (5, 6), as well as protection against dissecation in intertidal environments (28, 29, 30). The literature described the existence of migration patterns in according to tides and day-night (5, 6), under low tide, the intertidal crustaceans including *C. cinereus* lived in groups under rounded rocks that form a kind of favorable microenvironment (31), whereas under high tide the individuals are dispersed probably for avoid predation (5, 6). In this scenario, it would be necessary more detailed study that involves potential migration patterns in function of day-night and tidal rhythms, as well as topographical characteristics of each habitats, and at long term study the oceanographic conditions that can affect the population structure.

Author Contributions: P.D.E did field works and redact the manuscript. C.E. collaborated in data analysis and images, and M.A.R. M.G and O.Z. collaborated in redaction and literature compilation. All authors have read and agreed to the published version of the manuscript.

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