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Determination of the Taxonomic Diversity of the Intertidal Fish Communities on the Pacific Coast of Baja California Sur, México from 2015-2019

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Abstract

The coastal areas of the Baja California peninsula are characterized mainly by rocky areas, where rock pools dominate as important coastal habitats because of the tide cycle, when the water is trapped during the low tide, forming the pools. Environmental parameters like temperature, salinity and dissolved oxygen of the water trapped in the pools are key factors for the flora and fauna that inhabit these areas, particularly during the warmer months when the mean values of these parameters are usually higher than the mean values of the sea surface. The aim of the present study was to determine the variation of the taxonomic diversity of the fish communities that inhabit the rock pools in the common land known as Conquista Agraria in the Pacific coast of Baja California Sur, México, from 2015 to 2019. A total of 59 visual censuses were carried out monthly during the second low tide of the full moon. Temperature, salinity, and dissolved oxygen showed variation throughout the study period, with two distinct seasons (warm and cold), which influenced the taxonomic diversity and taxonomic distinctness of the species recorded in the area. There was a higher diversity in the warmer months (summer) and years (2015 and 2016). In addition, according to the MDS analysis, 2017 and 2018 showed high similarity of species.

Keywords

Rock Pools, Intertidal Zone, Taxonomic Diversity, Taxonomic Distinctness

1. Introduction

The coastal areas of the eastern Pacific Ocean are characterized by highly variable fish assemblages inhabiting a wide variety of coastal ecosystems like bays, coastal lagoons, and estuaries. In addition, there are many physical, biological, and ecological interactions which greatly influenced the energy transfer in these complex coastal systems [1]. The coastal areas of the Baja California peninsula are characterized mainly by rocky formations, where rock pool habitats predominate [2], in which many species of flora and fauna become trapped during the low tide [3].

In addition to the tide cycle, rock pools are also influenced by other coastal hydrodynamic and transport processes such as longshore currents and sea level change [4], which then influence the dynamic of key physicochemical factors such as temperature, salinity, and dissolved oxygen. During the summer months, warmer temperatures cause higher water evaporation, which then increases the salinity of the water trapped in the rock pools during the low tide. Moreover, the dissolved oxygen decreases as a response to high temperature and water evaporation. Flora and fauna inhabiting the rock pools during the low tide are then subjected to drastic environmental changes [5]. Many species inhabit the intertidal zones, rock pools are characterized mainly by invertebrates, algae, and fish, which use the rock pools as refugia from predators, as well as feeding ground [6] [7]. Hence, rock pools are dynamic and diverse ecosystems, and represent important biodiversity hotspots that can be used as bioindicators of the health status of intertidal areas [8]. Therefore, the aim of the present study was to determine the variation of the taxonomic diversity of intertidal fish assemblages in the rocky area of the common land Conquista Agraria on the Pacific Coast of La Paz, Baja California Sur, México, from 2015 to 2019.

2. Methods

Study Area

Conquista Agraria is a common land located 55 km northwest of the city of La Paz in the state of Baja California Sur, México. The study area is found in an area known as "El Faro", located 24 km west of Conquista Agraria, with specific coordinates from N 23˚57.553' and W 110˚52.654' to N 23˚57.622' and W 110˚52.705' (**Figure 1**).

A total of 59 visual census campaigns were carried out from January to December from 2015 to 2019, during the full moon and the second low tide of the day (approximately from 14:00 to 17:30 hrs). However, the campaign corresponding to October 2019 was not carried out because the harsh weather conditions

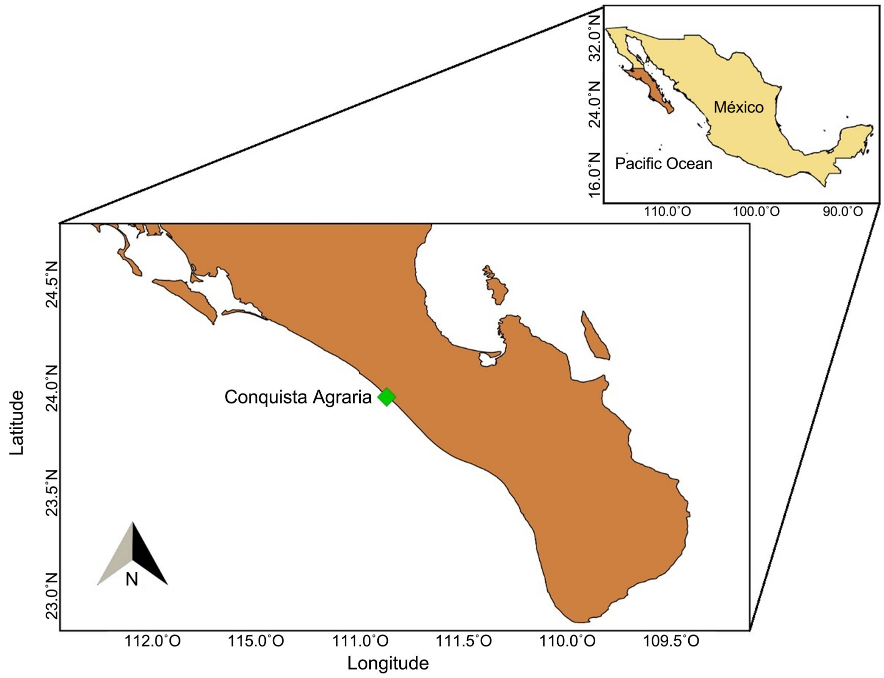

Figure 1. Geographic location of the study area in Conquista Agraria, located on the Pacific Coast of La Paz, Baja California Sur, México.

caused by Hurricane Lorena made access to the study area very difficult because of road damage. A total of 145 rock pools were sampled in transects of 156 × 5 m. Rock pools were classified according to their size: small (2 m^2), medium (4 m^2) and large (7 m^2); with an average depth between 20 - 40 cm.

Physicochemical variables (temperature, salinity, and dissolved oxygen) were measured using a YSI 2030 Pro multiparameter instrument.

Fish species were identified based on photographical evidence, as well as the experience of the person carrying out the sampling. In case of any identification issues arising during the census, animals were collected and later identified using specialized literature [9] [10] [11] in the Fish Ecology laboratory at Universidad Autónoma de Baja California Sur (UABCS).

Data analyses were carried out using the software PRIMER version 7 and STATISTICA version 12. Ecological indices were calculated as follow:

Fisher's alpha: this is a parametric index that assumes species abundance follows a logarithmic distribution [12].

$$S = \alpha \ln\left[1+\left(N/\alpha\right)\right] \quad (1)$$

where: S = number of species in the sample, N = number of individuals in the sample, and α = coefficient of diversity.

Alpha diversity (α): is the number of species in a community in a specific site and specific time, with respect to its species richness (total number of species in the sampling site). In this study, it refers to the alpha diversity of each month at each year.

Average alpha diversity ($\bar{\alpha}$): It is defined as the average value of the number of species between different sites but with the same type of community. In this study, it refers to the mean value of the alpha diversity calculated at each month within a year.

$$\bar{\alpha} = \frac{\sum_{i=1}^{n} \alpha_i}{n} \tag{2}$$

where: α_i = species richness of the *i*th site, and n = total number of sampled sites.

Beta diversity (β): it refers to the diversity pattern between different habitats or sites. It is defined as the variation of diversity resulting from differences between local assemblages of species [13] [26].

$$\beta = S/\bar{\alpha} - 1 \tag{3}$$

where: β = beta diversity, $\bar{\alpha}$ = mean alpha diversity, S = number of species.

Gamma diversity (γ): it is defined as the total species richness in a landscape, and is a consequence of the alpha diversity of individual communities and the variation in the diversity between communities (beta diversity) [14].

$$\gamma = \beta + \bar{\alpha} \tag{4}$$

where: γ = gamma diversity, β = beta diversity, $\bar{\alpha}$ = mean alpha diversity.

Taxonomic distinctness (Δ^*): evaluates the taxonomic distance, species richness and their abundance. It does not depend on sampling effort or sample size. It is considered a precise method to estimate diversity since it incorporates qualitative and quantitative aspects of the species [15].

$$\Delta^* = \frac{\sum\sum_{i<j} w_{ij} x_i x_j}{\sum\sum_{i<j} x_i x_j} \tag{5}$$

where: $x_i \left(i = 1, 2, \cdots, S\right)$ abundance of the *i*th species, w_{ij} = weight difference of the branches between species of the lines i and j in the hierarchical classification.

Average taxonomic distinctness (Δ^+): evaluates the species richness and taxonomic distance between each pair of species. It has been defined as a Linnean classification tree, using presence/absence data. Each hierarchical level gets a discrete value within a scale of 100 units [16].

$$\Delta^+ = 2\frac{\sum\sum_{i<j} w_{ij}}{S\left(S-1\right)} \tag{6}$$

where: S = species richness, w_{ij} = weight difference of the branches between species of the lines i and j in the hierarchical classification.

Multidimensional scaling (*MDS*) *analysis* is a visual representation of dissimilarities between different objects. The level of dissimilarity is represented by the distances between the objects, when two or more objects are similar, they will group closer together, while the further away they stand from each other, the more dissimilar they are.

Bray-Curtis dissimilarity index: it quantifies the compositional dissimilarity between different sites. It considers both presence/absence of species and their abundance, resulting in values ranging from 0 (dissimilar) to 100 (similar) [17].

$$S_B = 1 - \left[\frac{\sum \left| X_{ij} - X_{ik} \right|}{\sum \left| X_{ij} + X_{ik} \right|} \right] \tag{7}$$

where: S_B = Bray-Curtis dissimilarity index, X_{ij} and X_{ik} = number of individuals of the species i in the sample j and the sample k.

3. Results

3.1. Physicochemical Variables

Mean temperature showed significant differences between years ($F(9, 64) = 3.599$; $p = 0.0011$) and between months ($F(12, 105) = 10.230$; $p < 0.001$). The highest value was recorded in 2016 (28.69˚C), followed by 2015 (28.10˚C), and the lowest value was recorded in 2019 (25.19˚C), followed by 2018 (27.47˚C). Regarding differences between months, the higher temperatures were recorded in the summer and autumn months (August to October), with the highest value recorded in September (31.96˚C). The lowest temperatures were recorded during the winter months (December to March), with the lowest value recorded in January (25.02˚C) (**Table 1**).

Table 1. Physicochemical variables: temperature [T(˚C)], salinity (UPS), and dissolved oxygen [DO (mg/L)]. Ecological indices: Fisher's alpha (α-Fisher) and taxonomic distinctness (TD Δ^*) recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur, México.

Years/Months	T (˚C)	Sal (UPS)	DO (mg/L)	α-Fisher	TD Δ^*
2015	28.10	28.95	10.73	5.15	113.89
2016	28.69	30.56	7.53	4.71	118.09
2017	27.63	31.66	7.52	3.49	131.22
2018	27.47	35.10	7.32	3.31	128.65
2019	25.19	34.69	8.30	3.33	111.43
Jan	25.02	30.50	9.47	3.51	125.12
Feb	26.33	32.30	7.97	3.67	150
Mar	26.61	32.24	7.88	4.00	131.17
Apr	26.26	31.65	8.58	4.33	134.01
May	25.49	32.61	8.31	4.21	144.89
Jun	25.25	31.82	7.15	4.45	118.64
Jul	27.24	32.00	6.60	4.51	102.61
Aug	29.98	32.89	7.42	3.98	134.35
Sep	31.96	32.58	7.23	3.80	134.02
Oct	31.02	27.80	8.94	2.86	138.41
Nov	28.88	35.30	8.06	4.17	131.62
Dec	26.07	35.30	8.56	3.76	107.41
SEA	23.95	33.61	8.23	-	-

Mean salinity (UPS) showed significant differences between months (F(12, 105) = 2.229; $p = 0.015$) and between years (F(9, 64) = 13.921; $p < 0.001$). The highest value was recorded in 2018 (35.10 UPS), while the lowest was recorded in 2015 (28.95 UPS). Regarding differences between months, the lowest salinity value was recorded in January (30.50 UPS), while the highest values were recorded in November and December (35.30 UPS) (**Table 1**).

Mean dissolved oxygen (DO mg/L) showed significant differences between years (F(9, 64) = 14.75; $p < 0.001$) and between months (F(12, 105) = 1.847; $p = 0.049$). The highest value was recorded in 2015 (10.7 mg/L) and the lowest value was recorded in 2018 (7.3 mg/L). Regarding differences between months, the lowest value was recorded in July (6.60 mg/L), while the highest value was recorded in December (8.56 mg/L) (**Table 1**).

3.2. Taxonomic Diversity

A total of 14,995 organisms belonging to one class, one superorder, eight orders, 15 families, 27 genera and 30 species were recorded during the study period. Fisher's alpha diversity (α-Fisher) showed significant differences between years (F(4, 54) = 6.467; $p < 0.001$). The highest value was recorded in 2015 ($S = 5.15$), followed by 2016 ($S = 4.71$), and the lowest values were recorded in 2018 ($S = 3.31$) and 2019 ($S = 3.33$), showing a difference of 1.9 units between the highest and the lowest value. There were no significant differences between months (F(11, 47) = 0.328; $p = 0.975$) (**Table 1**).

The highest values of average alpha diversity ($\bar{\alpha}$) were recorded during the warmer years. with 2015 and 2016 recording 11.38 and 10.58 species, respectively. The lowest $\bar{\alpha}$ diversity values were recorded in 2018 and 2019 with 7.91 species each (**Figure 2**). The warmer months also showed the highest $\bar{\alpha}$ diversity values, particularly July with 11.2 species, contrary to the colder months like January, which showed 7.8 species (**Figure 3**).

Regarding beta diversity (β), the highest value was recorded in 2019 (12.09%), followed by 2015 (10.17%), while the lowest value (5.25%) was recorded in 2017 (**Figure 2**). High values of beta diversity were also recorded during the warmer months, like April and June (10.6%), compared to colder months like December (5.8%) (**Figure 3**). Finally, the highest value of gamma diversity (γ) was recorded in 2015 with 22 species (**Figure 2**), and during the warmer months (April and June) with 21 species. The lowest values of gamma diversity were recorded during in 2017, and during the colder months (December and January), with 14 species each (**Figure 3**).

3.3. Taxonomic Distinctness

The highest value of taxonomic distinctness was recorded in 2017 ($\Delta^* = 131.22$), while the lowest value was recorded in 2019 ($\Delta^* = 111.43$). By months, the highest value was recorded in February ($\Delta^* = 150$) while the lowest value was recorded in July ($\Delta^* = 102.6$) (**Table 1**).

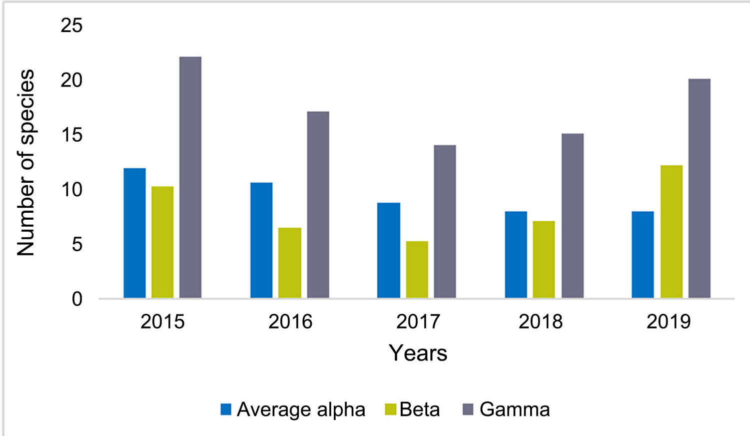

Figure 2. Annual values of average alpha diversity ($\bar{\alpha}$), beta diversity (β) and gamma diversity (γ) of the intertidal fish assemblages recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur, from 2015 to 2019.

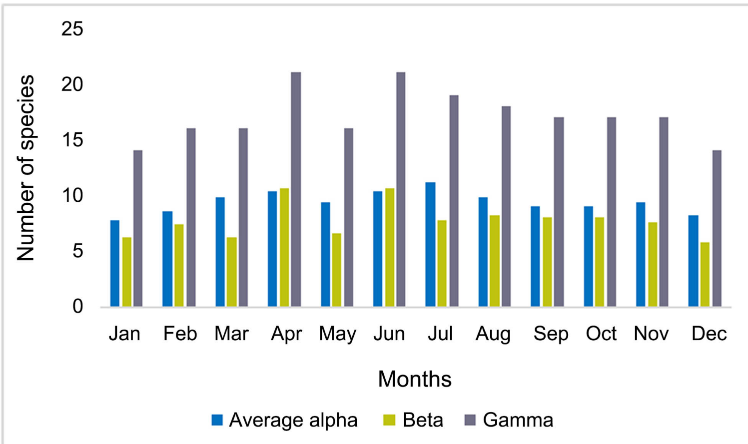

Figure 3. Monthly values of average alpha diversity ($\bar{\alpha}$), beta diversity (β) and gamma diversity (γ) of the intertidal fish assemblages recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur.

Average taxonomic distinctness (Δ^+) showed all years and months within the 95% confidence intervals, with 2019 recording the highest value ($\Delta^+ = 62.02$), and 2018 with the lowest value ($\Delta^+ = 61.43$), therefore not showing significant differences between the highest and lowest value (Figure 4). By months, the highest taxonomic distance was recorded in July ($\Delta^+ = 62.67$), while the lowest was recorded in February ($\Delta^+ = 60.0$), which was the lowest value recorded during the study period (Figure 5).

3.4. Multi-Dimensional Scaling (MDS) Analysis and Bray-Curtis Dissimilarity Index

For the nMDS analysis, annual values of number of species were used, which were obtained and registered by using thevisual censuses method during the study period, for this analysis total abundances were used, which were transformed (square root) and then use alongside the Bray-Curtis dissimilarity index,

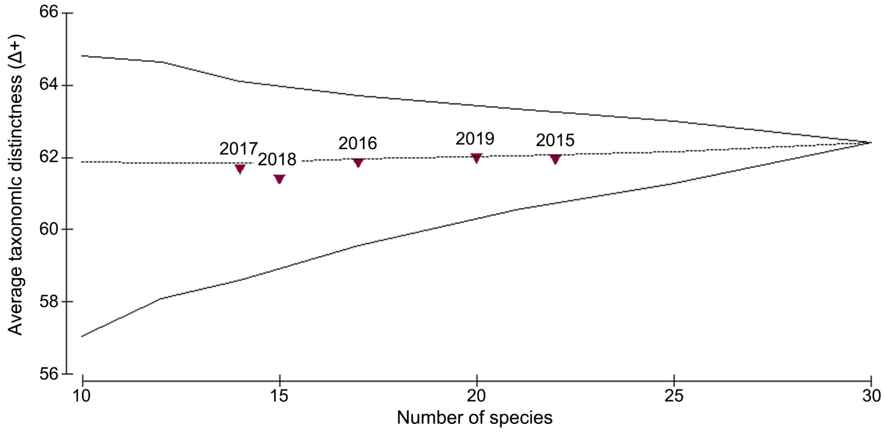

Figure 4. Annual values of average taxonomic distinctness (AvTD Δ^+) of the intertidal fish assemblages recorded in in the rock pools of Conquista Agraria in La Paz, Baja California Sur, from 2015 to 2019.

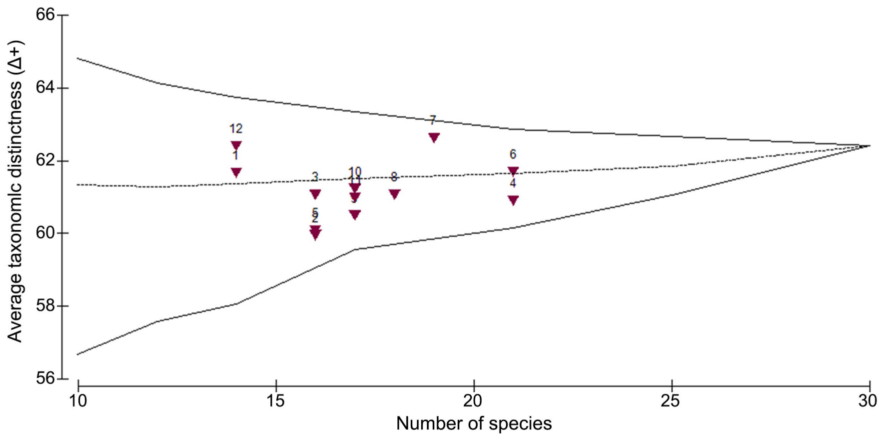

Figure 5. Monthly values of average taxonomic distinctness (AvTD Δ^+) of the intertidal fish assemblages recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur.

to represent the similarity between the fish communities during the study period. Accordingly, 2017 and 2018 showed the closest distance (similarity) regarding the species recorded in both years, with 80% similarity. In addition, the entire study period (2015-2019) showed 60% similarity, with a stress level of 0.01, indicating high similarity between years with minimum dispersion (**Figure 6**).

Finally, the dendrogram based on the Bray-Curtis dissimilarity index (**Figure 7**) showed similarities between the species recorded in Conquista Agraria during the study period, with seven groups: Group I (*Halichoeres nicholsi* and *Stegastes flavilatus*), Group II (*Ctenogobius sagittula* and *Girella nigricans*), Group III (*Diodon hystrix*, *Umbrina xanti*, *Chromis limbaughi* and *Gibbonsia montereyensis*), Group IV (*Abudefduf trschelii*, *Bathygobius ramosus*, *Mugil hospes*, *Bathygobius sp*, *Ophioblennius steindachenri* and *Sargocentron suborbitalis*), Group V (*Labrisomus xanti*, *Microspathodon bairdii* and *Thalassoma lucasanum*), Group VI (*Chirolepis minutillus*, *Hypsoblennius jenkinsi*, *Prionurus punctatus*, *Hypsob-*

lennius brevipinnis and *Malacoctenus margaritae*), and Group VII (*Kyphosus elegans*, *Melichthys niger*, *Epinephelus labriformis*, *Microgobius brevispinnis*, *Chaetodon humeralis* and *Johnrandallia nigrirostris*).

4. Discussion

4.1. Physicochemical Variables

The intertidal zone, particularly rock pools, are key habitats where physicochemical variables are strongly influenced by the mixed tidal cycle, which is characteristic of the study area, with two high and two low tides that differ in size each lunar day [18]. In addition, other coastal hydrodynamic processes such as longshore currents and sea level change can also influence the physicochemical variables measured in the rock pools [5]. Moreover, during the first two years of the study period (2015 and 2016), an El Niño Southern Oscillation (ENSO) event was happening, in addition to the warm tendency from the Pacific Decadal Oscillation (PDO) event. All these factors contributed to the variation of the physicochemical parameters measured throughout the study period, with significant differences between years ($p = 0.0011$) and months ($p < 0.001$), with 2015 and 2016 as the warmest years. According to Magaña *et al.*, [19], during an ENSO event the sea surface temperatures in the central and eastern Pacific Ocean become warmer than usual, and rainfall increases. In addition, in a study of the water quality of the Magdalena River, Ospina-Zúñiga *et al.*, [20] concluded that El Niño event from 2015-2015 strongly influenced the temperature variation of the water, recording maximum temperatures of 30.3˚C. Regarding differences between months, the highest temperatures were recorded during the summer/autumn months (July to November), while the lowest temperatures were

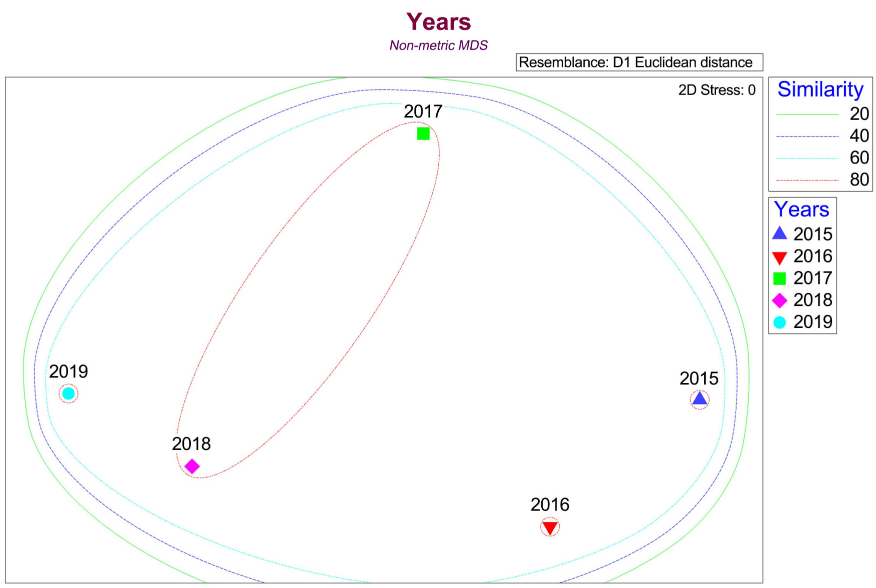

Figure 6. Multi-Dimensional scaling (nMDS) analysis of the intertidal fish species recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur, from 2015 to 2019.

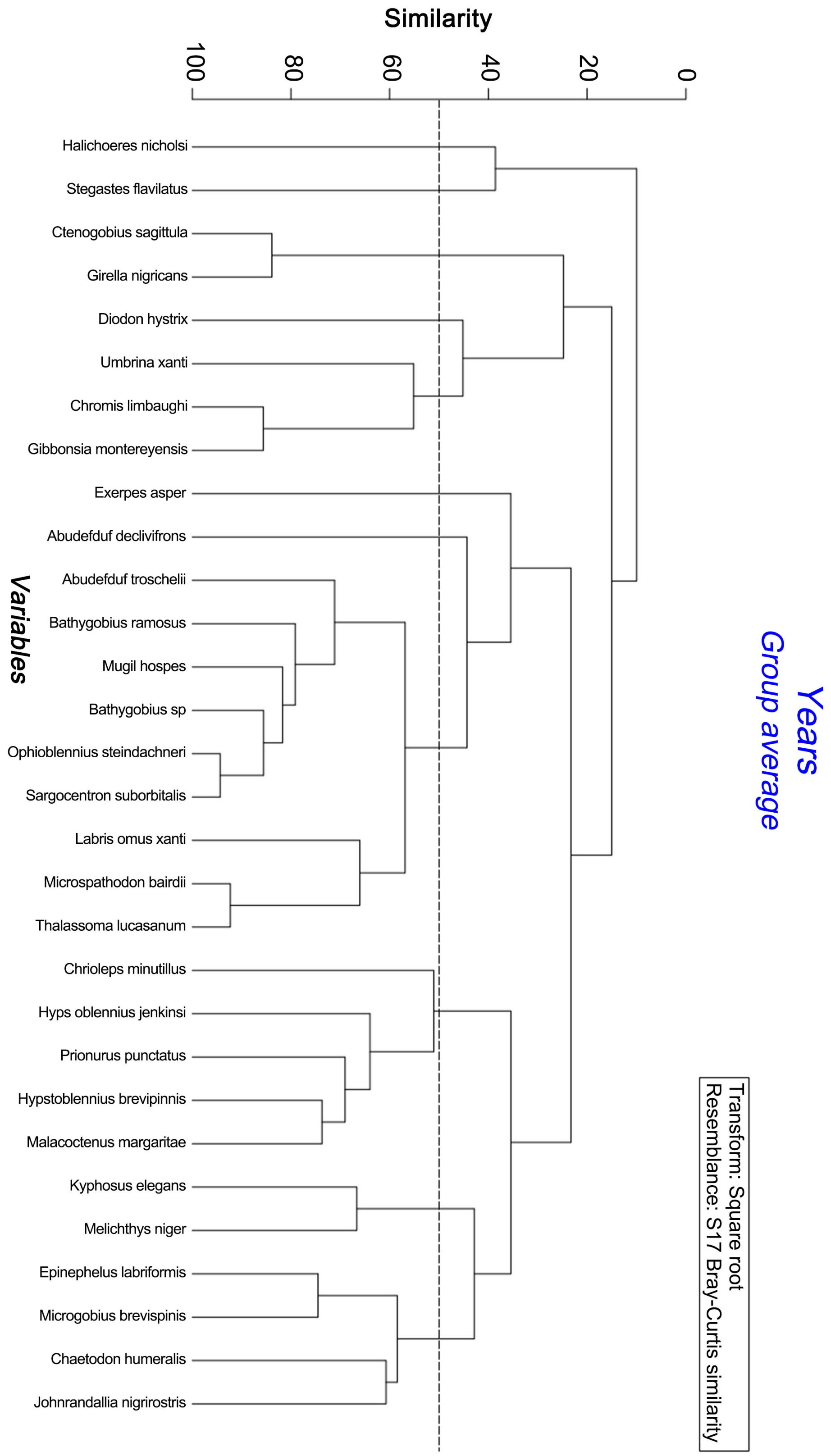

Figure 7. Hierarchical clustering dendrogram from the Bray-Curtis dissimilarity analysis showing the intertidal fish species recorded in the rock pools of Conquista Agraria in La Paz, Baja California Sur.

recorded in the winter/spring months (December to June) (**Table 1**). During the warmer months, rock pools are exposed to drastic changes of temperature due to water evaporation while being exposed to air and intense solar radiation, typical of the summer months. This is supported by Little and Kitching [21], who mentioned that rock pools are characterized by a lack of water exchange due to the low tides, which causes more thermal heterogeneity compared to open sea temperatures. In addition, González-Ruano [22], in a study of rock pools in Spain, recorded high temperatures during the summer months (July) and lower temperatures during the winter months (December and January). Moreover, González-Murcia *et al.*, [23] reported increments of temperature and rainfall during the summer months in El Salvador, which share similar climatic conditions as our study area Conquista Agraria.

Salinity (UPS) showed significant differences between years ($p < 0.001$) and months ($p = 0.015$), with 2015 and 2016 recording the lowest values (**Table 1**). According to González-Murcia [24], the increase of rainfall in the summer months during an El Niño event, can result in lower salinity values due to a higher accumulation of freshwater in the coastal areas, compared to colder months when rainfall is scarce. Regarding differences between months, the highest values were recorded during the warmer months, perhaps due to greater water evaporation because of the high temperatures. Our results are consistent to previous reports by González-Murcia [24], Pérez-Castillo [25] and González-Murcia *et al.*, [23].

Dissolved oxygen showed significant differences between months ($p = 0.049$) and years ($p < 0.001$). The oxygen demand from the fauna inhabiting the rock pools strongly influences the dissolved oxygen concentration, which changes throughout the seasons. According to Barjau-González *et al.*, [26], during the warmer months, intertidal species of fish, crustaceans, anemones, etc. are exposed to higher temperatures, particularly during the lowest tide, which causes an increase of their metabolic rate, and therefore their oxygen demand, decreasing the dissolved oxygen in the water. In addition, González-Murcia [24] mentions that photosynthesis by the algae inhabiting the rock pools also influences the dissolved oxygen concentration in the water, which is also consistent to that reported by Barjau-González [27], describing lower values of dissolved oxygen in the summer months and higher values during the cold season, which is supported by González-Ruano [22], who explains that dissolved oxygen is influenced by other physicochemical variables like temperature, such that cold water has a higher capacity to hold oxygen compared to warm water.

4.2. Taxonomic Diversity

Fisher's alpha diversity showed significant differences between years, with 2015 recording the highest diversity value ($S = 5.15$), followed by 2014 ($S = 4.41$), while the lowest value was recorded in 2018 ($S = 3.3$) (**Table 1**). According to González-Ruano [22], these increments of diversity during the warmer years are a result of fish species affinity to these areas perhaps because of favorable environmental conditions during those months, compared to a decrease of diversity during the colder months. These results are consistent to those reported by Laroche *et al.*, [28], describing a variation of diversity and abundance of species according to the climatic seasons. In addition, Cota-Ortega *et al.*, [29] reported the highest Fisher's alpha diversity during 2015 and the lowest value in 2019, consisted to that reported in the present study.

All measures of diversity (average alpha, beta, and gamma) showed significant differences between months (**Figure 2**) and years (**Figure 3**). Average alpha diversity showed a tendency to increase during the warmer years (2015 and 2016) and the warmer months. Similar results have been reported by Barjau-González [30] in a study at La Paz Bay, with higher diversity values recorded during the warmer months (July and August). In addition, Juaristi-Videgaray [31] reported higher diversity values of soft-bottom fish communities in San Ignacio lagoon during the summer months. Regarding beta diversity, the highest diversity values were recorded in 2019, and during the months of April and June, which indicates greater exchange of species compared to other months and years. According to Laroche *et al.*, [28], spatial species exchange is independent from the regional pool of species, therefore, if beta diversity is low, the exchange of species is considered is poor. Moreover, contrasting results were reported by Pérez-Castillo *et al.*, [25] in San Ignacio lagoon, with lower diversity values during the warmer months (8.72 species).

Gamma diversity showed the highest value in 2015, with a total of 22 species, compared to 2017 with 14 species (**Figure 2**). By months, the highest values were recorded during the summer months (June-July), while the lowest were recorded in the winter months (December-January). Pérez-Castillo [25] reported similar results, with 23 species in the summer months and 14 species during the winter months. In addition, Vásquez *et al.*, [32] mention that another factor that influences the diversity patterns throughout the seasons is an oceanographic process known as upwelling, which is the movement of cooler and nutrient-rich masses of water from deeper areas, that promote higher primary productivity in coastal areas. Furthermore, Pérez-España *et al.*, [33] and Rodríguez-Romero *et al.*, [34] mention that the increase of species numbers during the warm season might also be a result of the life cycle of certain species, which find warmer temperatures more suitable for reproduction, therefore, increasing the number and abundance of species during the summer months.

4.3. Taxonomic Distinctness

Taxonomic distinctness (Δ^*) showed the closest lower values during the warmer months, while the highest values were recorded in the colder months (**Table 1**). On the contrary, Barjau-González [30] reported significantly lower values during the warmer months ($\Delta^* = 56.8$). In addition, Barjau-González *et al.*, [26] reported similar results, with April falling close to the 95% confidence intervals, while June and January were closer to the mean. An explanation for these differences could be duration of sampling, since the present study lasted five years, while Barjau-González *et al.*, [26] study only lasted one year (2015), which was a particularly warmer year. By years, 2019 showed the lower value (Δ^* = 111.4) and 2017 with the highest value (Δ^* = 131.2). Contrary to results reported by Barjau-González *et al.*, [35] which showed significantly higher values (Δ^* = 229.3), perhaps due to the different study area as well as sampling technique.

Average taxonomic distinctness (Δ^+) showed similar values throughout the study period, ranging from Δ^+ = 58.7 to 60.66, inferring high taxonomic similarity between species recorded in Conquista Agraria (**Figure 4**). By months, higher values were recorded during the summer months (July), while the lower values were recorded during the colder months (**Figure 5**), which is consistent to results reported by Pérez-Castillo *et al.*, [25] in San Ignacio lagoon. Likewise, all months fall within the 95% confidence intervals, consistent to reports by Barjau-González *et al.*, [26] for the same study area, which suggests that despite the variability of environmental conditions throughout the study period, Conquista Agraria is an ecologically stable area.

4.4. Multi-Dimensional Scaling (MDS) Analysis and Bray-Curtis Dissimilarity Index

According to our dissimilarity analysis, 2017 and 2018 shared 80% of the species recorded in the study (**Figure 6**), which is also consistent with the similar temperatures (**Table 1**) and diversity values (**Figure 3**) recorded in both years. In addition, average taxonomic distinctness also shows 2017 and 2018 as highly similar years. According to Ruiz-Campos *et al.*, [36], the fish species that inhabit the intertidal rocky areas of the West coast of the Baja California peninsula have a greater affinity for the Mexican and Cortes zoogeographic provinces, with the family Pomacentridae recording the highest number of species, particularly *A. declivifrons* and *A. troschelii*. This is consistent to that reported by Cota-Ortega *et al.*, [29], who also mentioned these species as the most abundant.

The Bray-Curtis dissimilarity index dendrogram showed seven species groups with an overall similarity of 60%. Group IV shows the most abundant species (dominant group), which can be linked to habitat heterogeneity and favorable environmental conditions, because these species are present in the study area throughout the year. According to Cava [37], habitat heterogeneity provides a wide variety of suitable resources (feeding ground, shelter). Likewise, species with low abundances indicates that certain taxa may have affinity to other areas with different environmental conditions. Closs, Downes and Boulton [38] mention that environmental factors like temperature, salinity and dissolved oxygen impact the presence and distribution of species on intertidal areas, particularly rock pools, which is reflected by the variation of abundance of species from groups V and VI, with higher abundances only during the colder months, contrary to species from groups II and VII, which showed higher abundances, therefore affinity, during the warmer months. Based on this, we can infer that diversity shows temporal variation throughout the seasons, in response to the variability of abiotic factors in the intertidal areas.

5. Conclusion

Physicochemical variables showed variations throughout the study period. This environmental variation influenced the diversity patterns recorded in the present study, with the highest values of Fisher's alpha (α-Fisher), average alpha diversity ($\bar{\alpha}$), beta diversity (β) and gamma diversity (γ). In addition, 2017 and 2018 were highly similar, according to the species recorded in both years; yet, 2015, 2016 and 2019 were dissimilar. Finally, although there are seasonal differences regarding the number and abundance of species recorded throughout the study period, based on the taxonomic distinctness results, it can be inferred that Conquista Agraria is an ecologically stable area, at least during the 2015-2019 period.

Authors Contributions

JECR analyzed data and wrote the manuscript. EBG designed and carried out visual censuses, including counting and identification of the fish species. JAAQ georeferenced the sampling site. EBG, JMLV, JAAQ, JAP and EEAF revised the manuscript. All authors read and approved the final manuscript. Likewise, all authors declare no conflict of interest.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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