

Variation of the Structure of the Intertidal Fish Community of the Pacific Coast of Baja California Sur, México

Emelio Barjau-González¹ ✉, Abril Karim Romo-Piñera¹, Juan Manuel López-Vivas¹, José Pérez-Castillo¹, Myrna Barjau-Pérez Milicua²

¹ Departamento Académico de Ciencias Marinas y Costeras, Universidad Autónoma de Baja California Sur, CP 23080, La Paz, B.C.S., México

² School of Biology, Faculty of Biological Sciences, University of Leeds, LS2 9JT. Leeds, UK

✉ Corresponding author email: ebarjau@uabcs.mx

International Journal of Marine Science, 2017, Vol.7, No.48 doi: [10.5376/ijms.2017.07.0048](https://doi.org/10.5376/ijms.2017.07.0048)

Received: 21 Nov., 2017

Accepted: 12 Dec., 2017

Published: 22 Dec., 2017

Copyright © 2017 Barjau-González et al., This is an open access article published under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Preferred citation for this article:

Barjau-González E., Romo-Piñeda A.K., López-Vivas J.M., Pérez-Castillo J., and Milicua M.B.P., 2017, Variation of the structure of the intertidal fish community of the Pacific coast of Baja California Sur, México, International Journal of Marine Science, 7(48): 455-461 (doi: [10.5376/ijms.2017.07.0048](https://doi.org/10.5376/ijms.2017.07.0048))

Abstract The intertidal zone is a transition zone between terrestrial and coastal systems. During low tide, rocky pools are exposed to air for several hours throughout the day, and environmental conditions such as temperature and salinity are highly variable. There are not many studies of fish communities inhabiting the intertidal zone in México. Therefore, the aim of the present study was to analyze the variation of the community structure of intertidal fish considering temperature, salinity and dissolved oxygen of the water that remains trapped in the tide pools during low tide. Visual censuses were carried out monthly during spring tides on full moon days, when fluctuations of environmental variables are significant. From January to December 2015 visual census were performed in the intertidal zone of El Faro, a locality belonging to the common land of Conquista Agraria in the City of La Paz, west coast of Baja California Sur, México. Extension of censuses was 156*5 m, 145 tide pools were divided in three groups (small, medium and large) according to size and depths that ranged from 20 to 45 cm. Temperature, salinity and dissolved oxygen fluctuate throughout the year of study. Thermal difference between open ocean and tide pools ranged from 3.5 to 4.5 °C. A total of 3,754 organisms from 22 species, 12 families, four orders and one class were recorded. To analyze community structure, the following ecological indices were used: species richness (SRI); evenness (J'); Shannon-Wiener's diversity (H') and Fisher's alpha (α -Fisher) with overall values of 2.80, 0.91, 3.20 and 5.15, respectively. According to BVI, 12 species were dominant. All species recorded were grouped as abundant (2), frequent (11), common (5) and rare (4), according to their relative abundance and frequency.

Keywords Structure; Exposed area; Solar incidence; Climate change

Background

The intertidal zone is an area of transition between low and high tide, and it is characterized by key ecosystems such as sandy and rocky beaches. During a typical tidal cycle, there are variations of physicochemical variables such as temperature and salinity, as a result from solar incidence and evaporation during low tide. Intertidal zones are also a source of important ecosystem services; therefore, anthropogenic impacts may increase vulnerability of these ecosystems to climate change (Yáñez and Day, 2010). Geomorphology of coastal areas regulates their structure and ecological dynamic, and is a useful reference to interpret impacts of climate change (Yáñez-Arancibia, 2005); particularly considering critical habitats, defined as the range of environmental conditions in which species can live and develop (Yáñez-Arancibia et al., 2009). These habitats include complex rocky areas which intertidal fish use as shelter to survive and withstand environmental change. During low tide, physicochemical variables such as temperature, salinity and dissolved oxygen can be highly variable during the day, particularly in exposed habitats such as tide pools. There are not many studies of fish communities inhabiting the intertidal zone in México, that include critical environmental parameters. Therefore, the aim of the present study was to determine the structure of the fish community trapped in tide pools during low tide and its relationship with physicochemical variables of the water such as temperature, salinity and dissolved oxygen.

1 Materials and Methods

1.1 Study area

The site "El Faro" is located 24 km west of the common land known as Conquista Agraria, at N23 57.351 and

W110 52.437. The study area is located 524 m north of El Faro, from N23 57.553 and W110 52.654 to N23 57.622 and W110 52.705 (Figure 1).

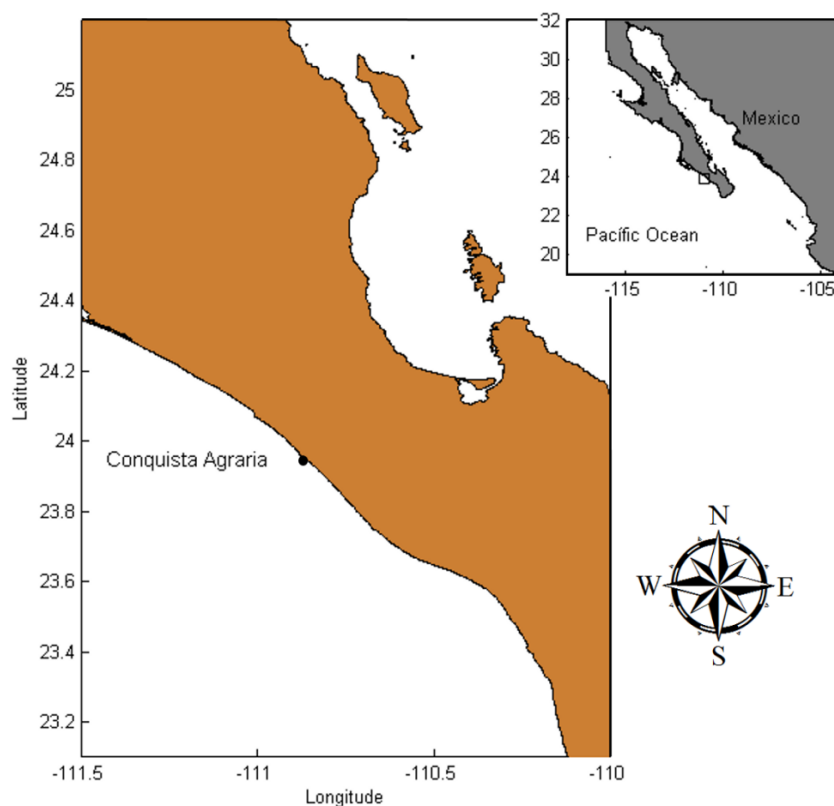


Figure 1 Geographic location of the sampling sites of fish species sampled in Conquista Agraria Baja California Sur, Pacific coast

From January to December 2015, monthly samplings were performed in the intertidal zone during full moon days. Visual censuses of fish were performed using transects of 156*5 m. 145 tide pools were recorded and divided in three groups (small: 2 m², medium: 4 m² and large: 7 m²) according to size and depths that ranged from 20 to 45 cm. Tide pools are located 122 cm above sea level. To determine structure of the fish community the following ecological indices were used: species richness (SRI); evenness (J'); Shannon-Wiener's diversity (H'); Fisher's alpha (α -Fisher); dominance (Biological value Index-BVI) which is an indicator of the general dominance by species (Sander, 1960). It is recommended to use 95% of the relative abundance of individuals per sample to eliminate data lacking relevant information (Loya-Salinas and Escofet, 1990). Finally, considering their relative abundance and occurrence, species were classified as abundant, frequent, common and rare. Physicochemical variables (temperature, salinity and dissolved oxygen) were recorded using a YSI 2030 Pro multiparameter instrument. Ecological indices were analysed using the software Primer-E & Permanova 6 and statistical analysis was performed using Statistica v.7. Species identifications were carried out using specialized literature (Meek and Hildebrand, 1923-1928; Zahuranec, 1967; Miller and Lea, 1976; Whitehead, 1985; Whitehead et al., 1986; Fischer et al., 1995; Allen and Robertson, 1998; Thomson et al., 2000).

2 Results

2.1 Physicochemical variables

Temperature of the water trapped in the tide pools showed greater variation. Mean temperature was 28.18 °C, with significant differences between months ($p < 0.05$). September was the warmest month (32.64 °C), followed by August and October (32.53 °C and 32.43 °C, respectively). The coldest month was January (24.30 °C) (Table 1). Comparing between tide pools of different size and depths, there were no significant differences of temperature ($p = 0.97$). The overall mean salinity was 30.31 UPS, with significant differences between months ($p < 0.05$). Highest salinity was recorded in September (32.3 UPS) and the lowest was recorded during April (27.56 UPS)

(Table 1). Comparing between tide pools of different size and depths, there were no significant differences of salinity ($p=0.33$). Overall dissolved oxygen of the water trapped in the tide pools was 10.21 mg/L (Table 1). There were no significant differences between months ($p=0.48$). Comparing between tide pools of different size and depths, there were no significant differences of dissolved oxygen ($p=0.26$).

Table 1 Physicochemical variables: temperature (T °C), salinity (Sal. UPS), dissolved oxygen (DO), and community structure values: species richness (SR), evenness (J'), Shannon-Wiener's diversity (H') and Fisher's alpha diversity (α -Fisher), recorded at tide pools of the intertidal zone at El Faro, Conquista Agraria, Baja California Sur, México

Months	T °C	Sal. UPS	DO	SR	J'	H' (log2)	α -Fisher
January	24.2	28.65	15.77	2.28	0.81	2.70	3.69
February	27.4	31.75	7.55	2.20	0.87	2.87	3.44
March	26.2	31.85	8.975	2.67	0.91	3.26	4.45
April	24.8	27.65	10.93	3.56	0.94	3.66	7.16
May	26.3	31.65	6.69	2.93	0.92	3.30	5.52
June	27.15	29.5	6.55	3.34	0.92	3.49	6.57
July	29.3	30.55	5.77	3.53	0.89	3.48	7.02
August	32.4	31.95	9.64	3.07	0.94	3.47	5.73
September	32.65	32	8.575	2.55	0.95	3.14	4.77
October	32.25	28.6	11.85	2.74	0.91	3.26	4.71
November	29.5	28.35	11.5	3.10	0.92	3.41	5.86
December	25.1	29.95	25.05	1.66	0.93	2.40	2.89
Average	28.10	30.20	10.74	2.80	0.91	3.20	5.15

2.2 Community structure

A total of 3,754 organisms from 22 species, 12 families, four orders and one class were recorded and distributed in the tide pools as follows: 85 small tide pools (1,914 organisms), 48 medium tide pools (1,314 organisms) and 12 large tide pools (526 organisms).

Margalef's species richness (SRI) showed significant differences ($p<0.05$) (Margalef, 1969). April and July recorded the highest values (3.56 and 3.53, respectively), and the lowest values were recorded during December and February (1.66 and 2.20, respectively) (Table 1). Considering the size of the tide pools, there were no significant differences ($p=0.216$).

There were also significant differences ($p<0.05$) of evenness recorded each month. September showed the highest value (0.95), and January showed the lowest value (0.81) (Table 1). Considering the size of the tide pools, there were no significant differences ($p>0.05$).

Shannon-Wiener's diversity (H') mean value was 3.20 bits/ind. There were significant differences ($p<0.05$) between months, with April showing the highest H' value (3.66 bits/ind.), and December showing the lowest value. There were no significant differences when comparing between different size tide pools. Fisher's alpha was also used as a diversity index because it includes rare species and has higher biological significance. Its mean value was $S=5.15$. April registered the highest value ($S=7.16$), and December had the lowest value ($S=2.89$). There were significant differences between months and size of tide pools ($p<0.05$) (Table 1).

According to BVI, there were 12 dominant species. The species with the highest ranking were *Abudefduf declivifrons*, *A. troschelii* y *Bathygobius ramosus* (12, 11 and 10, respectively) (Figure 2).

According to relative abundance and frequency, 22 species recorded in this study were classified in four groups (Figure 3):

(1) Abundant species: *A. declivifrons* and *A. troschelii* with relative abundance of 26%.

(2) Frequent species: 11 species (*Bathygobius ramosus*, *Bathygobius lineatus*, *Chriolepis minutillus*, *Sargocentron suborbital*, *Ophioblennius steindachneri*, *Thalassoma lucasanum*, *Mugil hospes*, *Microspathodon bairdi*,

Labrisomus xanti, *Hypsoblennius jenkinsi* and *Malacoctenus margaritae*) with relative abundance ranging from 1.148 to 6.364%.

(3) Common species: Five species (*Prionurus punctatus*, *Hypsoblennius brevipinnis*, *Ctenogobius sagittula*, *Johnrandallia nigrirostris* and *Chaetodon humeralis*) with relative abundance ranging from 0.261 to 0.756%.

(4) Rare species: Four species (*Epinephelus labriformis*, *Microgobius brevispinis*, *Kyphosus elegans* and *Melichthys niger*) with relative abundance ranging from 0.026 to 0.186%.

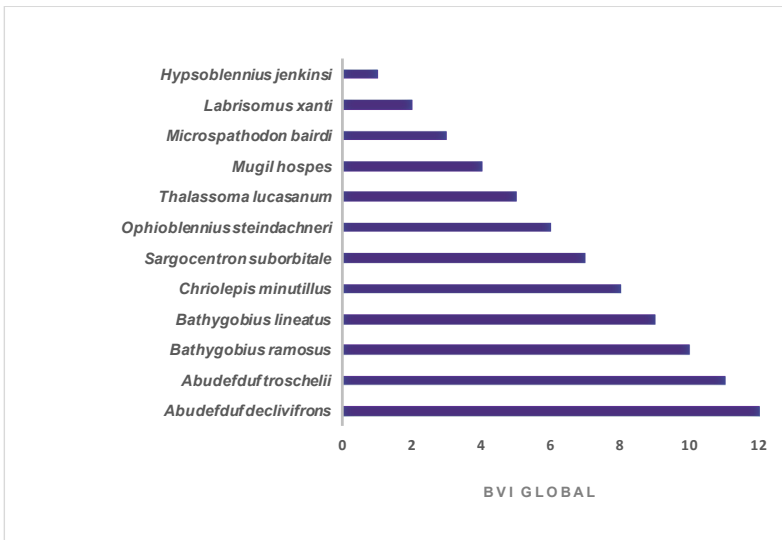


Figure 2 Dominant fish species in the intertidal zone of Conquista Agraria according to Biological Value Index (BVI)

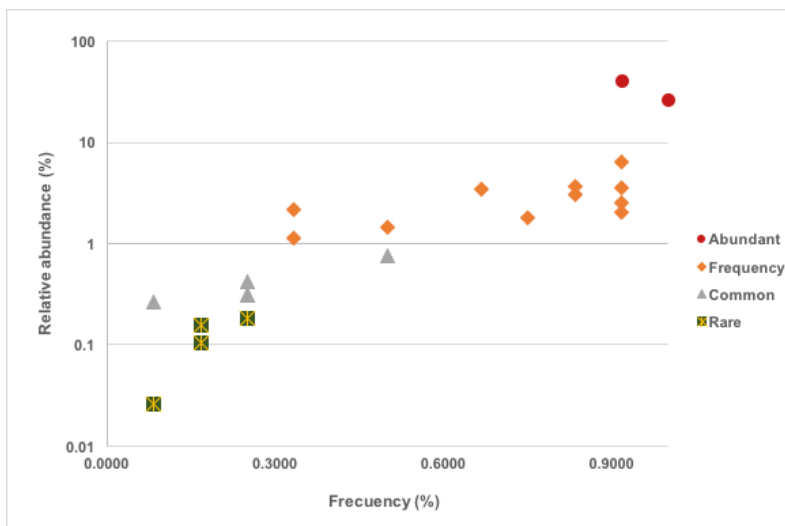


Figure 3 Classification of species according to relative abundance and frequency during visual censuses

3 Discussion

The intertidal zone is highly variable through time and space (Bridges, 1974; Little and Kitching, 1996) due to seasonal and daily variations of tide and solar radiation (Metaxas and Scheibling, 1993; 1994). Our study area is characterized by a mixed tidal cycle, which is why physicochemical variables were measured during the afternoon low tide (between 16:00 and 17:00 hr.). Exposed time of pools during low tide was 6 h 20 min. According to our results, temperature variations during the year ranged from 24.2 °C to 32.65 °C (Table 1), similar to previous studies on Chile and El Salvador (Hernández et al., 2002; González-Murcia et al., 2016). Thermal difference between open ocean and tide pools was 4.6 °C, maximum temperature (32.65 °C) was recorded in September. According to González-Murcia et al. (2016), as the water gets warmer, fish increase their metabolic activity, and considering an increase of frequency and intensity of warming events due to climate change, fish and other

ectothermic organisms may be challenge, particularly because their survival, growth and reproduction rely on critical temperature ranges. Organisms inhabiting the rocky intertidal zone are assumed to live very close to their thermal tolerance limits, therefore are considered as potential harbingers of the effects of climate change on species distributions in nature (Helmuth et al., 2002).

Tide pools in our study area are located 122 cm above sea level (lowest tide). According to White et al. (2015), isolation of tide pools, as well as water evaporation, are important factors that determine composition and distribution of intertidal fish. These authors selected tide pools according to their position above the lowest tide (low, medium, high), and used larger and deeper tide pools, obtaining different temperature, salinity and dissolved oxygen values compared to our own. These results might be due to geographical differences, since our tide pools are in a subtropical region, where fish have tropical and temperate affinities, while their tide pools are in a temperate region.

Salinity showed significant differences throughout the year because of water evaporation of tide pools, similar to previous studies (Hernández et al., 2002; González-Murcia et al., 2016). Oxygen levels increased during the day (due to photosynthesis) and decrease at night (Velazco-Gil, 2006). Dissolved oxygen showed significant differences between months, ranging from 5.5 to 25 mg/L. These variations might result from difference on oxygen demand because of the presence of different organisms (molluscs (gastropods, polyplacophora, cephalopods), crustaceans, annelids, sipunculids, anemones, sea urchins and limpets; as well as brown, red and green algae) throughout the year (Velazco-Gil, 2006). Temperature, salinity and dissolved oxygen did not show significant differences when comparing size of tide pools, which suggests that there is no preference on size because environmental conditions are similar in all tide pools, and therefore they are all used as shelters during low tide.

Structure of the intertidal fish community of tropical zones in Mexico and other regions has not been well studied. According to González-Murcia et al., (2016), studies on the intertidal zone of tropical regions are limited. Therefore, the present study is an important contribution to the understanding of temporal changes of the structure of the intertidal fish community of the West coast of the Baja California peninsula (Ruiz-Campos and Mammann, 1987; Ruiz-Campos et al., 2010).

Species richness describes changes in the number of species according to sample size. Environmental variables and time fluctuations have a significant impact on the number of species. Overall species richness recorded in the present study was 2.80. González-Murcia et al. (2016) found no significant difference on species richness between tide pools, but did found changes between different water volumes. According to White et al. (2015), structure of fish community of tide pools is regulated by biological factors such as shelter availability, feeding, and others. Considering these factors within our study area, species richness can be modified through time (Table 1). According to Pielou (1976), evenness is an important component of diversity that estimates a maximum value of diversity when all species are equally abundant. This ecological index describes the proportional distribution of abundance between species; its value ranges from 0 to 1, with 1 meaning that all species are equally abundant (Magurran, 1988). According to our results, there is a good level of evenness between the recorded species and their relative abundance reaching an overall value of 0.91. Previous studies of the fish community of tide pools do not include this ecological index in their analysis, therefore the present study is the first one using this index. Shannon-Winner's diversity index has not been widely used to describe structure of the fish community of tide pools. According to our results, an overall diversity value of 3.20 bits/ind., is considered a good indicator of diversity, although it is important to mention that this index may present some inconvenient at the time of analysis, such as departure from normality, related to sample size (Krebs, 2006). On contrast, Fisher's alpha diversity index (Fisher et al., 1943) evaluates diversity more efficiently considering number of organisms and number of species (Condit et al., 1996), therefore, from an ecological perspective, all species have the same weight (Moreno, 2001; Magurran, 2004). This index, alongside evenness and Shannon-Winner's diversity have not been used in this type of studies with intertidal fish. Grouping fish species according to relative abundance and frequency, might shed some light into their ecological role in the ecosystem, from the 22-species recorded in the present study, only two

were considered abundant (*A. declivifrons* y *A. troschelii*), and both species belong to the same trophic level, are oviparous, have medium resilience because it takes from 1.4 to 4.4 years to double the size of their population, both species have demersal eggs that attached to rocks, live in rocky and coral reefs, and parental care relies on the males (Robertson and Allen, 2008; Froese and Pauly, 2009).

4 Conclusion

Physicochemical variables measured in this study showed significant temporal variation. However, considering size and depth of tide pools, there were no significant differences, which suggests because all tide pools have similar environmental conditions, there are no size preferences and all tide pools are used as shelters during low tide. The present study is an important contribution to the understanding of temporal changes on the structure of the intertidal fish community of the West coast of the Baja California peninsula and its relationship with environmental parameters such as temperature, salinity and dissolved oxygen.

Authors' contributions

EBG designed and carried out fish sampling, analyzed data and wrote the manuscript. AKRP revised the manuscript. JMLV made out the figures. JPC helped with fish sampling. MBPM revised and contributed with the English editing of the manuscript. All authors read and approved the final manuscript. Authors declare no conflict of interest.

Acknowledgments

Authors would like to acknowledge UABCS for the use of its facilities (Laboratorio de Ecología de Peces). Dr. Juan Ángel Armenta Q. for georeferencing sampling site.

References

- Allen G.R., and Ross-Robertson D., 1998, Peces del Pacífico Oriental Tropical, Crawford House Press Pty Ltd., 2da. Edición en español, CANABIO y Agrupación Sierra Madre, S.C. p.327
- Briggs J.C., 1974, Marine Zoogeography, McGraw-Hill Book Company, New York, p.475
- Condit R., Hubbell S.P., and Foster R.B., 1996, Changes in tree species abundance in a Neotropical forest: impact of climate change, *Journal of Tropical Ecology*, 12: 231-256
<https://doi.org/10.1017/S0266467400009433>
- Fischer W., Krupp F., Schneider W., Sommer C., Carpenter K.E., and Niem V.H., 1995, Guía FAO para la identificación de especies para los fines de la pesca, Pacífico centro-oriental. Roma, FAO, Vol. II,III: 647-1813
- Fisher R., Corbet S., and Williams C., 1943, The relation between the number of species and the number of individual in a random sample of an animal population, *J Anim Ecol.*, 12: 42-58
<https://doi.org/10.2307/1411>
- Froese R., and Pauly D., Editors, 2009, Fish Base, World Wide Web electronic publication
- González-Murcia S., Batresand F.C., and Lovo M.H., 2016, Community structure and height distribution of intertidal rockpool fish in Los Cábanos, El Salvador, *Pan-American Journal of Aquatic Sciences*, 11(3): 227-242
- Helmuth B., Harley C.D.G., Halpin P.M., O'Donnell M., Hoffmann G.E., and Blanchette C.A., 2002, Climate change and latitudinal patterns of intertidal thermal stress, *Science*, 298(5595): 1015-1017
<https://doi.org/10.1126/science.1076814>
PMid:12411702
- Hernández C.E., Neill P.E., Pulgar J.M., Ojeda F.P., and Bozinovic F., 2002, Water temperature fluctuations and territoriality in the intertidal zone: two possible explanations for the elevational distribution of body size in *Graus nigra*, *Journal of Fish Biology*, 61: 472-488
<https://doi.org/10.1111/j.1095-8649.2002.tb01578.x>
- Krebs C.J., 2006, *Ecology: the experimental analysis of distribution and abundance*, 6th edition, Benjamin Cummings Publisher, p.453
- Little C., and KitChing J.A., 1996, *The biology of rocky shores*, Oxford, Oxford University Press, p.252
- Loya-Salinas D.H., and Escofet A., 1990, Aportación al índice de Valor Biológico (Sanders, 1960), *Ciencias Marinas*, 16(2): 97-115
- Margalef D.R., 1969, *Perspective in ecological theory*, Chicago University, Illinois, EEUU
PMid:5372794
- Magurran A., 1988, *Ecological diversity and its measurement*, Princeton., NJ: Princeton, University Press, p.250
<https://doi.org/10.1007/978-94-015-7358-0>
- Magurran A., 2004, *Measuring biological diversity*, Blackwell Publishing, London, p.256
- Metaxas A., and Scheibling R.E., 1993, Community structure and organization of tidepools, *Marine Ecology Progress Series*, 98: 187-198
<https://doi.org/10.3354/meps098187>

- Metaxas A., and Scheibling R.E., 1994, Spatial and temporal variability of tidepool hyperbenthos on a rocky shore in Nova Scotia, Canada, Marine Ecology Progress Series, 108: 175-184
<https://doi.org/10.3354/meps108175>
- Meek S.E., and Hildebrand S.F., 1923-1928, The marine fishes of Panama, Publ. Field. Mus. Nat. Hist., Zool. Ser., 15(1-4): 1-1045
- Miller D.J., and Lea R.N., 1976, Guide to the coastal marine fishes of California, California Dept. Fish and Game, Fish. Bull., 157: 1-249
- Moreno C.E., 2001, Métodos para medir la biodiversidad. M and T-Manuales y tesis SEA, vol. I. Zaragoza, España, p.84
- Pielou E.C., 1976, Ecological Diversity, J. Wiley and Sons, New York. N.Y. p.286
- Robertson D.R., and Allen G.R., 2008, Peces costeros del Pacífico oriental tropical: sistema de información en línea, Versión 1.0. Instituto Smithsonian de Investigaciones Tropicales, Balboa, República de Panamá
- Ruiz-Campos G., González-Guzmán S., Ramírez-Valdez A., González-Acosta A.F., Castro-Aguirre L.J., and Cruz-Agüero J. D., 2010, Composition, density and biogeographic affinities of the rocky intertidal fishes on the western coast of the Baja California peninsula, Mexico, California Cooperative Oceanic Fisheries Investigations, 51: 210-220
- Ruiz-Campos G., and Mammann M.G., 1987, A species list of the rocky intertidal fishes of Todos Santos Bay, Baja California, Mexico, Cienc. Mar., 13(1): 61-69
<https://doi.org/10.7773/cm.v13i1.524>
- Sanders H.L., 1960, Benthic studies in Buzzards Bay, III. The structure of the soft-bottom community, Limnol. Oceanogr., 5: 138-153
<https://doi.org/10.4319/lo.1960.5.2.0138>
- Thomson S., L. Findley y A. Kerstitch. 2000. Reef Fishes of Sea of Cortez. The Rocky-shore Fishes of the Gulf of California, University of Texas Press. EUA. pp.353
- Velasco Gil, 2006, Ictiofauna intermareal de una plataforma rocosa del Golfo de Cádiz: ciclos de vida, utilización del espacio y relaciones tróficas, Tesis doctoral, Universidad de Cádiz
- White G.E., Hose G.C., and Brown C., 2015, Influence of rock-pool characteristics on the distribution and abundance of inter-tidal fishes, Marine Ecology, 36(4): 1332-1344
<https://doi.org/10.1111/maec.12232>
- Whitehead P.J.P., Bauchot M.L., Jureau J.C., Nielsen J., and Tortonese E., 1986, Fishes of the North-eastern Atlantic and the Mediterranean. Vol. I, II, III, UNESCO. Paris, France, pp.1473
- Whitehead P.J.P., 1985, FAO Species Catalogue, Clupeid of the world, an annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings, Part I. Chirocentridae, Clupeidae and Pristigasteridae, FAO Fisheries Synopsis (125), Vol.7, Part 1: pp.1-303
- White G.E., Hose G.C., and Brown C., 2015, Influence of rock-pool characteristics on the distribution and abundance of intertidal fishes, Marine Ecology, 36(4): 1332-1344 (España, p.313)
- Yáñez A., and Day J., 2010, La zona costera frente al cambio de un sistema bio-complejo y las implicaciones en manejo costero, Instituto Nacional de Ecología, México
- Yáñez-Arancibia A., 2005, Middle America, coastal ecology and geomorphology, In: M.L. Schwartz, ed., The encyclopedia of coastal sciences, Springer, Dordrecht, Países Bajos, pp.639-645
- Yáñez-Arancibia A., Ramírez-Gordillo J.J., Day J.W., and Yos-kowitz D., 2009b, Environmental sustainability of economic trends in the Gulf of Mexico: What is the limit for Mexican coastal development? In: J. Cato, ed. Ocean and coastal economy of the Gulf of Mexico, Harte Research Institute for Gulf of Mexico Studies, Texas A and M University Press, College Station, TX, pp.82-104
- Zahuranec B.V., 1967, The gerreid fishes of the genus *Eucinostomus* in the Eastern Pacific, Tesis Maestría en Ciencias, Scripps Institution of Oceanography, University of California, La Jolla, San Diego, USA, p.74