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Project Report

Large-scale project ‘Chiton of the Mexican Tropical Pacific’: *Chiton articulatus* (Mollusca: Polyplacophora)

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Abstract

The marine mollusc, commonly called sea cockroach or chiton *Chiton articulatus*, is a mollusc belonging to the group known as Polyplacophora because its shell is composed of eight individual plates. This mollusc inhabits the rocky intertidal shore of the Mexican Tropical Pacific, where it is endemic. It has ecological, but also economic, importance. Ecologically, it is the preferred food of the snail *Plicopurpura pansa*, a protected species, in the cultural heritage of the country. Additionally, it is a basibiont (generates substrate for other individuals) that maintains the biodiversity of the Region. Economically, it has changed from artisanal consumption to become a culinary tourist attraction, offered at restaurants as an exotic and aphrodisiac dish, in tourist places like Huatulco or Acapulco. Despite being an exploited resource for decades, little is known about its life history. The Mexican Authorities have not yet recognised this mollusc as a fishing resource, so that it does not have any law that controls its extraction, sale and consumption, putting at risk the recruitment, survival and permanence of this species. The goal of this project is the preservation and support for the management of the species. The Project "*Quiton del Pacifico Tropical Mexicano*" seeks to provide the biological, ecological, reproductive, genetic, anatomical and morphometric bases of the populations of *Chiton articulatus*. The project was structured in four stages: 1) field sampling and obtaining samples, 2) disclosure and presentation of the project, 3) inclusion of students at the undergraduate

and graduate level, 4) application of results. The inclusion and recognition of *C. articulatus* as a fishing resource will achieve impact at the national and regional level through the implementation of laws that regulate its fishing, as well as its inclusion in management and food security policies. Additionally, this Mexican Chiton Project is currently replicating with chiton species in Galapagos, Ecuador.

Keywords

Polyplacophora, *Chiton articulatus*, Mexico, fisheries, Mollusca

Introduction

Chitons (Polyplacophora) are marine molluscs that mostly inhabit rocky intertidal shores. Chitons have been harvested and used since ancient times as subsistence food by native peoples from coastal areas (Kyle et al. 1997, Salomon et al. 2007, Turner and Turner 2007), as bait for other fisheries (Garcia-Ibañez et al. 2012) or for use in traditional medicine (Herbert et al. 2003), in general, at several islands from the Caribbean, Southeast Asia (Matthews 1992), along the Pacific coasts of North and South America (Ricketts et al. 1985, Osorio-Ruiz 2002, Herrera et al. 2003, Turner and Turner 2007) and South Africa (Kyle et al. 1997, Herbert et al. 2003).

Studies of local artisanal resources are scarce and seldom considered as a potential commercial fishery. Several marine invertebrates present artisanal exploitation, but are now considered possible fishing targets. The number of such species is rapidly expanding globally, partly as a consequence of declining fin-fish fisheries (Anderson et al. 2011, Fröcklin et al. 2014). The lack of attention given to invertebrate harvesting may, theoretically, jeopardise ecologically-viable invertebrate populations and could have severe impacts on peoples' livelihoods (Fröcklin et al. 2014).

Changes in human behaviour and the exploitation of coastal organisms (Salomon et al. 2007, García-Ibáñez et al. 2013, Olea-de-la-Cruz et al. 2013) are turning the harvest of chitons into a real emergent fishery.

Some of the largest species of chiton that inhabit the Pacific coasts of America, shown an unusual behaviour towards the commercial harvest, as they are evolving as small-scale commercial fishery, such as the "Lengua de Perro or Cucaracha de mar" *Chiton articulatus* in Oaxaca, Guerrero and Sinaloa, in Mexico (García-Ibáñez et al. 2013, Olea-de-la-Cruz et al. 2013, Avila-Poveda, pers. obs.), the "canchalagua" *Radsia goodallii* and *Radsia sulcatus* in the Galapagos Islands, Ecuador (Herrera et al. 2003, Avila-Poveda & Abadia-Chanona, pers. obs.) and the "apretadores" *Acanthopleura echinata, Chiton magnificus* and *C. granosus* in Chile (Osorio-Ruiz 2002), although in Chile, landings are not currently reported. Perhaps the situation in Mexico is unique in having a growing commercial harvest that is promoted at present.

Although, in the Mexican waters (Pacific and Atlantic), respectively, there are thirty-eight species (Reyes-Gomez 2003) and twenty-one species of chitons (Reyes-Gómez et al. 2017), reported so far, historically, *Chiton articulatus* (Fig. 1) is the largest species (size), most abundant (amount) and with most frequency (density over time) (Bullock 1988, Ferreira 1983, Holguin-Quiñones and Michel-Morfin 2002), whose characteristics have allowed it to support a commercial harvest, such small-scale fishery that is growing at an accelerated rate towards a commercial harvest (García-Ibáñez et al. 2013, Olea-de-la-Cruz et al. 2013).

Figure 1. doi

Specimens of the mollusc *Chiton articulatus* in its habitat on the intertidal rocky shore.

Chiton articulatus is endemic to the Mexican Tropical Pacific, occurring from Oaxaca (16°N) to Sinaloa (23°N) (Ferreira 1983, Bullock 1988, Poutiers 1995, Reyes-Gomez 2003, confirmed by Avila-Poveda & Abadia-Chanona, pers. obs.). It is a dominant grazer in the rocky intertidal shores (Poutiers 1995) and represents the main basibiont of several epibionts and endobionts (Alvarez-Cerrillo 2017). It may, therefore, generate microhabitats and probably plays a critical ecological role in increasing diversity and epibiotic relationships (Alvarez-Cerrillo 2017).

Chiton articulatus is collected by local people for use as bait in other fisheries, and as a subsistence food item (Holguin-Quiñones 2006, Rios-Jara et al. 2006) or as a delicacy food item (Ferreira 1983). Recently, in some restaurants, it is offered to tourists at Acapulco (Guerrero), Huatulco (Oaxaca), and Mazatlan (Sinaloa) as a typical regional dish (Villegas-Maldonado et al. 2007, Garcia-Ibañez S et al. 2009, Flores-Garza et al. 2012) (Fig. 2). Particularly in Acapulco, the consumption of chiton is nowadays part of its gastronomy (Fig. 3). It has been indicated that the supply of molluscs in general for human consumption (tourism) for example, in Acapulco it comes from other states like, Sinaloa and Oaxaca, where, in the future, may affect the population dynamics (ecological aspect) of *Chiton articulatus*.

Figure 2. doi

Example of sale and consumption of meat (foot, in colloquial Spanish “Lengua”) of *Chiton articulatus*. Sale of chitons in beaches of Acapulco (left upper). Sale of chitons in streets of Pochutla, Oaxaca, close to Huatulco (left lower). Dish (Lengua a la Mexicana) in a restaurant in Huatulco (right upper). Artisanal fishing of chitons for a family weekend reunion at Puerto Angel, Oaxaca close to Huatulco (right lower).

Figure 3. doi

The food menu of some restaurants in Acapulco, Guerrero, including a dish with chiton, common name "Cucaracha/cockroach".

Landing estimates of chiton meat (the foot mass) represent 1 tonne per year (approximately 700,000 chitons) with an estimated value of 35,000 US dollars (Garcia-Ibañez et al. 2012). *Chiton articulatus* consumption has been promoted owing to its mineral contribution to the diet (Melo et al. 2011). Formerly, *Chiton articulatus* represented an economic potential to become a coastal artisanal fishery (Poutiers 1995). However, the

current collection of this species is not regulated (Olea-de-la-Cruz et al. 2013). Futhermore, it is used as crafts in the form of charms and pendants.

Since chiton fishing is gaining economic importance as a fishing resource, it is necessary to recognise and incorporate it into the National Fisheries Chart. The exploitation might have significant consequences on the population dynamics of the target species *C. articulatus*, as well as on the trophic structure on different levels of the rocky intertidal communities of much of the Pacific coast of Mexico. A complete understanding of biological, ecological and reproductive processes (amongst others) of this species would provide an essential component for the implementation of the fishery management decisions (e.g. seasonal restrictions, minimum sizes, volumes, closed areas, etc.), including its aquaculture. At present, there is a void of most information required for *C. articulatus*.

Overall objective

The overall objective of the chiton project is to generate the necessary information of the mollusc Polyplacophora *Chiton articulatus* in different topics (general biology, ecology, reproduction, growth, morphometry, genetics, aquaculture, amongst others), documenting diverse aspects of the life history, for the future formulation of fisheries regulation measures at local, regional and national levels. For this, a monthly research campaign conducted from October 2015 to October 2016 was set out to provide the basis for the official incorporation of *Chiton articulatus* as a fishing resource.

Specific themes and advances

The general (fundamental) objective was split into eight specific themes and an additional one was raised that covers some aspects of the basic life history of *Chiton articulatus*:

Objective 1: Reproductive strategy

Reproduction is an essential aspect of the life history of any organism since it is crucial for the perpetuation of the species. For the fishing and aquaculture sector, it is essential to know in depth the reproductive aspect of species of commercial interest, to establish fishing and closed seasons, in addition to farming strategies. Under this premise, the anatomy of the gonad, the early stage of life (sub-juvenile, juvenile, sub-adult), and different reproductive traits such as reproductive season, reproductive cycle, size of sexual maturity, sex proportion, will be estimated according to ecological and latitudinal context.

At present, we will process the gonads by histological methods

Previous supporting studies:

- **Avila-Poveda OH**, Abadia-Chanona QY, Alvarez-Garcia IL, Arellano-Martinez M (**2021**) Plasticity in reproductive traits of an intertidal rocky shore chiton (Mollusca:

Polyplacophora) under pre-ENSO and ENSO events. Journal of Molluscan Studies. https://doi.org/10.1093/mollus/eyaa033

- Abadia-Chanona QY, **Avila-Poveda OH**, Arellano-Martinez M, Ceballos-Vazquez BP, Benitez-Villalobos F, Parker GA, Rodriguez-Dominguez G, Garcia-Ibañez S (**2018**) Reproductive traits and relative gonad expenditure of the sexes of the free spawning *Chiton articulatus* (Mollusca: Polyplacophora). Invertebrate Reproduction and Development 62(4): 268-289. https://doi.org/10.1080/07924259.2018.1514670

- Abadia-Chanona QY, **Avila-Poveda OH**, Arellano-Martínez M, Ceballos-Vázquez BP (**2016**) Observation and establishment of gonad development stages in polyplacophorans (mollusca): *Chiton (chiton) articulatus* a case study. Acta Zoologica 97(4): 506-521. https://doi.org/10.1111/azo.12165

- Abadia-Chanona QY, **Avila-Poveda OH**, Arellano-Martínez M, Ceballos-Vázquez BP, Flores-Campaña LM, Moreno-Sánchez XG, Ramírez-Pérez JS (**2015**) Talla inicial de madurez sexual (Tim) y/o talla de madurez sexual (Tm50%) − medida de manejo pesquero para el poliplacóforo *Chiton (Chiton) articulatus*: caso de estudio. Foro Iberoamericano de los Recursos Marinos y la Acuicultura 7: 389-398. https://es.slideshare.net/WilliamSenior/vii-foro-iberoamericano-de-los-recursos-marinos-y-la-acuicultura

- **Avila-Poveda OH**, Abadia-Chanona QY (**2013**) Emergence, development, and maturity of the gonad of two species of Chitons 'Sea Cockroach' (Mollusca: Polyplacophora) through the early life stages. PLOS One 8: e69785. https://doi.org/10.1371/journal.pone.0069785

There is a Master thesis ready and some publications in process. The most important conclusion is that the intensity of the reproductive season of *C. articulatus* (percentage of body mass devoted to gonad by gonadosomatic index), changing with latitude, in turn, with temperature:

- Alvarez-Garcia IL (**2020**) Variación en los rasgos reproductivos de *Chiton articulatus* (Mollusca: Polyplacophora) en localidades frontera de su distribución geográfica. [M.Sc. Thesis]. Facultad de Ciencias del Mar, Universidad Autonoma de Sinaloa. Mazatlan. [In Spanish].

Despite previous advances, according to the government, to establish some protection measure, it is necessary to evaluate the life-history traits (reproductive, growth) of the species for its entire distribution area and the differences and similitude along with its distribution range. Only then, can management measures be established and determine if they should be regional or local, which allows the government to make fisheries management decisions, based on the reproductive and growth aspects of the chiton in their geographical distribution.

Therefore, with these advances, we have to study the behaviour along the distribution range to be able to make comparisons across the seven locations.

Objective 2: Type of feeding

One of the greatest unknowns in this group of molluscs is the type of food they eat, which has resulted in the fact that most of the Polyplacophorans are considered generically as herbivores. Recent studies have shown that there are up to six types of diets (omnivorous, carnivorous, xylophagous, detritivorous, herbivores, spongivorous) within this taxon (Sirenko 2000, Sigwart and Schwabe 2017). In species with fishing potential such as *Chiton articulatus*, it is crucial to know food preferences, since this is one of the main aspects that indicate if the aquaculture production of the species is possible. For this purpose, the intestinal content of every chiton from every location and from each month was obtained and will be evaluated by metagenomics. Additionally, various aspects of the radula and its teeth through image processing for which indexes will be proposed (Fig. 4). For this objective specialized equipment and software has been requested.

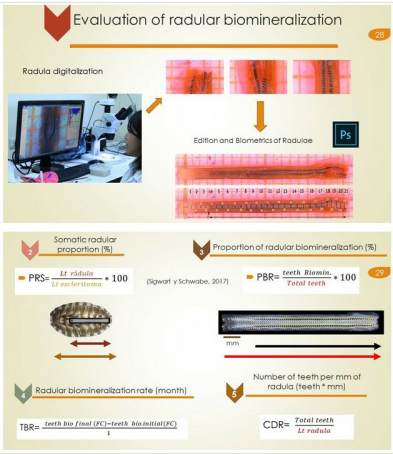

Figure 4. doi

Image processing and indices of the radula of *Chiton articulatus*.

The basis for evaluating the food items and the differences amongst the seven locations comes from a publication and a conference regarding indices, including a feeding condition index:

- Ramirez-Santana BP, Rodriguez-Dominguez G, **Avila-Poveda OH** (**2019**) De herbívoro a detritivoro: evidencia anatómica del tipo de alimentación en *Chiton articulatus* (Mollusca: Polyplacophora). RENAMAC, Reunion Nacional Malacologica, Congress. October 8-11, 2019, Merida, Yucatan, Mexico. https://smmac.org.mx/renamac-2019/
- **Avila-Poveda OH** (**2013**) Annual change in morphometry and in somatic and reproductive indices of *Chiton articulatus* adults (Polyplacophora: Chitonidae) from Oaxaca, Mexican Pacific. American Malacological Bulletin 31(1): 65-74. https://doi.org/10.4003/006.031.0118

There is a Master thesis ready and some publications in process. The most important conclusion is that *C. articulatus* is not a herbivore; the radula anatomy and its relationships with its body indicate that it is a detritivore.

> Ramirez-Santana BP (**2020**). Condición viscerosomatica, biomineralizacion radular y tipo de alimentacion en *Chiton articulatus* (Mollusca: Polyplacophora). [M.Sc. Thesis]. Facultad de Ciencias del Mar, Universidad Autonoma de Sinaloa. Mazatlan. [In Spanish]

Objective 3: Population phenotype (by Geometric morphometry)

The body shape of animals or the set of observable characteristics of an individual sometimes has variations that are difficult to observe with the naked eye. These variations are the result from the interaction of its genotype with the environment, due to the influence of the environment or physiological processes such as growth and reproduction. In order to compare variations in body shape of the chitons among the seven locations of its distribution, detailed photographs of whole specimen and dis-articulated chiton scleritome have been taken of dorsal and ventral views with a guide (10 mm), maintaining the same apertures and focal distances, following the fundamentals of photography for geometric morphometric analysis (Zelditch et al. 2012) (Fig. 5). These pictures will be processed (geometric morphometry) using requested software and a camera to identify the morphological patterns (phenotype) in space and time. Furthermore, biometrics of each chiton was performed to evaluated wide-length body correlations.

Figure 5. doi

Equipment used to take pictures of each chiton and example of some chitons photographed.

Objective 4: Growth pattern

One of the main aspects of the life history of any organism is its growth and longevity. To know these aspects of Chiton articulatus, there are direct and indirect methods that must

validate each other. Here we used Schnute models, where, in the absence of age data; the size structure (length measure) and individual growth of a population are modeled as a function of time. However, this type of analysis requires validation by directs methods as growth by growth lines and in situ growth measurements (marking-recapture). Therefore, sections will be made in the shell plates to observe growth lines; the growth rate will be estimated, and longevity will be calculated. Furthermore, in the field, chitons will be marked and measured periodically to see the difference in growth over time in their natural environment.

There is an advance paper published from a chiton population at the local level:

- **Avila-Poveda OH**, Rodriguez-Dominguez G, Ramirez-Perez JS, Perez-Gonzalez (**2020**) Plasticity in growth parameters of an intertidal rocky shore chiton (Polyplacophora: Chitonida) under pre-ENSO and ENSO events. Journal of Molluscan Studies 86 72–78. https://doi.org/10.1093/mollus/eyz030

This advance by indirect methods gives us an estimated 4-5 years of longevity in a regular climatic environment; therefore, we can compare amongst the seven locations and 13 months to see how the latitude (locality) and the months (time) modulate growth between populations.

Objective 5: Energy exchange between tissues

Using the measurement of the weight of each organ and the comparison between them, we can indirectly understand the exchange of energy between tissues. Therefore, somatic and reproductive indices of adults of *Chiton articulatus* (Mollusca: Polyplacophora) throughout the Mexican Tropical Pacific will be established.

There is an advance paper published from a chiton population at the local level:

- Avila-Poveda OH (**2013**) Annual change in morphometry and in somatic and reproductive indices of *Chiton articulatus* adults (Polyplacophora: Chitonidae) from Oaxaca, Mexican pacific. American Malacological Bulletin31(1): 65-74. https://doi.org/10.4003/006.031.0118

Objective 6: Meat yield

In aquaculture, it is essential to know the yield of meat produced by an organism for its production and marketing. It is also necessary to know which region of the distribution has a higher productivity in terms of meat yield and economic return and in the case of establishing aquaculture sites. Therefore, evaluating the natural meat yield of the chitons will allow us to appreciate which region is more productive and in what period of the year. It will also allow us to evaluate this regarding reproduction. Looking ahead to the fishery, it will also enable contrasting the best fishing season (meat yield) versus the closed season (during reproduction). The Somatic index, particularly foot index or meat yield, will be used.

One advance paper was presented at a congress. It is the basis for evaluating the meat yield, later comparing the seven locations:

- Martínez-Díaz P, Pérez-Gónzalez R, **Avila-Poveda OH** (**2019**) Rendimiento de la carne del quitón *Chiton articulatus* (Mollusca: Polyplacophora) de tres localidades de su distribución geográfica. RENAMAC, Reunion Nacional Malacologica, Congress. October 8-11, 2019, Merida, Yucatan, Mexico. https://smmac.org.mx/renamac-2019/

Objective 7: Phylogeography and genetic structure

This topic is the counterpart of the phenotype. Over time, the characteristics of the species change due to different intrinsic or extrinsic evolutionary forces. *Chiton articulatus* with a small range of distribution, low larval dispersion, and under strong pressure from the local fishery, it is necessary to know through genetics, if it is a single population or sub-populations in order of being able to implement a management plan and a fishing regulation.

There is an undergraduate thesis:

- Aguilar-Rendón TA (**2018**) Filogeografía y estructura genética de *Chiton articulatus* (Mollusca: Polyplacophora) endémico del Pacífico tropical mexicano. [Undergraduate thesis]. Facultad de Ciencias del Mar, Universidad Autonoma de Sinaloa, Mazatlan. 81 p. [In Spanish].

Objective 8: Ecology: host (basibiont) and the coloniser (epibiont)

Chiton articulatus, as a basibiont, represents an important substrate for the diversity of the intertidal rocky shore.

There is a Master thesis ready and a publication in process.

- Alvarez-Cerrillo LR **(2017**) Biodiversidad de invertebrados epibioticos de las poblaciones adultas de *Chiton articulatus* (Mollusca: Polyplacophora) en el Pacifico tropical Mexicano. [M.Sc. Thesis]. Facultad de Ciencias del Mar, Universidad Autonoma de Sinaloa. Mazatlan. p. 73. [In Spanish].

It was also presented at conferences:

- Alvarez-Cerrillo LR, **Avila-Poveda OH**, Benitez-Villalobos F, Ochoa-Izaguirre MJ, Gimenez J (**2017**) Comunidad de macroalgas epibiontes del quiton comestible *Chiton articulatus* (Mollusca, Polyplacophora) del intermareal rocoso del Pacifico Tropical Mexicano. X Congreso Latinoamericano de Malacologia. October 1-6, 2017, Piriapolis, Maldonado, Uruguay. [In Spanish]
- Alvarez-Cerrillo LR, **Avila-Poveda OH**, Benitez-Villalobos F, Escobar-Sanchez O, Rodriguez-Dominguez G, Garcia-Ibañez S (**2016**) Epibiont Biodiversity from the Basibiont *Chiton Articulatus* (Mollusca: Polyplacophora) through the Mexican

Tropical Pacific. 49th Western Society of Malacologists and 82nd American Malacological Society Annual Meetings. June 12-16. Ensenada, Baja California, Mexico [Oral presentations].

Extra objective: Shape and abnormality

During this large-scale project to explore the life-history traits of *Chiton articulatus* adults, several abnormal chitons have emerged at five of seven localities (Michoacan, Colima, Jalisco, Nayarit and Sinaloa) with a total of nine cases with tangible abnormality (i.e. at the level of chiton scleritome) and more than 50 cases with intangible abnormality (i.e. at the level of sclerites), as well as cases with combined teratologies (several anomalies co-occurring).

It allowed us to generate a publication:

- **Avila-Poveda OH**, Ramirez-Santana BP, Martinez-Diaz P, Ramirez-Perez JS, Saavedra-Sotelo NC, Vargas-Trejo B, Amezcua-Gomez CA, Melendez-Galicia C (**2019**) Complex abnormality combinations between the scleritome and the sclerites of *Chiton articulatus* (Mollusca: Polyplacophora): new findings to the teratological classification. Zoologischer Anzeiger 279: 68-81. https://doi.org/10.1016/j.jcz.2019.01.003

Another topic was that, during reproductive activity (gonadal maturity), the gonad increases in volume and exerts internal pressure in three dimensions (length, width and height), which compresses the ventral organs towards the foot and also pushes the collective set of plates (scleritome) dorsally. The pressure changes the scleritome influencing its width and height.

- Alvarez-García IL, Abadia-Chanona QY, Rodríguez-Domínguez G, **Avila-Poveda OH** (**2019**) ¿La madurez gonádica modifica la forma corporal del escleritoma? Chiton articulatus (Mollusca:Polyplacophora) caso de estudio. RENAMAC, Reunion Nacional Malacologica, Congress. October 8-11, 2019, Merida, Yucatan, Mexico. https://smmac.org.mx/renamac-2019/

In addition, *Chiton articulatus*, like any Polyplacophora, has a natural articulated armour (called scleritome) that gives them protection and robustness. As erosion on plates (each sclerite) was observed in *C. articulatus*; then the question arises whether the erosion changes with the change in size.

- Alvarez-Cerrillo LR, **Avila-Poveda OH**, Kawamoto-Camacho NA, Rodríguez-Domínguez G, Pérez-González R, Ramírez-Pérez JS (**2017**) Erosion facing size and latitude in a dominant herbivore polyplacophoran widely distributed in the intertidal rocky shore of the Mexican tropical Pacific. Western Society of Malacologists 50th Annual Meeting, June 19-23, 2017, Los Angeles, California, USA

Operating methodology

For the development of the previous objectives, the global methodology and the logistic and operational technical detail are presented.

Headquarters of this project

The facilities, laboratories and some basic equipment of the Faculty of Marine Sciences (FACIMAR), Autonomous University of Sinaloa (UAS), located in Mazatlan, Sinaloa, Mexico, are the headquarters of this project; therefore, in this faculty, the laboratory processes, storage, biometric measurements and dissection of chitons are carried out.

Training and transfer of chitons

A technical visit was made to each sampling site, the material was delivered and the coordinating researchers were trained on how to collect, fix and conserve organisms, both in the field and in the laboratory. Subsequently, every three months, the samples were sent to FACIMAR-UAS, in Mazatlán.

Collection locations

The chitons were collected simultaneously in the rocky intertidal of seven locations, one per State, throughout the total area of their distribution in the Mexican Pacific (Fig. 6):

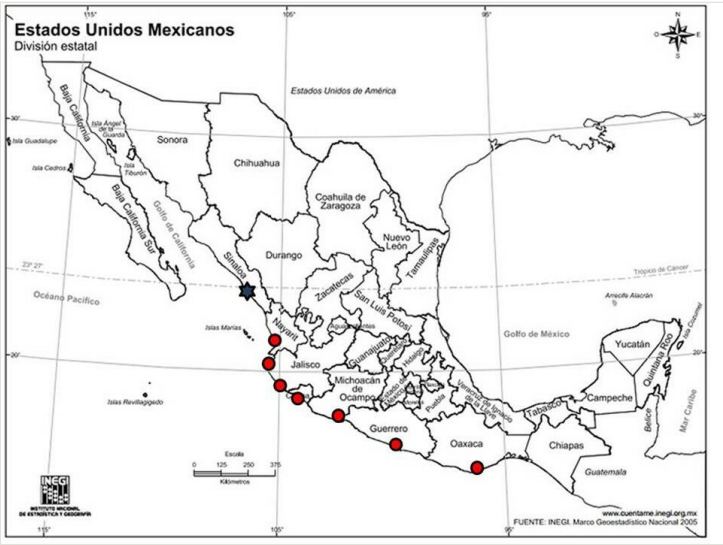

Figure 6. doi

Locations of *Chiton articulatus* collection. The star indicates the local headquarters of this project. The base map was taken from Instituto Nacional de Estadística, Geografía e Informática (INEGI). https://www.inegi.org.mx/

Chiton collection scheduling

The total collection time was one year. A monthly research campaign was conducted from October 2015 to October 2016. FISHING PERMISSION was made available by the government to carry out this research. The collections were monthly and simultaneous in each locality and around the second week of each month (days 7 to 16). To maintain simultaneous sampling, one researcher was supported by the State.

Number of chitons

Between 30 and 40 adult chitons of *Chiton articulatus* were collected (greater than 40 mm in total length, "TL": Avila-Poveda and Abadia-Chanona 2013), for each location (7) and month (13) for an approximate total of 3,000 individuals of *Chiton articulatus*.

Global laboratory methodology with the chitons

Under the premise of the previous general objectives (themes), a global methodology was established for the collection of organisms in each of the seven states of distribution of the species, following the ethics and care of the animals. Furthermore, **the project is using 100% of all the organs of each of the chitons sampled** (foot, gonad, plates, intestine, radula, mantle); therefore, a specific methodology was carried out for each of the aforementioned issues. Materials, reagents and equipment are required to develop each of the topics to research.

With the help of volunteers and students of FACIMAR-UAS (Fig. 7), the samples of fixed and preserved chitons that arrived at FACIMAR-UAS were processed in a general way. This methodology (general and specific) is illustrated below with a summary (Fig. 8): epibiont separation, biometrics taking, digitising chitons, dissecting chitons and separating the gonad and other organs (mantle, foot, digestive gland, plaques). These are the basic processes to meet the goals and objectives set.

Project development

The development of the project complies with the deadlines established in the work programme.

The first phase of the project (obtaining samples) was a success, with about 3000 chitons obtained during 12 months and seven localities to be able to respond to the particular objectives.

The second phase of this project was the dissemination and presentation of the project in different seminars, forums, workshops and congresses; a phase that continues with each topic.

The third phase incorporates students (training human capital) in the themes and in the different degrees (Bachelor, Master, PhD) of the postgraduate programmes that we offer in FACIMAR-UAS. A phase that continues with each theme.

Figure 7. doi

Group of volunteers and collaborators of the QUITÓN PROJECT in FACIMAR-UAS. The project has a logo registration (brand), which is used on the shirts. Shirts used in the field and presentations (congresses, workshops) are shown.

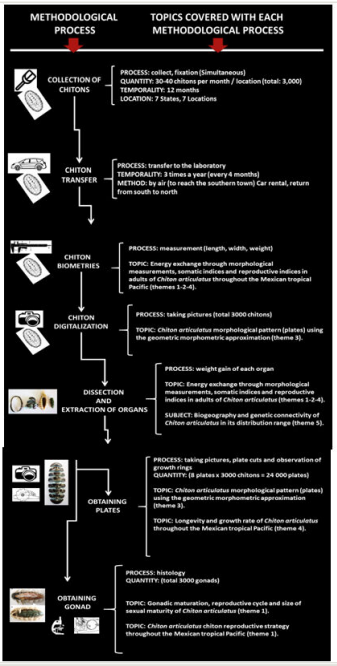

Figure 8. doi

Schematic diagram of the methodological process through which the chitons will pass to fulfil each of the proposed themes.

A fourth phase refers to fisheries management. Based on the information generated from the Chiton Project, a request has been made to CONAPESCA to include the species Chiton articulatus in the National Fisheries Chart (CNP).

Despite fulfilling each phase using equipment borrowed from other institutions, it is essential to continue to have the autonomy to use the equipment, agents and materials for better holistic progress in the project.

Application of results

With some advances of the information generated, a request was made to the CONAPESCA authorities regarding the regulation of the management of fishing resources and requesting the recognition and incorporation of this *Chiton articulatus* mollusc in the National Fisheries Chart. This requirement was made in conjunction with another institution (Fig. 9). It is expected that incorporation into the CNP will allow the formulation of a sustainability strategy, such as mechanisms for the transfer, assimilation or adoption of results by the fishing sector. The bases will also be given to initiating aquaculture proposals.

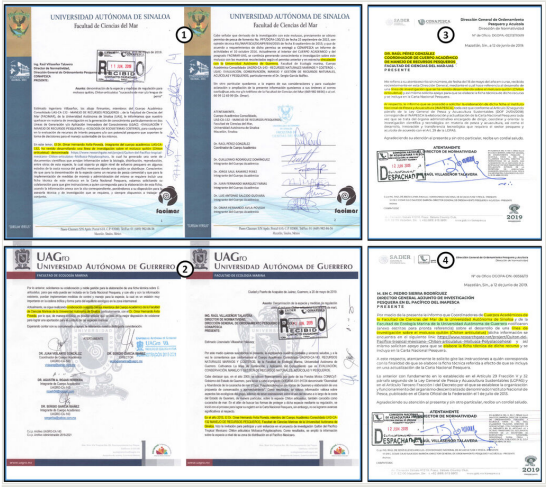

Figure 9. doi

Collage (application letters) of the procedure to request the recognition and incorporation of this *Chiton articulatus* mollusc into the National Fisheries Chart.

Collaborators

Attached is the list of **researchers and students** who coordinated and supported the collection of chitons in each State. The collaboration of these researchers was relevant to achieve the objective of the project and strengthen inter-institutional ties (Fig. 10).

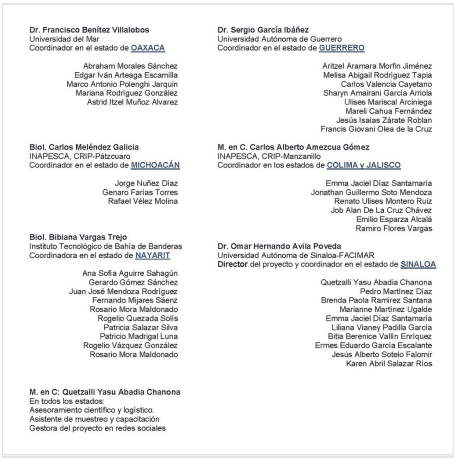

Figure 10. doi

List of collaborators in the project.

Weblinks

1. http://facimar.maz.uasnet.mx/maestros/dr-omar-hernando-avila-poveda/
2. https://www.researchgate.net/project/Quiton-del-Pacifico-tropical-mexicano--Chiton-articulatus--Mollusca-Polyplacophora
3. https://www.researchgate.net/profile/Omar_Hernando_Avila-Poveda_Avila-Poveda_OH
4. https://www.poresto.net/2019/10/10/pesquerias-emergentes-podrian-beneficiar-a-pescadores/
5. https://sonplayas.com/estudian-la-cucaracha-de-mar-en-la-facimar/
6. https://www.researchgate.net/project/Canchalaguas-chitons-de-San-Cristobal-Galapagos-Ecuador

Support for this project

The project had initial financing of $ 6344 USD from the Faculty of Marine Sciences, General Directorate of Postgraduate and Research, Universidad Autonoma Sinaloa, Mexico. This initial financing allowed sampling in the 7 locations per one year, obtaining around 3000 chitons, as well as the transfer of samples to FACIMAR, and the initial reagents for storage. However, exchange reagents for maintenance and lockers for storage of samples are missing.

Other topics of the project has been funded by myself. A large part of reagents and supplies have been contributed from my own resources.

By another hand, the project has been presented 3 times to CONACYT, and it has seemed fascinating but has never received support because after the fascination it seems to them

that it is not an issue that can meet the objectives. However, in 6 years of the project and a single annual sampling in 7 places, I have shown through students and publications that if it can be carried out showing results. **However, more support is needed to continue to efficiently process 100% of each sampled animal.**

With regard to equipment, I have had support from other institutions; however, sample transfers demand a cost and sometimes an equipment rental. Rental supplied by me.

Acknowledgements

Thanks to Quetzalli Yasu Abadia-Chanona for the scientific and logistical advice, sampling and training assistant and for acting as the online community manager of the project on social networks. Thanks to researchers and students (Figure 9) who coordinated and supported the collection of chitons in each State every month and for one year, which was relevant to achieve the overall objective of the project.

Grant title

Mexican Chiton Project

Hosting institution

Facultad de Ciencias del Mar (FACIMAR), Universidad Autonoma de Sinaloa (UAS), Mazatlan, Sinaloa, Mexico.

http://facimar.maz.uasnet.mx/maestros/dr-omar-hernando-avila-poveda/

Ethics and security

Specimen collection was done under a research permit (PPF/DGOPA-130/15) granted to O.H. Avila-Poveda by SAGARPA (currently Secretaria de Agriculturay Desarrollo Rural ‘SADER’) through Comision Nacional de Acuacultura y Pesca ‘CONAPESCA’.

Collection, relaxation and fixation were under specifications of scientific collection activities of wild fauna species (NOM-126-ECOL-2000) and the ethical recommendations for animal welfare, as established under Mexican Law (NOM-033-ZOO-1995) for euthaniing and killing the chitons in a humane way (Lincoln and Sheals 1979, Sneddon 2015).

Author contributions

Omar Hernando Avila-Poveda wrote and developed the entire theme, process and methodology of this project.

The project Chiton of the Mexican Tropical Pacific, arises as an activity and research proposal related with the commissioned of Avila-Poveda OH as **CATEDRA-CONACYT Research Fellow/UAS-FACIMAR (project No. 2137) to the Academic group "Manejo de Recursos Pesqueros UAS-CA-132, UAS-FACIMAR**", focusing on the evaluation of molluscs and particularly on a resource with artisanal riverside fishing, in this case, *Chiton articulatus*.

The start of the project was financed by the General Directorate of Postgraduate Studies and Research (PROFAPI-2014/023), UAS-FACIMAR, and CATEDRA-CONACYT, Mexico; and it was for the technical visit in each sampling location and delivery of sampling material.

Omar Hernando Avila-Poveda has financed the project himself, also with help of donations (reagents and supplies) from colleagues and collaborators at each sampling site. However, the project currently requires financial and logistical support to continue making efficient use of 100% of each sampled animal.

http://facimar.maz.uasnet.mx/maestros/dr-omar-hernando-avila-poveda/

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