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The Young Stages of the Cannonball Jellyfish (*Stomolophus* sp. 2) from the Central Gulf of California (Mexico)

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Abstract: Exploitation of the cannonball jellyfish (*Stomolophus* sp. 2) is increasing in Mexico and USA due to successful fisheries associated with seasonal blooms in coastal areas. Previously, it was proposed that such blooms could be identified by recognizing the presence of young stages in the water. In our work, we aim to describe the young stages (ephyra and metaephyra) found in the Las Guásimas lagoon, Sonora, Mexico. The description of specimens is based on photographs, drawings, and morphological measurements aimed at helping in the early detection of blooming events.

Keywords: ephyrae; development; edible jellyfish; rhizostome

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1. Introduction

In Western countries, jellyfish are usually associated with bad memories, mostly due to the stings these marine animals can inflict on humans [1–4]; however, in Eastern countries, jellyfish are synonymous with a fine dish or delicacy [5–8], and eventually have been associated with many medicinal properties [9]. The use of jellyfish as food has long been recognized in many places. It is only recently that Western countries have recognized its importance as an economic product [10–12]. In many places, jellyfish fisheries have been developed, and then declined [13], due to different factors (e.g., fluctuation of stocks or lower interest of fishery companies), but some countries are fortunate to have certain valuable species in their territorial waters. Among the most valued features are the thickness and weight of the gelatinous part [5,9,11]. The rhizostome genus *Stomolophus* L. Agassiz, 1860 morphologically embraces such features and is widely distributed on both sides of the American continents [14,15].

Historically, five species of *Stomolophus* have been described (*S. agaricus, S. chunii, S. collaris, S. fritillaria, and S. meleagris)* [15–18]. However, most records have mention only *S. meleagris*, with some of those possibly based on misidentifications [16,19,20]. Scyphozoan systematics currently considers only two of the species to be valid (*S. meleagris* and *S. fritillarius*), both from the Atlantic Ocean [15,21]. A recent study [22] revealed cryptic diversity within this jellyfish genus, hypothesizing five undescribed species from the Pacific Ocean. As mentioned by Gómez-Daglio and Dawson [22] and Getino-Mamet et al. [23], the existence of different species within the genus *Stomolophus* is an ongoing investigation that is not yet entirely conclusive, nor has it reached a broad scientific consensus. Although Gómez-Daglio and Dawson [22] proposed the existence of different species, the holotypes mentioned in their research have not yet been described; in addition, the distribution frequency of significant genetic distances that the authors reported only detected two discontinuities [24].

Jellyfish of the genus *Stomolophus* are commercially exploited by many different countries in the Americas [11]. In Mexico, especially in the Sonora region, there are favorable conditions for conducting jellyfish fisheries. Species in the area present marked seasonality (winter and spring) and can only be exploited during a few months [10]. Little is known about the polyp, planula, and ephyra stages of the jellyfish *S. meleagris*. Despite their commercial importance, much less is known about their distribution and settlement areas, which is information that is more than desirable for management purposes, as they are a reservoir for subsequent outbreaks, although this is still difficult to prove [25,26].

The identification of the early stage (ephyrae) can provide evidence for forecasting jellyfish blooms [27,28], which is importance for effective management of all aspects of the fishery.

Previous studies have described the ephyra stage of *S. meleagris* of some Atlantic populations [16,29,30], however, for the Pacific region, there is only a Panamanian study [31]. Although the species have been mentioned in several studies in the Gulf of California [24,32–36], little is known about how to recognize and identify the young medusae.

The goals of this work were to identify the young stage (ephyrae) found in Las Guásimas Bay and to describe the different developmental stages of the ephyrae. We highlight that, in the study area, the only adult jellyfish species found is *Stomolophus* sp. 2, which is heavily fished during the season.

2. Materials and Methods

The study was conducted in Las Guásimas lagoon, Sonora, Mexico (Figure 1) (27°49′–55′ N 110°29′–45′ W). The lagoon has an area of 51 km^2, with an opening of 2 km to the Gulf of California. There is seasonal variation in temperatures (winter/summer) from 17 to 34 °C, with a salinity of 36 to 41 ups.

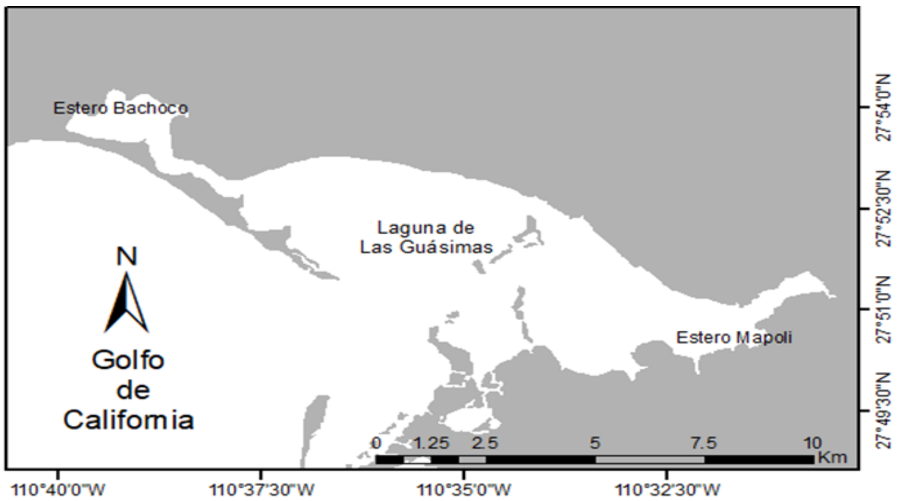

Figure 1. Collecting area, Las Guásimas lagoon, Sonora, Mexico, and central Gulf of California.

We performed superficial zooplankton tows (250 microns) every month from 2014 to 2016, inside and outside the lagoon. The samples were preserved in 4% formaldehyde solution (buffered with sodium borate) the samples were inspected and all ephyrae were sorted. All individuals were measured following Straehler-Pohl and Jarms [27], Straehler-Pohl et al. [37], and Holst [28] (Figure 2). Total body diameter (TBD), central disk diameter (CDD), total marginal lappet length (TMLL), lappet stem length (LStL), rhopalial lappet length (RLL), as well as the body proportions, i.e., CDD/TBD × 100, RLL/TMLL × 100, TMLL/TBD × 100, and LStL/TMLL × 100 were calculated (Figure 2).

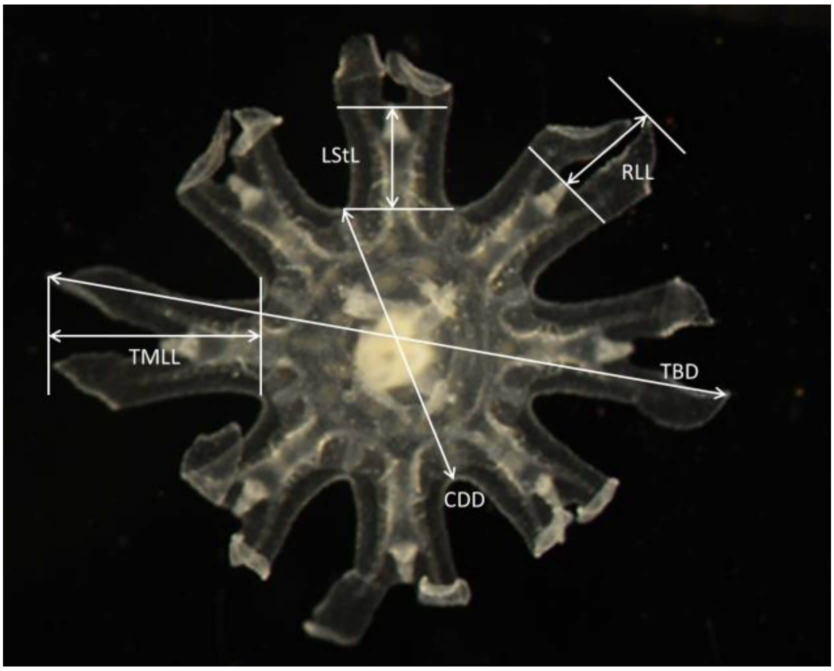

Figure 2. Ephyrae of *Stomolophus* sp. 2, and measurements taken following Straehler-Pohl and Jarms [27] and Straehler-Pohl et al. [37].

We also observed the shape of the "rhopalial lappet", "rhopalial canal", and "velar canal" of every specimen to record the differences in each stage. We additionally observed the gastrovascular system; the development of rhopaliar and velar canals; and changes in mouth, oral arms, and scapulets morphology in order to distinguish the different developmental stages of the ephyrae.

3. Results

Ephyrae were only found during the winter and spring (November to May). We examined a total of 28 samples and discovered 154 specimens of *Stomolophus* sp. 2. They were sorted in three different stages, which are described below.

3.1. Features of the Ephyrae of Stomolophus sp. 2

Ephyrae have eight pairs of rhopalial lappets which are lancet-shaped (sometimes sword-like, broadly oval, or breadknife-shaped). The rhopalia arise from the base of the rhopalial canal and have a small peduncle; there is a statocyst but no ocellus. The canal is divided, and each branch enters each of the lappets. The mouth has four lips, and the central stomach has three to four gastric filaments. In the earliest stage, the size varies from 0.6 to 1.7 mm (TBD), from 0.2 to 0.9 mm (CDD) (39–51% of TBD), and the proportion of the lappets (LStT/RLL-to-TMLL) are 50% each (Table 1).

Although we mentioned that the ephyrae had eight pairs of lappets, we found individuals with six or nine pairs. The shape of the lappets also varied (cf. Straehler-Pohl and Jarms [27]) and we found four types; the lancet-shaped lappets (65.8% for Stage I and 49.4% for Stage II) were predominant. The shape of the velar canal presented five different forms, i.e., "table-like", "triangular", "rhombic", "rounded", and "round spoon" with the most abundant being the "round spoon" in Stage I. All specimens were transparent in color.

Table 1. Proportions of body sizes in ephyrae of *Stomolophus* sp. 2. CDD, central disk diameter; TBD, total body diameter; TMLL, total marginal lappet length; RLL, rhopalial lappet length; LStL, lappet stem length.

Specimen	CDD/TBD × 100	TMLL/TBD × 100	RLL/TMLL × 100	LStL/TMLL × 100
1	41.66	29.58	60.46	50.55
2	48.41	29.30	51.93	52.80
3	37.71	33.72	54.70	49.91
4	54.29	26.87	53.59	57.13
5	53.54	29.67	50.33	46.63
6	44.78	26.45	65.66	68.67
7	45.05	32.57	53.52	57.78
8	48.01	30.56	51.57	48.43
9	39.46	29.84	47.18	42.91
10	48.75	27.87	62.19	48.06
11	41.58	32.42	57.94	47.84
12	49.19	30.98	55.57	46.78
13	42.32	28.39	52.66	45.94
14	44.24	28.61	57.89	42.83
15	38.31	32.18	54.68	43.53
16	45.68	27.98	57.20	49.69

3.2. Different Stages of the Development of Stomolophus sp. 2

In Stage I (Figure 3), the smallest and youngest form are found, due to its lower complexity. The gastric system is very simple and poorly developed, with only three to four gastric filaments that sometimes reach the outside through the small manubrium. The rhopalial lappets are lancet-like, and the rhopalial canals are also shortly bifurcated and lancet shaped. The mouth is small and rounded, there is little distinction of the mouth lips, and there are no traces of scapulets.

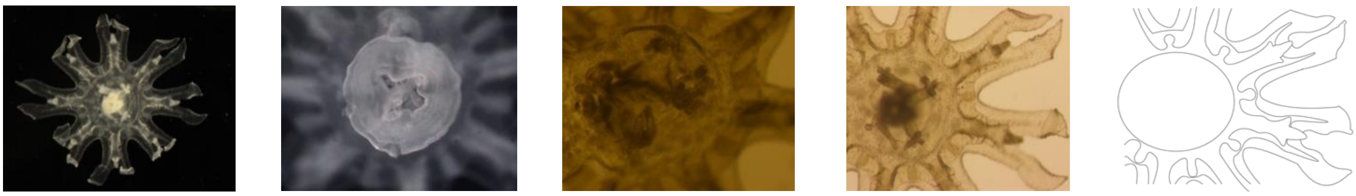

Figure 3. Stage I Ephyrae (*Stomolophus* sp. 2). Without scapulets, mouth poorly developed (only mouth lips distinguishable, without papillae or faintly developed), gastric system poorly developed with only velar and rhopaliar canals, four gastric filaments, lancet-shaped lappets. No velar lappets.

In Stage II (Figure 4), the gastric cavity is a somewhat more developed. The velar canals are anchor-like (growing to the sides and connecting with the rhopaliar ones), increasing the area. Velar lappets start to develop. Scapulets start to develop on the manubrium above the mouth arms, looking like small hollow tube-like protrusions. The mouth develops and the lips tend to form a cross-shaped contour with well-developed papillae on the margin.

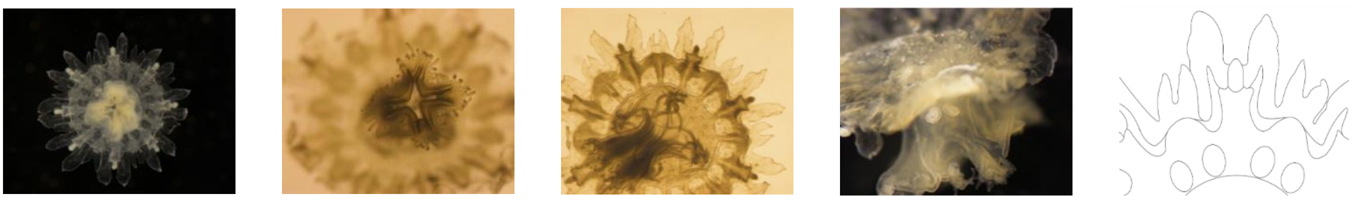

Figure 4. Stage II Ephyrae (*Stomolophus* sp. 2). Scapulets starting to develop. Mouth increasing in size and with papillae at the margin. Gastric system developing with connection of rhopaliar and velar canals forming a ring canal at the rim. Rhopaliar lappets are still lancet shaped, but becoming more rhomboid, velar lappets appearing between rhopaliar ones.

In Stage III (Figure 5), the internal gastric space increases in complexity, and it is easy to see all the connections of velar and rhopaliar canals. Between the rhopaliar and velar canals, it is possible to see additional canals forming, with a centripetal growing pattern. The umbrella also increases in size, and the connection of the central stomach with the radial canals (either velar or rhopaliar) is more evident. The mouth lips enlarge and branch, and the distance between them increases, the papillae (digitata) can be seen on both sides of the lips. The scapulets are more developed, with branches and papillae (digitata) developing.

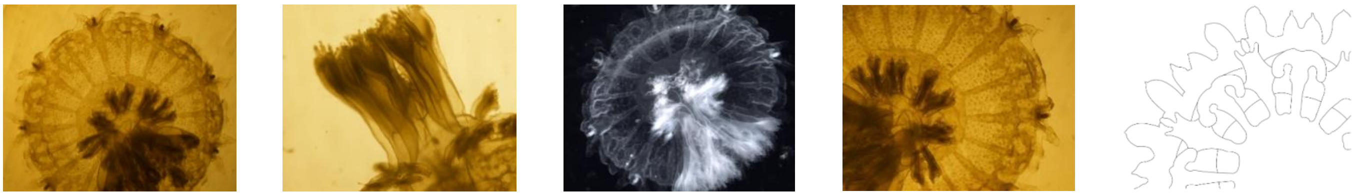

Figure 5. Stage III Ephyrae (*Stomolophus* sp. 2). Increased canal system, stomach connected to the margin via radial canals (rhopaliar and velar ones) that are connected to each other by a ring canal; additional radial canals developing centripetally. All marginal lappets becoming rounder and wider. Mouth lips elongating and already branched, with papillae (digitata) at the inner and outer rim.

4. Discussion

Detecting early jellyfish stages is an important step for recognizing possible jellyfish blooms which can have ecological and commercial impacts, causing some problems or benefits to local populations. In NW Mexico, it is quite relevant to detect young jellyfish stages because when the species *Stomolophus* sp. 2 (cannonball jellyfish) is blooming, it is exploited economically by local fishermen, and any early warnings can provide time enough for the local people to organize themselves and be ready when the bloom season starts. In general, the presence of ephyrae extends over the winter and spring seasons, during which time the presence of adult organisms can be observed.

Although there are some previous descriptions of ephyrae of the species *S. meleagris*, there are no detailed measurements, or body proportions, or even details of the gastric cavity development. Such descriptions are exclusively based on Atlantic [29,30] or Panamanian specimens [31] which seem to be a different species [22,23]. It is important to state that our data refer to the species occurring in the central area of the Gulf of California, comprising the blue variety recognized as *Stomolophus* sp. 2.

It is widely known that wild collected gelatinous animals suffer due to the collecting techniques, and the same applies to young ephyrae [27,28]. However, in this study, although we collected some damaged specimens, we were fortunate to obtain some individuals in relatively good shape that allowed us to provide a detailed description of the species. It was possible to describe several characteristics that are important for their recognition (lappets shape and gastric system), in very good conditions.

Even though we found four different shapes of the rhopaliar lappets, the lancet-like shape was the most common, found in 66% of the specimens inspected. Although some authors [27] have mentioned that environmental conditions (either in the sea or in lab conditions) can alter the morphology, the natural phenotypic plasticity in the species is not completely discounted. In other rhizostome species, the lancet-like shape of the ephyrae lappets was also observed, i.e., *Phyllorhiza punctata*, *Chrysaora fuscescens*, and *C. lactea* [27,37].

For the identification of medusae, body proportions are usually considered instead of absolute size, because such measurements tend to vary in specimens of the same species due to the nutritional condition and age of the polyps [27,38,39]. For instance, total diameters (TBD) vary with temperature [27,40] with differences ranging from 0.4 to 1.5–2.5 mm in *P. punctata* in temperatures of 25–28 °C. Additionally, in another example with the species *C. hysoscella* [27], the total diameter varied from 1.6 to 3.4 mm with temperatures of 5, 10, 15, or 22 °C. In our case, the ephyrae used for the description in this study were collected in temperatures from 18 to 22 °C (although they were found in a larger spectrum of 17.7–28.9 °C) with a TBD from 6.5 to 1.9 mm, opposite to what was expected, as both measurements were found in 21.2 °C. The body proportion CDD (related to TBD) was 39% in 23 °C and 51% in 21 °C; such variations were also reported for other species such as *Mastigias papua* and *P. punctata* when changing from 25 to 28 °C [27]. Similar results were found in *Aurelia*, which in the polyp stage releases ephyrae with larger CDD sizes at high temperatures (28 °C) as compared with at lower temperatures (20 °C) [40]. Thus, these results reinforce that temperature is an important factor in the development of scyphozoan species [40]. The proportions LStL and RLL (related to TMLL) on average both presented 50% as was observed in *Rhizostoma octopus*, *M. papua*, and *Cassiopea* (but we should highlight that our data showed up to 33% variation). Similar ephyrae of the Pelagiidae, Cyaneidae, and Aureliinae presented a ratio of RLL to TMLL of 58–60%, 56–57%, and 42–48%, respectively, [37] as compared with this study of 47–65%.

In this study, we only found transparent organisms, without any type of coloration. Transparent stains with brown color and dark red pigments in the sensory organs have previously been reported for ephyrae of *S. meleagris* [31]. However, these were organisms found in South Carolina in the Atlantic, while our specimens were from the Pacific Ocean.

Concerning the gastric system development, the Stage I ephyrae have a simple cavity without any connections between the radial (rhopaliar and velar) canals. Later on, in Stage II ephyrae, the velar canals develop and start to produce lateral branches that reach the rhopaliar canals, thus, forming a ring canal. The velar lappets start to form and continue to enlarge. In Stage III, ephyrae show a more developed canal system with new radial canals between the rhopaliar and velar canals.

Following the development of the gastric system is quite important because, in adult medusae, the identification is mostly based on this feature. In younger stages, determining gastric development brings greater reliability to ephyra identification [27,41,42].

Although, at first glance, the ephyrae of *Stomolophus* sp. 2 described by us have some similarities to other species such as *A. aurita* and *C. hysocella*; our samples allowed us to perform quite a good identification and also to provide proper descriptions of the different developmental stages. In general, the growth stages are related to the age of the animals awith a sequential series of changes, highlighting a general pattern of development. Further comparative studies would provide more data and contribute to more accurate identification of ephyrae from many different areas.

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Data Availability Statement: The ephyra samples and the data obtained from them are available in the Fisheries laboratory of the Guaymas Unit of the Centro de Investigaciones Biológicas del Noroeste, S.C. in Mexico (https://www.cibnor.gob.mx/unidades-foraneas/guaymas).

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