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ASSESSMENT OF A COMMUNITY MANAGEMENT PROGRAM OF RIVER TURTLES (PODOCNEMIDIDAE: *PODOCNEMIS*) IN ZÁBALO, ECUADORIAN AMAZON

EVALUACIÓN DE UN PROGRAMA DE MANEJO COMUNITARIO DE TORTUGAS DE RÍO (PODOCNEMIDIDAE: *PODOCNEMIS*) EN ZÁBALO, AMAZONÍA ECUATORIANA

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Resumen.— En la comunidad de Zábalo dentro de la Reserva de Producción de Fauna Cuyabeno, existe una iniciativa local de 26 años dirigida al manejo de las tortugas de río luego de una disminución significativa en las poblaciones de *Podocnemis unifilis* y *P. expansa*. A pesar de la larga historia del programa, procesos de seguimiento y validación limitados motivaron una evaluación integral de la eficacia de las prácticas de manejo para contribuir al fortalecimiento del programa comunitario. Esta evaluación considera tendencias temporales de estimadores poblacionales para datos de anidación (densidad, abundancia, éxito de eclosión, producción de crías) entre 1994 y 2019 para *P. unifilis*. Para el caso de *P. expansa* se recopilaron algunos datos disponibles ya que no ha sido el foco principal del programa comunitario. Los resultados resaltan una tendencia temporal positiva en los estimadores de población de *P. unifilis*, de la especie y se destaca un éxito de eclosión elevado consistente en el tiempo (81%), lo que sugiere una importante contribución del programa a la conservación. No obstante, es imperativo realizar más investigaciones para evaluar las tendencias poblacionales específicas por rangos de edad y mejorar las estrategias de seguimiento y manejo de la relativamente rara *P. expansa*.

Palabras clave.— Anidación, conservación, estimadores poblacionales, *Podocnemis unifilis*, *P. expansa*, tortugas de río.

Abstract.— In Zábalo community within the Cuyabeno Fauna Production Reserve, a 26-year local initiative aimed at river turtle management was initiated following a significant decline in *Podocnemis unifilis* and *P. expansa* populations. Despite the program's lengthy history, weak monitoring and validation procedures prompted a comprehensive evaluation of management efficacy to strengthen the communitarian program. This assessment encompasses population estimates derived from nesting data (density, abundance, hatching success, hatchling production) for *P. unifilis* between 1994 and 2019. Some available data were also compiled for *P. expansa* which has not been the main focus of the communitarian program. Results highlight a positive temporal trend in *P. unifilis* population estimators, and a consistent high hatching success (81%), underscoring the program's contribution to the conservation of the species. Nonetheless, further research is imperative to assess age-specific population trends and enhance monitoring and management strategies for the relatively rare *P. expansa*.

Keywords.— Conservation, nesting, population estimators, *Podocnemis unifilis*, *P. expansa*, population trends, river turtles.

INTRODUCTION

Turtles of the genus *Podocnemis* are aquatic reptiles that inhabit the Amazon basin as well as other continental ecoregions. Two of the *Podocnemis* species distributed in Ecuador (*P. expansa* and *P. unifilis*) are locally evaluated as Critically endangered and Vulnerable species respectively (Carrillo et al., 2005) and listed under the Appendix II of CITES convention (UNEP-WCMC, 2014), mainly due to excessive and constant consumption of eggs and meat by local communities along nesting beaches in the region (Acosta, 2001).

The capture and trade of *Podocnemis* turtles are ancient activities, dating back to the 16th century, mostly by conquerors, who hunt turtles for meat and oil (Moll & Moll, 2004). Currently, the exploitation of this resource extends throughout the Amazon region, including Ecuador, Colombia, Bolivia, Brazil, Peru, Venezuela, and Guyana, where dietary, medicinal, and ornamental uses have been attributed to these animals (Figueroa, 2010; Vinueza-Hidalgo & Romo, 2017; Forero-Medina et al., 2019).

Since the late 1980s, people from local communities on the banks of the Aguarico River have manifested their concern over the alarming decrease of *Podocnemis* turtles along the rivers, since it is an important source of protein in their daily diets (Acosta, 2001). Consequently, in 1989 Zábalo community implemented self-imposed ban on hunting and consumption of every *Podocnemis* turtles derived product, including eggs. Later in 1991 interested families began experimenting with the transfer of nests and young to protected sites, resulting in more than 200 turtles head-started and released back to the wild (Carrillo et al., 1996). In 1994–1995, turtle management intensified and some activities, such as nest monitoring and protection of young in captive conditions were carried out, with the result of approximately 990 *P. unifilis* head-started by local families (Carrillo et al., 1996; Townsend et al., 2005). Following these efforts, collaboration from different organizations and incoming funds from other sources have enabled a long-term program.

Currently, the Charapas Community Management Program (CCMP) involves the participation of local families in monitoring activities, which includes identification, transfer, and protection of clutches in artificial incubation beds, as well as a nursery for hatchlings, which are kept in captivity from 6 to 12 months to be subsequently released into the wild. As a reward, Cofanes receive a stipend for each surviving turtle. This is a globally popular management strategy that has being applied to several chelonian species, including marine and freshwater species, among these are several *Podocnemis* spp. (e.g., Alho, 1985; Andrade et al., 2004; Bonach et al., 2003; Fundação Pró-Tamar, 2000; Hernandez et al., 1999; IBAMA, 1989; Soini, 1999; Thompson, 1979; Vásquez, 2017; Yapu-Alcázar et al., 2018).

In addition to the reduction of small and large *Podocnemis* turtles consumption, the program has offset the influence of natural factors that negatively affect the survival and success of nests, such as predation and flooding events (Townsend et al., 2005). Given its effectiveness, CCMP has boosted management actions at other locations in Ecuadorian Amazon, such as Playas de Cuyabeno, Zancudo Cocha, Yasuní, and Tiputini, through the support of different institutions, including Fundación Natura, Fundación para la Sobrevivencia Cofán, World Wildlife Fund, Wildlife Conservation Society, among others.

Despite its long history (around 26 years), monitoring and evaluation of the program have been minimal. Therefore, our objective is to evaluate the effectiveness of the management strategy, along with the history of the community program, by analyzing population estimators for nesting data of both species of *Podocnemis* turtles. This information is key for the management and commercialization plans for *P. unifilis* in the Cuyabeno Reserve; in addition, it will contribute to the conservation of these threatened turtles.

MATERIALS AND METHODS

Study Area

The CCMP is a project lead by Zábalo Cofán Community, settled at the banks of the Aguarico River (0.356791° S, 75.66765° W), within Sucumbios Province, northeastern Ecuador (Fig. 1). It is part of the Cuyabeno Fauna Production Reserve, recognized as one of the largest and most biodiverse ecosystems in Ecuador

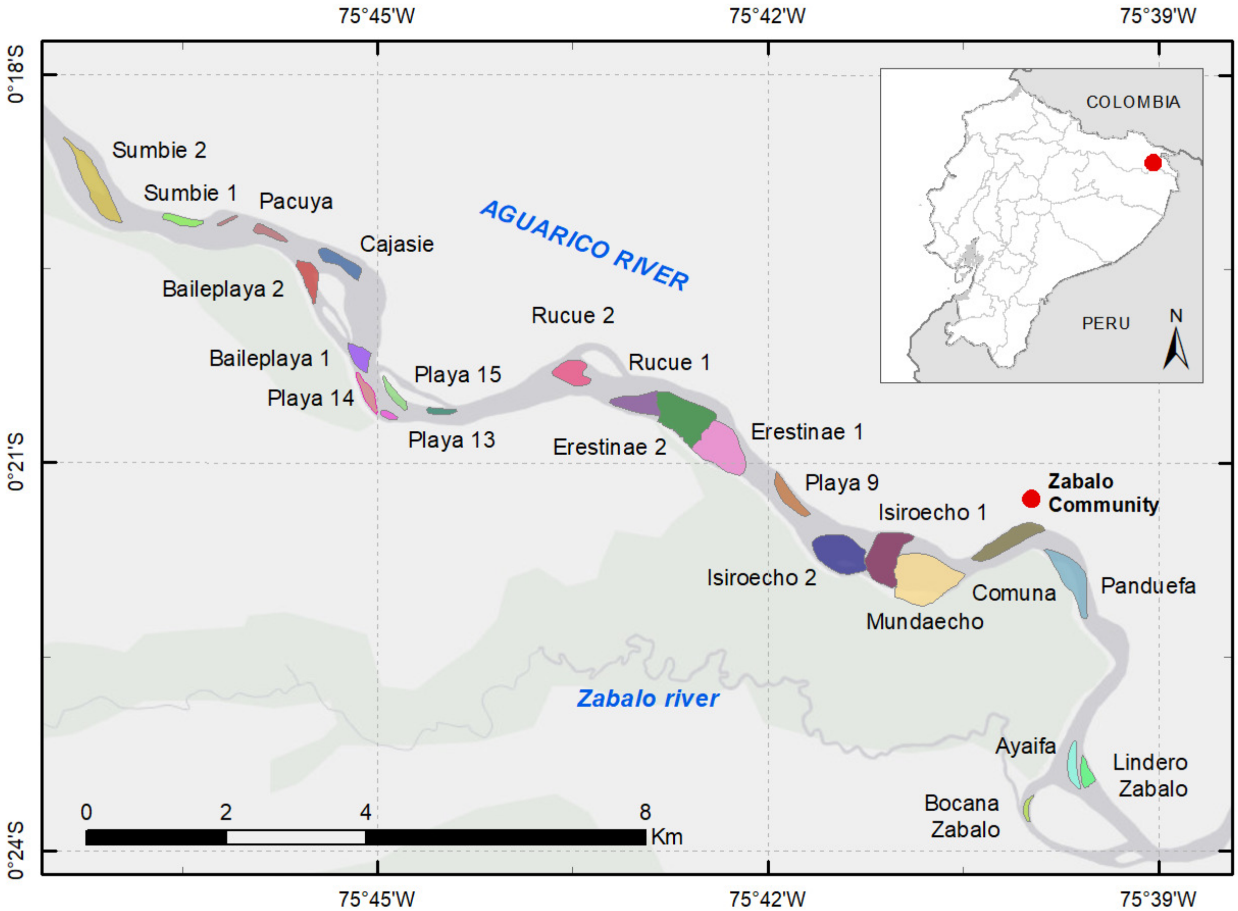

Figura 1. Playas de anidación de *Podocnemis* en la Comunidad Zábalo. / **Figure 1.** *Podocnemis* nesting beaches in Zábalo Community.

and globally (Zapata-Ríos, 2001). It is also part of the Cuyabeno, Lagartococha-Yasuní Ramsar wetland system (Ministerio del Ambiente, 2012; SISR, 2018).

The Aguarico River represents a meandering stream flowing east from the Andes, which connects several black and white wetland systems carrying high concentrations of nutrients and sediments, drawn from the Pimampiro mountain range. Towards the south, the Aguarico follows its course towards Peru, where it joins the Napo River, one of the main tributaries of the Amazon River (MAE, 2012).

Data collection

Nesting information consists of data collected by local Cofanes during daytime patrols on reproductive seasons (September-February) from 1994 to 2019. Available data were standardized and unified in a single database. These data were provided by different project participants, among them, Fundación para la Sobrevivencia Cofán and WWF Ecuador.

Data analysis

The following population estimators were evaluated: a) nest density; b) nest abundance; c) hatchling production, and d) hatching success. For all estimators, descriptive statistics were calculated, which include: range (min-max), mean ($\bar{X}$), and standard deviation (SD).

Nest density

In August 2019, a field survey was conducted by the research team along with local monitors during the mid-water level period. At this time, most part of the riverbanks were exposed over water level, allowing a conservative measurement of beach area considering the high variability of water level at small temporal scales (Dekinger, 2001).

To estimate the size of each nesting beach, a Garmin 64S GPS tracking application was used. Subsequently, GIS software tools (ArcGIS, 2014) were employed to calculate beach areas. This estimation, expressed as the number of nests per square meter (nests/m2), was only applied for the last season, as spatial data from other seasons were unavailable.

Nest abundance

Expressed as the number of nests, represents the total number of clutches, i.e., those destined for conservation, consumption, and those that were lost or damaged due to multiple factors. The association of this variable with beach size was tested with a Spearman correlation test.

Hatchling production. Refers to the number of live hatchlings produced during nesting seasons.

Hatching success. Responds to the following expression:

Hatching %=E/(E +NHE+I+ETNE+P)* 100;

Where: (E) emerged or live hatchlings, (NHE) unhatched eggs, (I) infertile eggs (without apparent development), (ETNE) unhatched term embryos, and (P) depredated eggs (Miller, 2000).

Data distribution for each estimator were tested by Shapiro-Wilk normality test, followed by Mann-Kendall test to analyze temporality of nest abundance and hatchling production. Variation of nest density along the 21 nesting beaches was tested by Kruskal-Wallis test. A one-way ANOVA test was run to compare the effectiveness of three nest management procedures (a) natural incubation, (b) relocation to natural beaches, and (c) incubation on artificial beaches based on hatching success. Normality of this estimator was tested using a Shapiro-Wilk normality test, and a Tukey-Kramer was used as post hoc test. These analyses were run using R software 4.1.0 (RStudio team, 2020) and Past 3.04 (Hammer et al., 2001).

RESULTS

***Podocnemis unifilis* population indices.** During 2018-2019 reproductive season, a mean of 0.26 nests/m2 (0-1.3 nests/m2, $\overline{X}$ = 0.26, SD = 0.38) was estimated for an area of 3,644.46 m2 along 21 beaches (Fig. 1). Baileplaya 1 and Rucue 1 showed the highest density (1.31 and 1.02 nests/m2), followed by Erestinae 2, Isiroecho 1, and Panduefa (0.78, 0.71 and 0.49 nests/m2), while the others presented lower densities between 0 and 0.24 nests/m2 (Table 1). However, significant differences were not observed through Kruskall-Wallis tests (H= 20, p = 0.46, df=20) and Spearman correlation between beach area and nest density was low (r = 0.13).

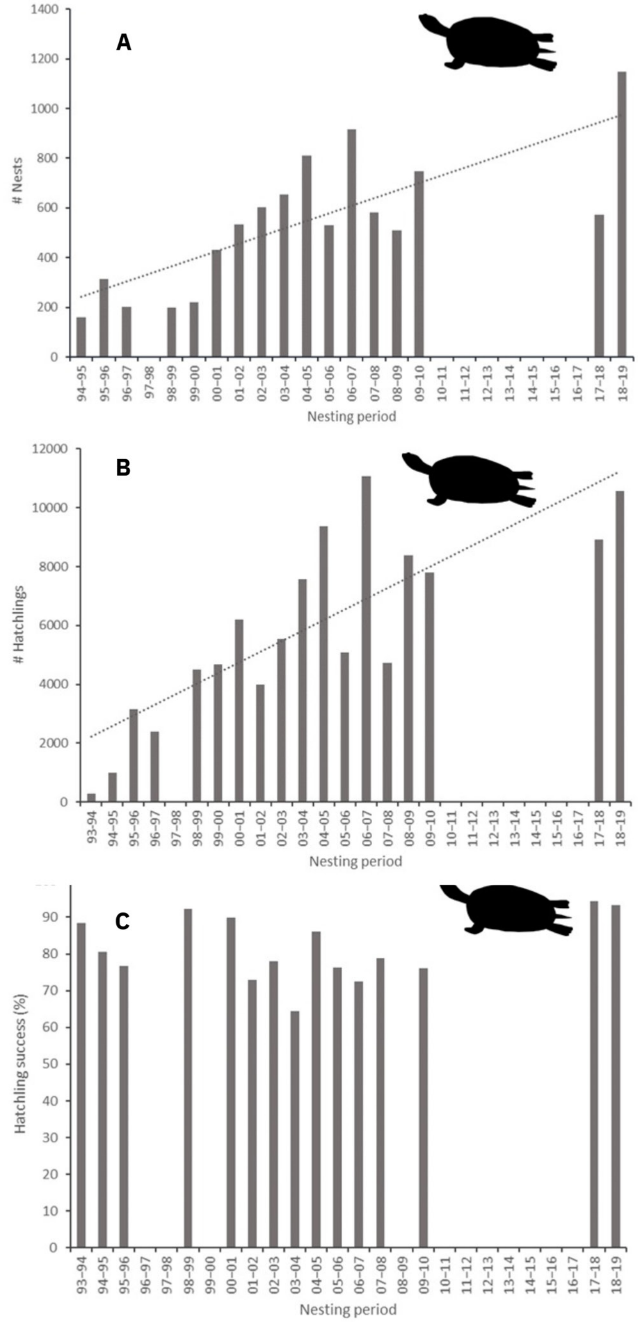

Figura 2. Estimadores de población de *Podocnemis unifilis* en la comunidad Zábalo. (A) Abundancia de nidos. (B) Tasa de producción de crías y (C) Éxito de eclosión.

Figure 2. *Podocnemis unifilis* population estimators at Zábalo community. (A) Nest abundance. (B) Hatchling production rate and (C) Hatching success.

Tabla 1. Área de playas de anidación y densidad de nidos de *P. unifilis* y *P. expansa* en la comunidad de Zábalo.

Table 1. Nesting beach areas and nest density of *P. unifilis* and *P. expansa* in Zábalo community.

Beach	Nesting beach area (m^2)	*P. unifilis* Nest density (nests/m^2)	*P. expansa* Nest density (nests/m^2)
Baileplaya 1	78.00	1.30	
Rucue1	150.00	1.02	0.006
Erestinae 2	380.00	0.78	
Isiroecho 1	310.00	0.71	
Panduefa	230.00	0.49	
Sumbie 1	57.97	0.24	
Lindero Zábalo			
55.26	0.24	0.03	
Baileplaya 2	99.64	0.16	
Sumbie 2	265.69	0.08	
Playa 15	51.67	0.08	
Erestinae 1	355.46	0.07	
Cajasie	107.52	0.07	
Mundaecho	518.96	0.05	
Playa 14	65.01	0.05	
Ayaifa	73.06	0.03	
Comuna	199.74	0.02	
Pacuya	60.00	0.02	
Rucue2	134.88	0.00	
Playa 9	101.82	0.00	
Isiroecho 2	327.64	0.00	
Bocana Zábalo	22.13	0.00	

A total of 9,126 nests was reported in Zábalo community along the Aguarico River in a 17-year time span, yielding an average of 537 nests per year (161-1146 nests, $\bar{X} = 537$, SD = 272.07). Annually, 56% were allocated for conservation purposes (108-583 nets, $\bar{X}$ = 131.82, SD = 298.7), 36% were exploited for local consumption (0-662 nests, $\bar{X}$ = 175.6, SD = 194), and 8% were lost to multiple causes from either natural or anthropogenic origin (e. g. domestic animals, natural predators). The Mann-Kendall test for nest abundance revealed a tau statistic value of 0.6 ($p < 0.05$). This indicates a non-uniform positive trend on a temporal basis. Thus, the period 2000-2001 marks the beginning of an upward trend that leads to the highest value (1146 nests) in 2018-2019 (Fig. 2A).

A total of 105,174 hatchlings has been estimated for the management program since 1993, with an average of 5843 per year (290-11080 hatchlings, $\bar{X}$ = 3136.4, SD = 5843). The Mann-Kendall test displayed a tau statistic value of 0.7 ($p < 0.05$). The estimator exhibited a positive temporal trend with 10573 hatchlings during the last season 2018-2019 (Fig. 2B).

Hatching success was estimated only for nests with complete information yielding an average success of 81.35 % (64.44-94.44 %, $\bar{X}$ = 8.86, SD = 81.35). Hatching success values have remained heterogeneous over time (Fig. 2C) and it is likely that different management practices on clutches had an effect on hatching success ($F = 10.76$, $p > 0.05$) (Fig. 3). We infer that the average percentage of eggs hatching was higher when incubation occurred on natural or artificial beaches, but not in nests relocated to natural beaches (Fig. 2). As the post-hoc Tukey test shows, the percentage of egg hatching does not

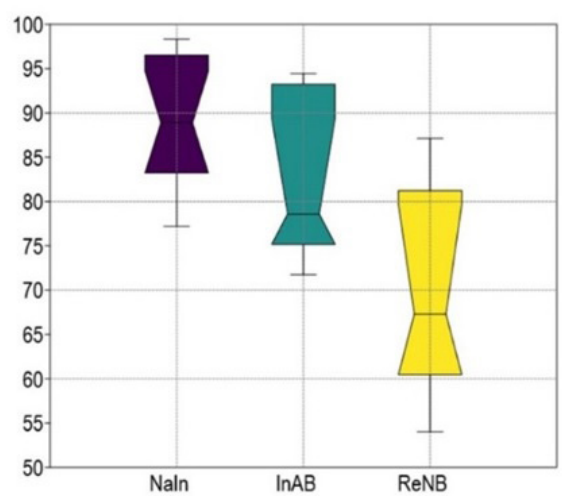

Figura 3. Diagrama de caja del éxito de eclosión de *P. unifilis* para tres prácticas de manejo: (NaIn) Incubación natural. (InABb) Incubación en playa artificial. (ReIn) Reubicación en playas naturales.

Figure 3. Box plot of *P. unifilis* hatching success for three management practices. (NaIn) Natural incubation. (InABb) Incubation on artificial beach. (ReIn) Relocation to natural beaches.

differ statistically between incubation on natural beaches and incubation on artificial beaches. However, the relocation of nests to natural beaches was significantly lower than incubation on natural beaches (Q = 6.559, p > 0.05 and incubation on artificial beaches (Q = 3.791; p > 0.05) (Fig 3).

***Podocnemis expansa* population indices.** We present nesting data for this species as a general approach, considering that it has not been a focal species of the program and possibly nest information was not complete. For the 2018-2019 season, nest density was estimated as 0.0067 nests/m2 in Rucue 1 and 0.036 nests/m2 in Lindero. Abundance did not show a temporal trend (Fig. 4), according to a Mann-Kendall test that indicated a tau statistic value of 0.08 (p = 0.7). This is to say that abundance of nests for this species has remained low (1-11 nests, $\bar{X} = 3.48$, SD = 3.5) throughout the years (Fig. 4).

DISCUSSION

The analysis suggests that Baileplaya 1, Rucue 1, Erestinae 1, and Isiroecho 1 exhibit the greatest use as nesting habitats for *P. unifilis*, even though, a geographical stratification was not evident. Consistent with Escalona and Fa (1998) beach size does not explain this preference, but there could be some physical characteristics not examined in this study, such as slope, substrate, vegetation cover, as well as anthropogenic disturbances, that may play an important role in nesting beach selection (Pignati et al., 2013; Soini, 1995e). It is well known that selection of incubation sites is key to ensure offspring survival, related in most cases to the length of the incubation period. The design of artificial incubation sites is key to hatching success and it is associated with temperature control and decreased egg loss (Escalona et al., 2009; Fachín-Terán & von Mülhen, 2003; Valenzuela, 2001), highlighting the importance of further research to understand these factors in Zábalo community.

Through the management program, population estimators such as density or spatial parameters, such as changes in nesting habitat availability due to the natural dynamics of aquatic systems, have not been evaluated. This fact limits the analysis on temporal tendencies regarding nest density. However, a beach with a size and location similar to Rucue 1 monitored in 1996 by Chávez (1998), a density of 0.00039 nests/m^2 for *P. unifilis* was estimated. Assuming the locations are comparable, the current density in this location (1.02 nests/m2) is considerably higher than 25 years ago. Following the trend of nest abundance (Fig. 2), the 2000-2001 period marks the starting point of the positive trend, following the 1994 start of the management program. Considering the biology of the species, it could be inferred that the recruitment of new generations to the sexually mature population 6 years after hatching (Soini, 1999) had a positive effect on the local population in the Zábalo community.

Turtle egg consumption is still an important source of protein in isolated sites, such as the Cofán Community. However, it is important to highlight the community's effort to conserve *P. unifilis* considering more than a half (56%) of the clutches have been protected under management practices. The percentage

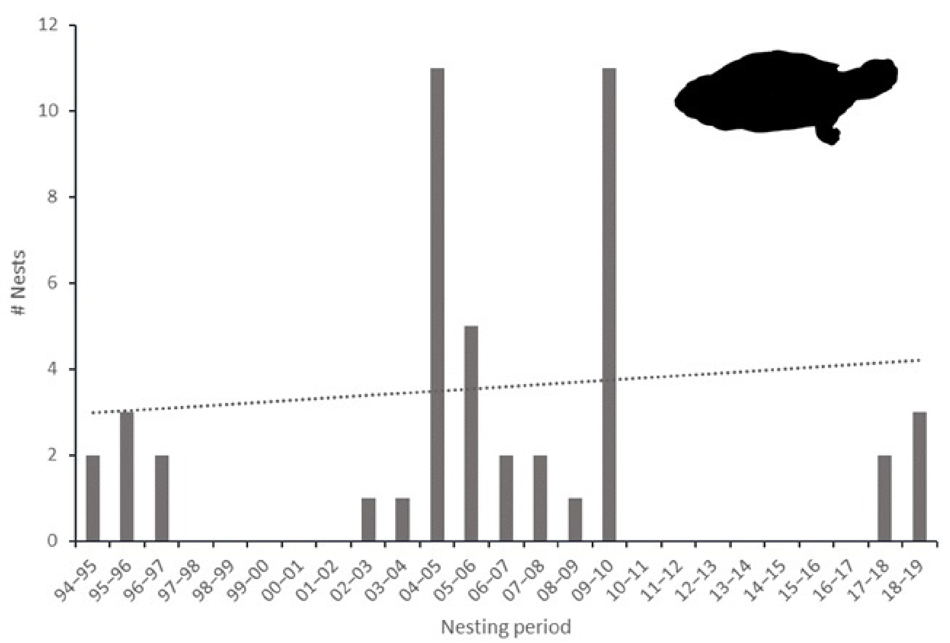

Figure 4. Abundancia anual de nidos de *Podocnemis expansa* en la comunidad Zábalo.

Figure 4. Anual *Podocnemis expansa* nest abundance in Zábalo community.

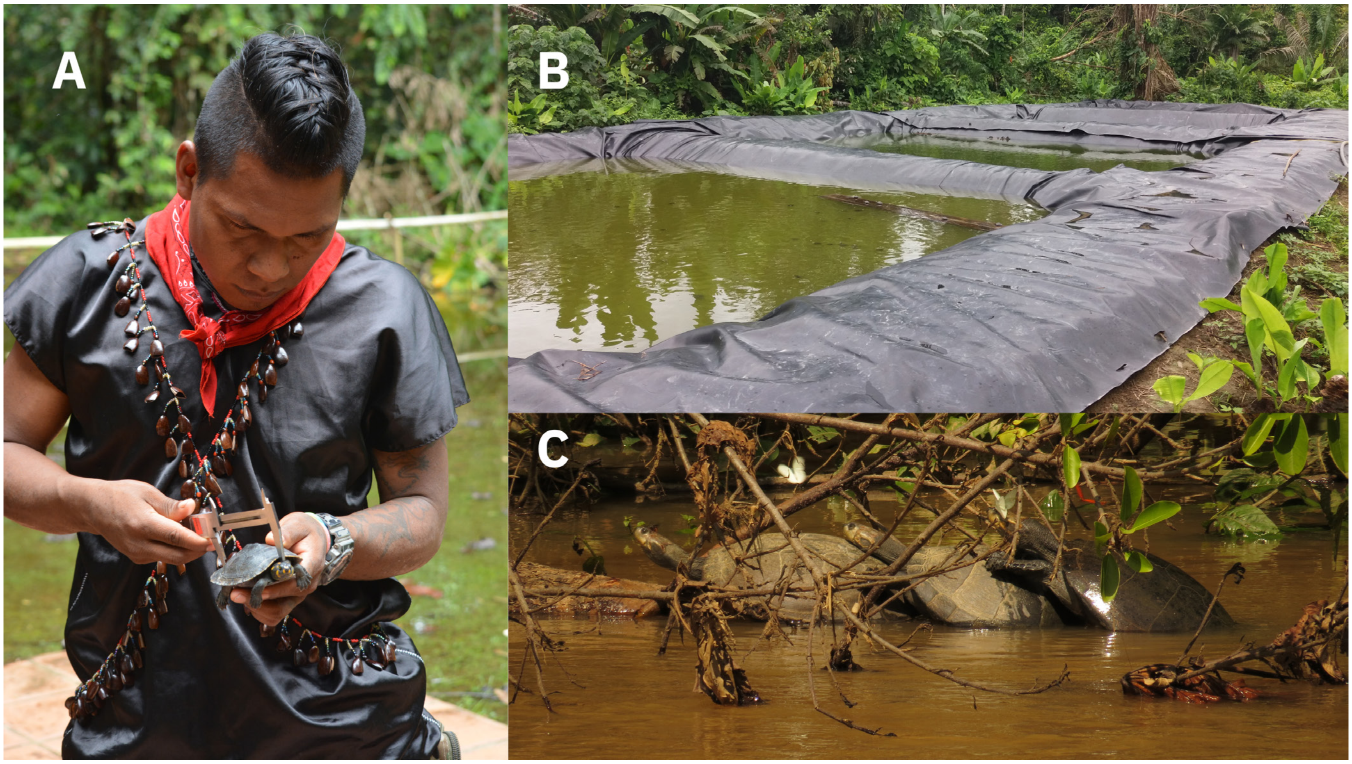

Figura 5. (A) Monitor Cofán evaluando morfometría de *Podocmenis unifilis*. (B) Piscinas artificiales para tortugas *Podocnemis* en Zábalo. (C) Individuos de *P. expansa* en el río Aguarico.
Figure 5. (A) Cofán monitor evaluating morphometrics of *Podocnemis unifilis*. (B) Artificial pools for *Podocnemis* turtles in Zábalo. (C) Individuals of *P. expansa* in the Aguarico River.

corresponds with the available funds that cover the payment costs for each young turtle and the project's operating expenses.

As expected based on the temporal increase in nest abundance, hatchling abundance also displayed a temporal increase given that a larger number of nests is related to a larger number of eggs and, therefore more turtle hatchlings.

The evaluation of hatching success in a management program helps to understand the adequacy of beaches or nurseries as incubation systems, and to make adjustments as needed. It also provides information about reproductive population health (Miller, 2000). Thus, a favorable incubation process can be attributed to the management practices of Cofán people, which manifest a high hatching rate compared to other programs in the region, such as the community program in Yasuni with a hatching success of 57% (Cueva et al., 2011).

Several factors warn against egg manipulation: a) movement, which could damage the embryo's membranous structures, causing mortality; b) confinement of a high concentration of clutches in a reduced area which can be potentially infested by fungi, bacteria, and parasites; and c) alteration of the incubation temperature that may influence embryonic development success (Eckert et al. 2000). Each of these factors can be managed, if technical information is available in each scenario. In the case of Zábalo, results suggest that manipulation of clutches did not affect embryonic development, which also was reported by Ortega et al. (1998), who demonstrated through experimentation that manipulation of *P. unifilis* eggs, regardless of the status of embryonic development, does not affect their viability as long as precautions are taken; i.e., not turning the eggs and keeping the eggs in the same position in which they were found, a practice followed by local monitors. Ortega et al. (1998) also demonstrated that confining numerous nests in a small area does not increase predator infestation. Alteration of incubation temperature during manipulation for relocating is poorly documented and should be taken into consideration to know the viability of future populations based on sex ratio, as we infer that the projected increase in temperature could skew hatchling sex ratios significantly toward females (Ortega et al., 1998).

Small number of nesting female *P. expansa* in the Zábalo community is similar to experiences at other localities within the region, e.g., the Tiputini River (Vinueza-Hidalgo & Romo, 2017) and it is probably associated with a reduced population that has greater spatial requirements for nesting (Ferreira-Júnior & Castro, 2005), although we emphasize the possibility of data loss.

Just like Zábalo, several management programs in the Amazon region have achieved success in the recovery of *P. unifilis*. For example, the case of Pacaya-Samiria Peruvian National Reserve where first experiments started in 1978 that later evolved into a participatory management program in 1994. This project resulted in the rapid growth of the local population, managing to obtain the management patent under a non-detrimental extraction. Actually, commercialization of eggs and adults in Pacaya began in 2008, with an initial quota that has been gradually increased under technical criteria (MINAM, 2014, 2017).

Management practices for the conservation of *P. expansa* in Brazil, Peru, and Colombia have experienced some successful results when vigorous protection and management strategies were applied (Forero-Medina et al., 2019); therefore, we suggest a vigorous management of the species by Zábalo community (FAO, 1997; Soini, 1996).

To conclude, temporal evaluation of CCMP in Zábalo reflects an increase in *P. unifilis* population estimators, pointing to a successful management strategy based on an effective head-starting technique under community leadership; however, it is crucial to maintain regional ecosystem integrity to preserve every life stage of river turtles along their distribution to ensure long-term viability of wildlife biodiversity. It is also important to expand efforts to *P. expansa*, as well as branching out with a successful design and monitoring effort to other localities in the Ecuadorian Amazon basin.

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