New record of Vallisneria americana Michx. in the transitional zone in the Usumacinta river system

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Short Report

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Abstract

Vallisneria americana is a submersed rooted macrophyte with ample geographic distribution in North America, which as a structured habitat, shelters high biodiversity of aquatic fauna and helps to sink Carbon. However, their populations have drastically decreased or disappeared in the free-flowing Usumacinta river system. Physico-chemical parameters in water, measurements of quantitative habitat complexity, and records of the fish collected were quantified in the unique path of V. americana. This patch of 4 m 2 registered a low average density (96 ∓ 48 stems/m 2), 61.7 ∓ 0.9 g ash free dry weight /m 2 of biomass, and 192 ∓ 42.3 masculine inflorescences/m 2. Six fish species of the Poecillid and Cichlid families were caught, with an average density of 19 ∓ 1.9 fish/m 2 , all of them less than 6.3 cm of standard length. This first record of V. americana in the transitional longitudinal zone (20-60 MASL) of the Usumacinta river system strengthens the relevance of the Wanhá Biosphere Reserve, as it was mainly decreed for their records of relictual inland of red mangrove populations, and high diversity of tropical swamp woody communities. Moreover, the American eelgrass patch represents a nursery area for at least six native fish of Poeciliids and Cichlids, which are the two more diverse fish families in Middle America. Moreover, Cichlid´s fishery is a relevant component to environmental sustainability.

1 Introduction

Aquatic macrophytes are considered key species useful to monitoring and restoring freshwater ecosystems since they are nursery habitats that shelter high biodiversity and provide carbon sink [1–16]. Among the aquatic macrophytes, the American eelgrass, *Vallisneria americana* Michx. is an aquatic submersed rooted macrophyte, frequently distributed in freshwater ecosystems from Canada, North America to Honduras, Central America, and Antilles [17–18]. This macrophyte also survives in brackish environments, but it grows faster in oligohaline and limnetic environments in temperatures greater than 20 ºC [19, 20]. Their patches are relevant primary producers, raise sedimentation and represent structured habitats that increase the abundance and diversity of freshwater invertebrates and vertebrates, as fish and manatees, since they provide food and physical refuge [9–11, 21, 22]. In the Mexican coastal plain of the Southern Gulf of Mexico, *V. americana* is commonly distributed in lentic ecosystems [18, 23, 24]. Particularly in the Usumacinta river system, the American eelgrass patches have been registered in the San Pedro river, Guatemala at 100 MASL [25, 26] and Pantanos de Centla Biosphere Reserve (PCBR) México at less of 10 MASL [18, 22, 27]. The San Pedro river Guatemala is located in the headwater longitudinal hydrogeomorphic zone of the Usumacinta fluvial system, while the RBPC is placed on the depositional longitudinal hydrogeomorphic in the same fluvial system, since topographically the Usumacinta basin can be divided in three longitudinal zones: headwater (> 60 MASL), transitional (20–60 MASL) and depositional or alluvial plain (< 20m MASL) according to Zavala-Cruz et al. [28].

The relevance of the first record of *V. americana* in the Wanhá Biosphere Reserve (WBR) is that it represents a freshwater nursery area in the transitional zone of the Usumacinta river system. In this sense, the finding would strengthen the relevance of the WBR, which was supported by reports of relictual populations of red mangrove in the interior and a high diversity of woody communities of tropical swamps [29–31]. Moreover this finding could raise the question of whether populations of *V. americana* could register a continuous distribution pattern along the longitudinal dimension of the Usumacinta fluvial system, which open the opportunity to evaluate the possible impact of the drastically reduction or disappearance of American eelgrass populations [16, 22, 32, 33] on the high biodiversity associated with this macrophyte [21, 22, 34] as well as its essential service as nursery habitat according Lefcheck et al. [12].

2 Methods

2.1 Study area

The WBR is located in the transfer longitudinal zone of the Usumacinta river system (20 to 60 MASL) in the San Pedro river drainage area. San Pedro river drains from Guatemala until it flows into the main course of the Usumacinta river in Mexico at 163 km upriver in a straight line to the discharge of the Grijalva-Usumacinta rivers. The Usumacinta river feeds both the Palizada River that runoff into Laguna de Términos, and the San Pedro y San Pablo river that drain into the Gulf of Mexico 24 km to the East of the confluence of the Usumacinta and Grijalva rivers. Moreover, the Usumacinta river is a mainstream of a complex hydraulic net inside PCBR, which comprises 302,000 ha flooded by the Bitzal, Grijalva, and Usumacinta rivers before the last two main rivers merge 24.3 km before both discharge into the South of the Gulf of Mexico.

WBR occupies 38,255.64 ha along the San Pedro river [35]. It was decreed as Protection Area due to the records of relictual inland of red mangrove populations, high diversity of tropical swamp woody communities [29–31] and probably registers of stromatolites [35]. Moreover, there are published records of submersed rooted macrophytes (*Cabomba palaeformis* Fassett) associated with floating-leaved macrophytes (*Hydrocotyle umbellata* L. and *Nymphaea ampla* DC.), and freely floating macrophytes (*Salvinia auriculata* Aubl.) in the WBR [35]. Upstream, in the Laguna del Tigre in Guatemala was recorded an unique population of *Vallisneria americana* and inland red mangroves [25]. Also, there are *V. americana* records downriver in the PCBR [22].

2.2 Sampling and data analysis

The density and biomass of *V. americana* were measured through three samples taken with a quadrant of 0.0625 cm^2 to conserve the bed. The aboveground material of each quadrant was refrigerated at 4ºC. Later the leaves and inflorescences were counted by shoot. The inflorescences were carefully separated, before measuring the height and width of each blade in centimeters. Each sample of shoots and inflorescences was dried for two days in an oven at 80 ºC. The biomass in ash free dry weight ($_{AFDW/}m^2$) was estimated through a linear regression of dry weight values from the *V. americana* database published by Sánchez *et al*. [22] using R software [36]. There was a statistically significant linear relationship between parameters as ash free dry weight ($_{AFDW}/m^2$) = 0.6925 * dry weight + 0.1379

($t_{0.05(2)120}$=59.79, $p < 2e^{-16}$, $R^2 = 0.097$). The leaf area was estimated through the rectangle formula. The density and biomass of shoots as well as the number of leaves and inflorescences were referenced to one m^2. Also, the number of male inflorescences was counted by sample. The height and width of each blade were measured in cm. Additionally, the water temperature (°C), percentage of dissolved oxygen saturation (DOS), and electric conductivity (EC) in $\mu S\ cm^{-1}$ were measured *in situ* through a YSI-Pro2030 multiparameter. The pH was quantified with a portatil potentiometer Hanna model HI98107; while water transparency (m), depth (m) and turbidity (NTU) were measured with a Secchi disk, ecosound Hondex PS-7, and photometer YSI 9500, respectively, according to APHA [37].

The fauna was sampled through three replies with a drop net of 0.25 m^2. All fauna was identified at a specific level and measured *in situ* to release it alive. The identification of fish species was following the criteria published by Miller et al. [38] and Sánchez et al. [39] and the taxonomic validation of the name of the species according to Fricke et al. [40]. The standard length (SL) of all fish were measured.

Searches through the scientific literature were carried out to corroborate this first report of *V. americana* in the San Pedro River into the WRB. Sources included the revision of the Global Biodiversity Information Facility (GBIF: www.gbif.org) world species distribution database, Missouri Botanical Garden [26], National Herbarium of Mexico (https://www.ib.unam.mx/ib/colecciones-biologicas/herbario-nacional/) and UJAT´s Herbarium. The georeferenced records published were registered in a map (Fig. 1). Additionally, 10 American eelgrass patches found in the depositional longitudinal zone or alluvial plain of the Usumacinta river system [22, 27, 34] or unpublished data) were also pointed out in Fig. 1. Finally, Redalyc (www.redalyc.org), and ScienceDirect (www.sciencedirect.com) were consulted using the keywords *Vallisneria* or macrophyte or “American eelgrass” or Tapegrass, and wetland or lake or pond or channel, and Usumacinta or Pedro river and Middle America or Mesoamerican.

3 Results

The *Vallisneria americana* patch was located in the river margin beside the San Pedro town (17º46´21.71´´ N; -84º09´03.67´´ W) inside the WBR in the Usumacinta river system (Fig. 1). This patch is between two zones with *V. americana* patches registered in the headwaters in Laguna del Tigre Guatemala at 153 km upriver, and in the PCBR México at 136 km downriver in the floodplain (Fig. 1). The American eelgrass patch is a backwater of 4 m^2 protected both by an upriver embankment and downriver limestone levee formation. In this oligohaline site (1,774 $\mu S\ cm^{-1}$ of EC) with oxic (DOS = 84%) and neutral conditions (pH = 7.1), the water registered 32°C and a low turbidity (10 NTU). The values of water transparency and depth (0.9 m) were equal, which indicates a good light disponibility for the VAS photosynthesis. A specimen of *V. americana* is deposited with the voucher number UJAT 37199 in its Herbarium.

V. americana recorded a density of 96 ∓ 48 stems/m^2, 76.4 ∓ 1.96 g/m^2 of biomass in dry weight and 61.7 ∓ 0.9 g_{AFDW}/m^2. The average of height and width of leaves were 22.9 ∓ 2.2 and 0.71 ∓ 0.1 cm, with a range from 1.36 to 53 cm of height and from 0.3 to 1.1 cm of width. The average of the leaf area was

17.5 ∓ 2.5 cm^2 with a range from 1.4 to 53 cm^2. *V. americana* registered 192 ∓ 42.3 masculine inflorescences/m^2, while the female inflorescences were absent.

Fish assemblage was preliminary represented by six species belonging to the Poeciliid and Cichlid families (Table 1), of which the Poeciliid *Gambusia yucatana* and the Cichlid *Trichromis salvini* resulted numerically dominants, while the Poeciliids *Belonesox belizanus* and *Carlhubbsia kidderi* were very scarce. The average density was 19 ∓ 1.9 fish/m^2 with a SL average of 2.54 ∓ 0.29 cm with a range from 1.2 to 6.3 cm of SL.

Table 1
Cichlids and Poeciliids recollected in a Vallisneria americana Michx. patch in the San Pedro river (SL = standard length in cm)

Species	*SL average ∓ standard error*	*SL range*
Thorichthys meeki Brind	3.2 ∓ 1.0	1.6–6.3
Trichromis salvini (Günther)	2.9 ∓ 0.6	1.6–5.0
Vieja melanurus (Günther)	2.6 ∓ 0.1	2.5–2.7
Belonesox belizanus Kner	-	4.8
Carlhubbsia kidderi (Hubbs)	-	1.6
Gambusia yucatana Regan	1.9 ∓ 0.17	1.2–2.1

4 Discussion

Submersed rooted macrophytes are relevant primary producers that shelter high diversity of epibionts, invertebrates and fish since these macrophytes are structured habitats that provide nursery, reproduction and feeding sites [9–12]. However, natural fluctuations of wind velocity, turbidity, electric conductivity, temperature, water transparency, alkalinity and hypereutrophic conditions inhibit both the growth and survival of *V. americana* [21, 33, 41–44]. Also, the interactions among plants-epibionts-fauna [45] and the perturbation produced by human activities helps to explain its ample individual and population variation, drastic decrease and loss [13, 19]. Additionally, the macrophytes distributed in wetlands help to mitigate the negative effects of the climate changes, as the wetlands are considered relevant reservoirs of sunked carbon [14, 15].

The finding of the *Vallisneria americana* patch located in the WBR within the transitional longitudinal zone, and placed between the Laguna del Tigre, Petén Guatemala and PCBR Mexico in the Usumacinta drainage area [18, 22, 25, 26] could indicate that this submersed macrophyte is distributed throughout the Usumacinta river system, from the headwaters to the depositional longitudinal zones. Prior this finding, the lack of intermediate published records of *V. americana* between the Laguna del Tigre and RBPC patches along approximately 289 linear km in the Usumacinta river system may be linked to the scarcity of botanical samplings focused on collecting submersed rooted macrophytes at lentic or sluggish lotic sites (for example Martínez-Camilo et al. [30]). Additionally, the ephemeral characteristic of the *V. americana* patches [46] can contribute to the difficulty of recording them, since the probable continual pattern distribution throughout the Usumacinta fluvial system may be supported by hydrochory, zoochory, and thallachory, which are the mainly natural mechanisms of macrophyte´s dispersal [46–48]. The low human population density in the Petén Guatemala and WBR practically rules out the probability of anthropochory dispersal. There are other geographic records of *V. americana* nearby to the East of the WBR, but they were registered in another basin, that of the Candelaría river [26].

The oligohaline environment measured in the finding site of this study (1,774 µS cm^{-1} ≈1.1 PSU) could be attributable to the frequent presence of limestone levees since this salinity condition is evidently infrequent in the wetlands, without tidal currents influence, located along the fluvial river system (for example Soria-Barreto et al. [49], Cruz-Ramírez et al. [50]). However, the 1,774 µS cm^{-1} (≈ 1.1 PSU) measured in the collected site of American eelgrass is under both the upper limit of the salinity tolerance concentration [19, 21, 41, 51] and the patch registered in a bank with annual EC values from 277 to 8000 µS cm^{-1} located in the same Usumacinta river system.

The relationships between the high diversity of fauna associated and the amount of microhabitats that provide the submersed aquatic macrophytes have helped to explain their value as nursery habitat, which have been measured basically through the density and biomass of stems and leaf area to estimate the quantitative and qualitative habitat complexity [45, 52–54]. The density of *V. americana* in the RBW was lower than in Florida and Louisiana [9, 32, 55], as well as the low density values (300 shoots/m^2) reported for *Vallisneria natans* (Lour.) H. Hara in China [56]. Among these results, Bortone & Turpin [55] registered the highest densities (≈ 1,440 shoots/m^2) in Florida. Also, the American eelgrass biomass (g_{AFDW}/m^2) measured in the WBR is like the lower biomass values in the PCBR (56.6 to 217.7 g_{AFDW}/m^2) published by Sánchez et al. [34].

In the *V. americana* patch of WBR, the fish average density of 19 org/m^2 resulted intermediate regarding the density values of mollusks, crustaceans and fish (from 4.7 to 55.5 org/m^2) recorded in the PCBR [22]. The highest values of density in the PCBR were related to the highest habitat complexity values, and the effect of the high abundance of the no native invasive gastropod *Melanoides tuberculata* (Müller), which represented 61% of the fauna density [22]. In other ecosystems, the abundance of aquatic invertebrates, in this case crustaceans, exceeded the fish one [9]. Concerning to the six fish species identified in only one sampling for this finding, these represented 16% of the total species reported in the *V. americana* patches in the RBPC which were collected at low and high water levels during some years [22, 57]. Among the six species collected in the *V. americana* patch of WBR, the Poeciliid *Belonesox belizanus* Kner point out since it is a predator [58] previously associated with emergent rooted vegetation, none with submersed rooted macrophytes [59]. Moreover, the species richness of fish fluctuated from 6 to 11 and three to 11 for low and high water level respectively, by site in six American eelgrass patches [22], while in this study, there was six fish species recollected in one sampling done in the transition to high water level. In the patches of the PCBR, *Astyanax finitimus* (Bocourt) (Characidae), *Dormitator maculatus*

(Bloch) (Eleotridae), and *Trichromis salvini* (Günther) (Cichlidae) were the three more frequent species, and the Cichlids and Poeciilds were the more diverse families [22]. In this study, the absence of mollusks and crustaceans is tied to the selectivity of the only one sampling device used, since there are with eight crustacean species or 23 species of both invertebrate groups registered in the *V. americana* patches in Barataria Bay system and the PCBR, respectively [9, 22, 57]. Among these, the two species of commercial mollusks (*Pomacea flagellata* [Say] and *Rangia cuneata* [Soweby], three shrimp species of *Macrobrachim* spp. two species of the swimming crab *Callinectes* spp. [22] are part of the local fisheries related to ecosystem services provided by the aquatic macrophytes [60–64]. Moreover, the gastropod *P. falgellata* and the brachyuran *Callinectes sapidus* Rathbun are reported as invasive species in other regions (for example Mancinelli et al. [65], Solovjova et al. [71], Faillettaz et al. [66]).

The reduced area of the unique *V. americana* patch (4 m^2) of this finding does not underestimate its ecological relevance since it can shelter a similar high diversity of fauna associated with other submersed rooted macrophyte patches. Then, independently of its area, this structured habitat functions as an important nursery site for juvenile fishes and invertebrates and it should be included as a priority in conservation programs [12]. As an example, in the depositional longitudinal zone of the same fluvial system, the *V. americana* patches only covered less than 0.1% of the total area of the aquatic substrates in the PCBR [67]. Notwithstanding, there were registered more fish species (24 species) than in the other two structured habitats (woody debris and emergent rooted macrophytes) and another no-structured (non-vegetated soft substrates) [34]. Similar results were published by Rozas & Minello [9] and Lefcheck et al. [12] Concerning to the exclusive caught of Poeciliids and Cichlids in this finding, both families are the most diverse in the depositional, transitional and head-water longitudinal zones of the Usumacinta fluvial system [49, 59, 68–72]. Furthermore, both families are among the most diverse in other fluvial systems in Middle America [73, 74] or only the Cichlids for the freshwater fish in South America (for example, Barros et al. [75], Reis et al. [76], Silva-Oliveira et al. [77]). In the depositional longitudinal zone of the Usumacinta fluvial system, Poeciliids and Cichlids represented 58% of the total fish species recorded in the *V. americana* patches [34, 59]. In the transitional longitudinal zone, 56 fish species have been reported [35, 78–79]. Sequentially, Chávez et al. [78] collected 14 Cichlids and none Poeciliid. Later, Castillo-Domínguez et al. [79] added four species of Poeciliids and nine species of Cichlids. Finally, the Comisión Nacional de Áreas Protegidas [35] summed five species of Poeciliids and five of Cichlids in the WBR Creation Decree. In the draining area of the San Pedro river, Guatemala, were recorded 15 species of Poeciliids and 19 of Cichlids [68–70, 72, 80] of which the six were collected in this finding were previously reported in this area of the headwater longitudinal zone by Valdez-Moreno et al. [69]. The relevance of both families goes beyond their domain as the more diverse families in this region of Middle America [49, 69–71, 81]. Particularly, the drastic loss of structured habitats in the Usumacinta fluvial system [34] threatens most of the Poeciliid species because they are small body fish, which according to Olden et al. [82] and Theis et al. [83] are very vulnerable due to their specific sensitivity to water stress, lack of knowledge of its biology, and distribution associated with structured habitats under high anthropogenic pressure. While, the Cichlids are under pressure from artisanal fishing [70, 62, 84] and also for the drastic loss of nursery habitats by human activities [12, 34, 53]. Finally, native Cichlids are a relevant component to environmental sustainability as food resources [62].

5 Conclusions

The unique patch of *V. americana* recorded in the transitional longitudinal zone highlights the relevance of the second fluvial system with more discharge into the Gulf of Mexico. The minimal area of this structured habitat that shelters six species of the two most diverse families recorded in Middle America does not underestimate its function as nursery habitat. Although, the number of American eelgrass populations is underestimated due to scarcity of samplings focused to evaluate the submersed rooted macrophytes throughout the Usumacinta fluvial system, this finding opens the opportunity to generate a hydrogeomorphological monitoring to support policies in key habitats by their environmental services and benefits, as nursery sites, that are under threat around the world due mainly to habitat loss and overfishing.

Declarations

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Conflicts of interest/Competing interests. The authors declare no competing interests.

Data availability. All data used in this study are available upon reasonable request

Author contributions. AJS designed the sampling, sampled and drafted the manuscript. RF designed the sampling, sampled and approved the final manuscript. HHT verified the taxonomic identity of the submerged rooted macrophyte and approved the final manuscript. NAP sampled and identified the fauna *in situ* and reviewed the main manuscript. MAS sampled, analyzed and interpreted water column parameters as well as support in. the discussion of them. EB reviewed the main manuscript and its final approval.

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Figures

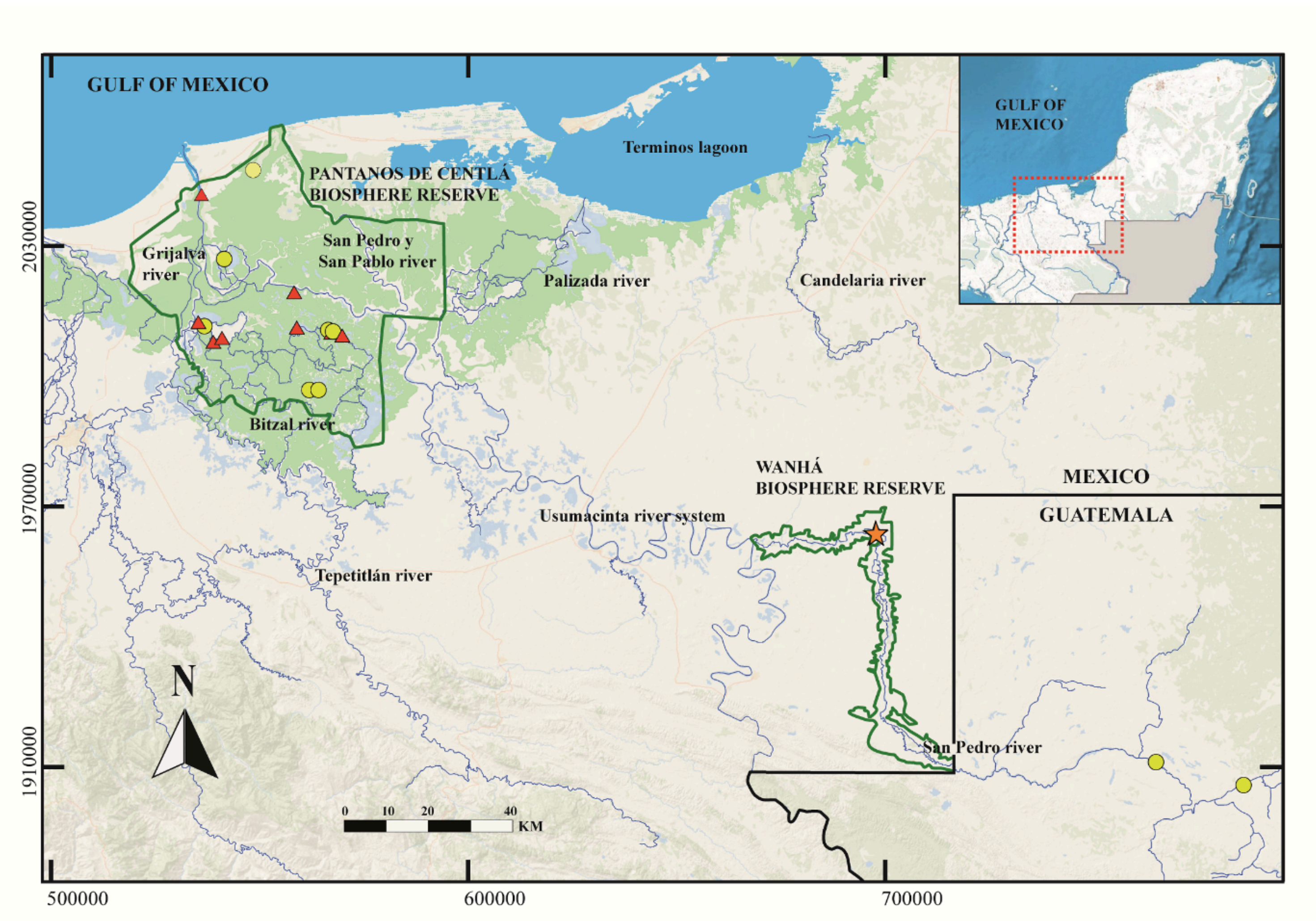

Figure 1

Distribution of *Vallisneria americana* patches in the Usumacinta river system (finding = orange star, published records by other authors = yellow circles, own published and unpublished data = red triangles)