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In search of the Narrow-bridged Mud Turtle, *Kinosternon angustipons* Legler, 1965: a knowledge gap and forgotten species

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Biodiversity loss is an accelerating global crisis, with species extinctions accelerating across nearly all major taxonomic groups (Ceballos et al., 2017; IPBES, 2019). Habitat destruction, climate change, pollution, and overexploitation are the major threats contributing to these declines (Butchart et al., 2010; Betts et al., 2020; Stanford et al., 2020). Sound conservation decisions – including policy design, funding allocation, and the establishment of protected areas – depend on knowing which species are most imperilled and why. While International Union for the Conservation of Nature (IUCN) Red List Categories and Criteria currently provide the most widely adopted framework for assessing extinction risk and guiding such decisions (Rodrigues et al., 2006; Mace et al., 2008), a substantial proportion of species remains classified as Data Deficient (DD), indicating that available information is inadequate to assess their extinction risk based on distribution, population status, or trends (Böhm et al., 2013; Cazalis et al., 2023; IUCN, 2024). A DD classification does not imply low risk but reflects fundamental gaps in the available data about population size, threats, basic ecology, and even range limits. Many species currently listed as DD may in fact be highly threatened but their threat status remains unrecognized (IUCN, 2001; Bland et al., 2015; Caetano et al., 2022).

Causes of data deficiency include sparse or outdated records, restricted ranges, limited research effort, cryptic habitats, unresolved taxonomy, and a lack of information on life history or population trends (Howard and Bickford, 2014; Bland et al., 2017). These data limitations pose a critical problem, as DD-species are frequently excluded from conservation prioritization schemes, potentially leaving highly threatened species unrecognized and unprotected (Bland et al., 2015; Jarić et al., 2016). Because conservation resources are finite, strategically prioritizing research and reassessment for DD species is both efficient and ethically essential (Cazalis et al., 2023). For all the same reasons listed above for DD species, species that are considered "knowledge gap species," even though they have a Red List assessment, can be missed by conservation planners simply due to the lack of information.

Reptiles, particularly turtles, exemplify the challenges of biodiversity assessment and conservation. Turtles are among the most threatened vertebrate groups worldwide, with over 60% of species considered threatened or extinct in the wild (Stanford et al., 2020; TTWG, 2025). Despite this, a notable fraction (< 10%) of turtle species is classified as DD, especially in regions with limited survey effort or where taxonomic uncertainty persists (Buhlmann et al., 2009; Böhm et al., 2013; IUCN, 2024). Many freshwater turtles inhabit remote or politically unstable regions, where sustained fieldwork is difficult to maintain, making it hard to gather the necessary field data. Furthermore, their elusive behaviours and reliance on aquatic habitats hinder detection during standard biodiversity surveys (Gibbons et al., 2000). Consequently, persistent gaps in ecological and distributional data continue to hinder accurate population assessments and the development of effective, species-specific conservation strategies.

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The case of the Narrow-bridged Mud Turtle (*Kinosternon angustipons*). The Narrow-bridged Mud Turtle (*Kinosternon angustipons*), also known as the Central American Mud Turtle, is emblematic of the many tropical freshwater species that have received little field attention since their description (Fig. 1). It is known from the Caribbean versant of southeastern Nicaragua through northern Costa Rica to northeastern Panama (Legler, 1965; Sunyer et al., 2009; TTWG, 2025). The original description by Legler (1965) was based on specimens from Los Diamantes, Limón Province, Costa Rica, and subsequent reviews (Legler, 1966; Iverson, 1980, 1982) have added little new locality or ecological information.

The IUCN Red List currently classifies *K. angustipons* as Vulnerable (B1+2c) under version 2.3 of the criteria, based on a limited range and continuing habitat decline. However, this assessment dates to 1996 and is annotated as "Needs updating" (TFTSG, 1996). In practice, *K. angustipons* is a knowledge gap species, with critical unknowns regarding historic or current distribution, population dynamics, and ecological requirements (TFTSG, 1996). Essentially, there is nothing known about this species outside of the original description and follow-up by Legler (1965, 1966) and some new observations by Acuña Mesén (1998); Savage (2002) just included all known knowledge into his comprehensive Costa Rican encyclopaedia; the range map and locality data presented in TTWG (2025) is also a new contribution on the known distribution of the species. Threats such as wetland drainage, pollution, and agricultural conversion are presumed but unquantified. Similarly, there is minimal information regarding overlap with protected areas or the species' persistence at historical sites.

To address these gaps, the Turtle Survival Alliance, along with our collaborators CR Wild, Turtle Love Costa Rica, and students, conducted targeted field surveys within the centre of the species' known and potential range in Costa Rica (Fig. 2).

Materials and Methods

Study Sites. Fieldwork was conducted in northern central Costa Rica within the lowland Caribbean region surrounding Laguna del Lagarto Ecolodge, Alajuela Province, and at three sites in Heredia Province, the specifics of which we do not report for conservation reasons. The area is characterized by humid tropical forest and a mosaic of natural and modified wetlands. Sampling was performed across two large lagoons as well as various emergent and forested wetland systems.

Figure 1. A Narrow-bridged Mud Turtle (*Kinosternon angustipons*) captured on 9 Oct 2025 in Heredia Province, Costa Rica.

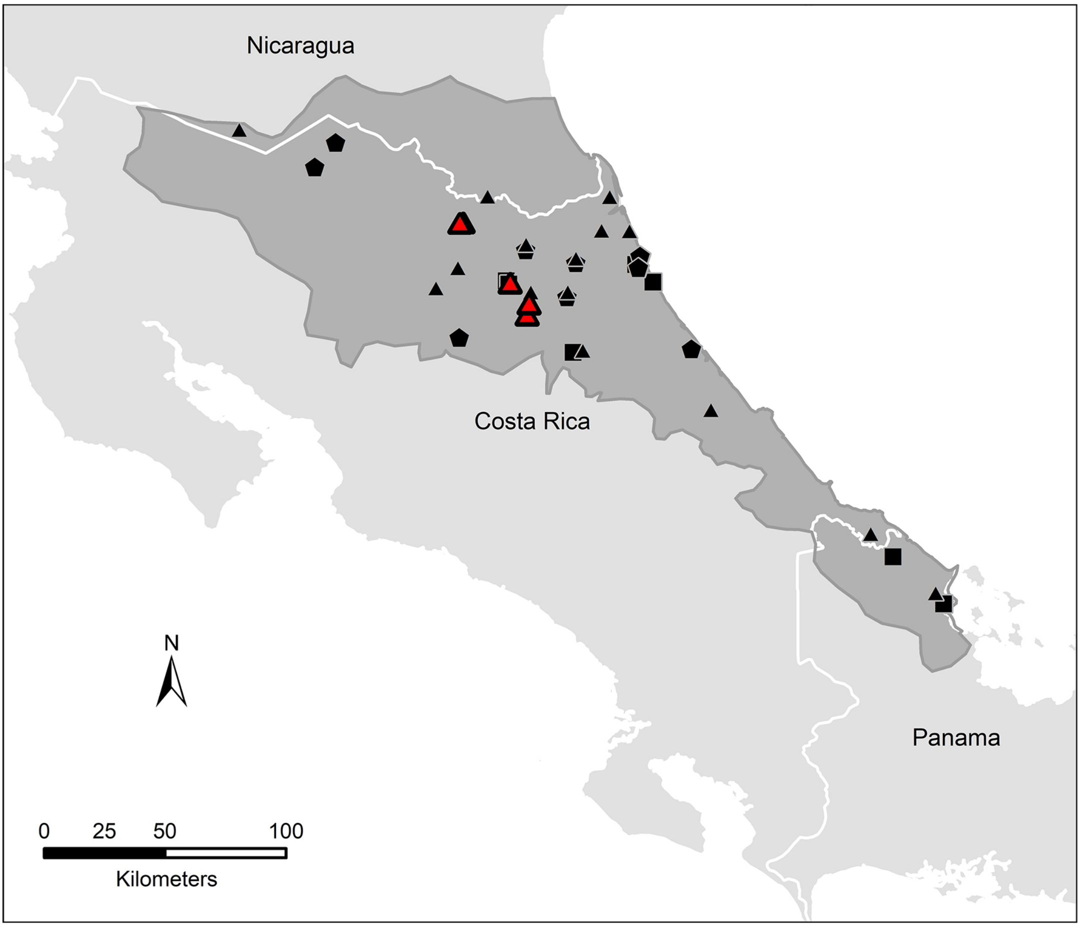

Figure 2. Expected (dark grey area) and known (symbols) range of the Narrow-bridged Mud Turtle (*Kinosternon angustipons*). The map includes observations listed by the Turtle Taxonomy Working Group (black triangles; TTWG, 2025), the Global Biodiversity Information Facility (squares), and on iNaturalist (pentagons), as well as our recent observations (red triangles). Localities are slightly obscured to protect this threatened taxon.

Lagoon Wetlands.—The primary sampling site consisted of the lagoon and its associated wetland complex in the vicinity of Laguna del Lagarto Ecolodge. This system comprises a shallow, tannin-stained lagoon surrounded by dense emergent vegetation and swamp forest. Water levels fluctuate seasonally, with extensive mats of floating and rooted macrophytes providing ample basking and foraging habitat for aquatic turtles. The surrounding matrix includes secondary forest and small clearings maintained for lodge operations. We also trapped at similar lagoon systems within 3 km of Laguna del Lagarto.

Habanero House Stream Wetland.—Located in Heredia Province, this privately owned site includes a narrow stream bordered by mixed wetland habitats. The system transitions along its course from a constructed drainage ditch into a semi-natural emergent marsh, and finally into a forested wetland with slow-moving blackwater. Overhanging vegetation, submerged roots, and coarse woody debris provide structural habitat complexity that supports both aquatic and semi-aquatic species. The emergent portion of this wetland has abundant in-water vegetation.

Cow Pasture Emergent Wetland.—This site lies within an actively grazed pasture in Heredia Province. The wetland is composed primarily of emergent vegetation, interspersed with shallow pools and ephemeral channels. The habitat experiences regular disturbance from cattle activity and seasonal drying but remains productive and attractive to opportunistic turtle species.

Legler (1965) Wetland Community.—To provide historical context, we also trapped turtles in the historical wetland community described by Legler (1965) in his seminal work on Costa Rican turtles. This habitat is an old oxbow that consists of a mixture of ephemeral, emergent, and forest wetlands, connected by shallow drainages with abundant aquatic vegetation, leaf litter, and submerged woody debris. Water clarity was low, with the water being dark and tannic. Currently, this wetland complex is heavily impacted by rotational cattle grazing and infill/dumping from local businesses.

Trapping Methods. Turtle trapping was conducted using a combination of baited hoop and box-type traps designed to capture a broad size range of species and minimize trap bias. Trap types included collapsible crab traps (81.3 cm × 50.8 cm × 30.5 cm; Promar, Gardena, California, USA; promarahi.com), Promar TR-503 collapsible crawfish/bait traps (30.48 cm × 30.48 cm × 60.96 cm), D-frame collapsible turtle traps (60.96 cm × 60.96 cm × 121.92 cm; Wildlife Control Supplies, Suffield, Connecticut, USA; wildlifecontrolsupplies.com), and cathedral umbrella crawfish traps (93 cm; PuDong, Shanghai, China).

Traps were baited with a mix of sardines, fried chicken, freshly caught local fish, and native fruits, depending on availability. This type of bait was selected to attract both carnivorous and omnivorous species common to neotropical wetlands. Bait was secured in "bait chambers," which are mesh bait bags positioned centrally in each trap to prevent removal by non-target species. Traps were typically deployed along the wetland margins and in shallow zones (< 1 m depth) where turtle activity was highest, anchored securely to vegetation, or staked in place. Each trap remained active for approximately 24 h per sampling period, and traps were checked 1–3 times per day and rebaited as necessary. Captured individuals were identified to species, sexed, measured, and released at the point of capture.

For each captured turtle, we recorded detailed morphometric measurements (mid- and maximum carapace and plastron lengths, shell width, shell height, and weight) and collected blood samples for future genetic analyses. Turtles were marked using a variation of the notching technique described by Cagle (1939) and outfit with passive integrated transponder (PIT) tags as a secondary identification method for turtles with a carapace length (CL) > 70 mm. We inserted PIT tags under the turtle's right bridge (Buhlman and Tuberville, 1998; Runyan and Meylan, 2005). Capture and handling protocols conformed to published animal use guidelines (ASIH, 2001). For comparative purposes, we used measurements of Legler's museum specimens that were measured during another project by Taggert Butterfield.

Analysis. We calculated the ratio of midline carapace length to carapace width, midline plastron length, and shell height. We then performed a Principal Components Analysis in R (v4.2.3; R Core Team, 2021) on the normalized ratios to determine dominant axes of variation and to visually assess whether there was structure to the variability in terms of sites or sex.

Results

Our surveys allowed us to document *K. angustipons* in all four sampled habitat types, encompassing a range of hydrological and vegetative conditions that broaden the previously assumed ecological envelope of the species (Fig. 2). Across these sites, we captured a total of 16 individuals (11 male and 5 female), representing multiple size classes and both sexes (Fig. 3; Table 1). Legler (1966) reported on 1494 individuals of *Kinosternon* collected during four expeditions in Central America (Nicaragua, Costa Rica and Panama) in 1960–1965, of which only 14 (less than 1%) were *K. angustipons*.

The Principal Component Analysis revealed that over 80% of the variation in ratios was explained by the first two principal components (PC), with PC1 corresponding to carapace length (longer turtles with higher CL/CW, CL/SH, and CL/PL ratios had positive scores) and PC2 corresponding to shell width and height (narrower, more domed turtles with lower CL/SH and higher CL/CW ratios had positives scores while wider, less domed turtles with higher CL/SH and lower CL/CW ratios had negatives scores; Fig. 4). There was no apparent site or sex structure to the PC1 and PC2 scores, but considerable intra-site and intra-sex variability was observed.

Discussion

Evidence for recruitment limitation and demographic vulnerability. Our dataset nearly doubles the original sample collected by Legler (1965) and significantly expands our understanding of *K. angustipons*. Our survey team captured individuals in four distinct habitat types across the central core of the species' expected range. Notably, one of our confirmed capture sites coincided with one of John Legler's original

1961 study localities, the source of the paratype series for this species. Our successful recapture at this historical site represents the first verified record of *K. angustipons* at the site in over 64 years, confirming the population's persistence despite extensive regional habitat alteration.

Even though our sample size of 16 is relatively small, morphometric analyses indicate substantial inter-individual variation in carapace and plastron proportions, with no statistically robust evidence of spatially or sexually structured morphotypes. Adults captured during our recent survey were, on average, smaller than those reported by Legler (1965), and our largest specimen was recovered at Legler's original locality. In combination, these facts might suggest that habitat-specific differences in growth or survivorship may produce some size disparity at different locations. Such among-site variation in body size and shell form is commonly associated with differences in microhabitat conditions (e.g., flow regime, substrate, thermal environment) and resource availability, which can alter growth trajectories and functional shell morphology (Rivera, 2008). Generally, there appears to be a trade-off with few long, dome-shaped turtles and no short, flat turtles in our sample.

The rediscovery at Legler's original site, together with relatively low total captures and the apparent absence of juveniles, may indicate that *K. angustipons* populations are small, confirming Legler's first statements, and potentially experience limited recruitment. Similar patterns have been observed in other long-lived freshwater turtles when nesting success or juvenile survival is reduced (Congdon et al., 1993; Heppell, 1998). Morphometric distributions from our samples appear to be dominated by adults with relatively few individuals in smaller size classes, which could reflect infrequent recruitment, though alternative explanations – such as differences in capture probability or seasonal activity patterns – cannot be ruled out.

Habitat breadth, ecological plasticity, and vulnerability. Our records across four habitat types reveal greater ecological flexibility for *K. angustipons* than previously known, suggesting that these turtles can persist under varied hydrological and vegetative conditions. However, this apparent plasticity may not equate to security if all available habitats are undergoing degradation. More research is needed, but it is worth mentioning that each habitat may vary in its ability to support reproduction, and distinguishing between source and sink populations will be vital for effective management.

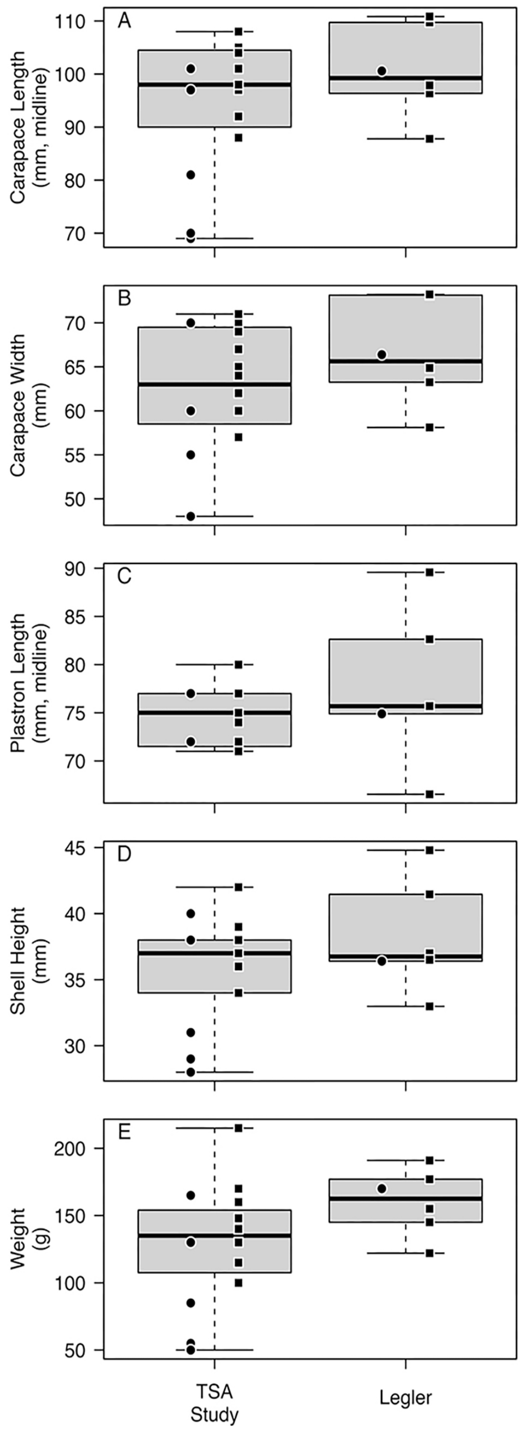

Figure 3. Boxplots of *Kinosternon angustipons* measurements comparing the TSA study and the studies by Legler (1965, 1966) for (A) carapace length, (B) carapace width, (C) plastron length, (D) shell height, and (E) weight. Females are indicated by circles, males by squares.

Table 1. Measurements (in mm) and weight (in g) of *Kinosternon angustipons* captured in October 2025 in Heredia and Alajuela Provinces, Costa Rica, organised by study site and sex (males, M; females, F), including six museum specimens from Legler's (1965) collection. Listed lengths include the midline carapace length (Mid CL) and the midline plastron length (Mid PL).

Origin	***n***	**Sex ratio**	**Mid CL**		**Mid PL**		**Weight**	
		M:F	**M**	**F**	**M**	**F**	**M**	**F**
Laguna de Lagarto	1	1F	0	69	0	50	0	55
Habanero House	3	1:2	108	85 (69–101)	77	70 (63–77)	170	125 (85–165)
Legler's Site	1	1M	111	0	84	0	215	0
Cow Pasture	11	9:2	99 (88–105)	86 (70–97)	75 (72–77)	65 (55–75)	133 (100–160)	90 (50–130)
Combined	16	11:5	100 (88–108)	84 (69–101)	76 (71–80)	67 (55–82)	144 (100–215)	97 (50–165)
Legler	6	5:1	101 (88–111)	101	78 (76–90)	75	158 (122–191)	170

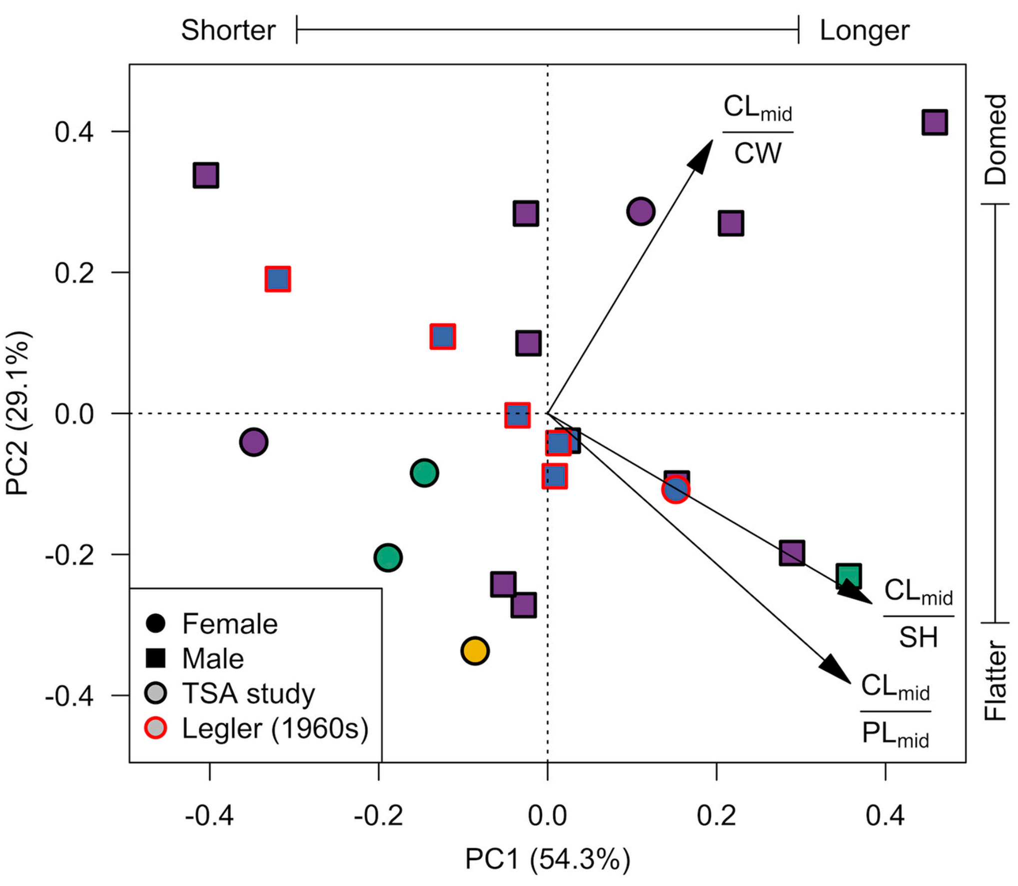

Figure 4. First and second principal components from a Principal Components Analysis of ratios of midline carapace length to carapace with (CL_{mid}/CW), to midline plastron length (CL_{mid}/PL_{mid}), and to shell height (CL_{mid}/SH) for *Kinosternon angustipons* captured in October 2025, with comparison to some of Legler's (1965, 1966) values measured on museum specimens. Location is indicated by symbol colour (cow pasture, purple; Habanero house, green; Legler's site, blue; Laguna de Lagarto, yellow), circles are females, squares are males, and symbols with black outlines are scores from the TSA study while red outlines are values obtained by Legler in the 1960s.

Threats, range contraction, and the data-deficiency paradox. The case of *K. angustipons* exemplifies the problem of underestimating extinction risk among knowledge gap species. Bland and Böhm (2016) and González-del-Pliego et al. (2019) demonstrated that many DD taxa would likely be considered threatened once sufficient data become available. Likewise, Borgelt et al. (2022) found that inclusion of DD reptiles in probabilistic models increases the estimated proportion of threatened species by up to 25%. Similarly, with more than 50% of all turtles threatened with extinction (Rhodin et al., 2018; Turtle Conservation Coalition, 2025), it stands to reason that similar percentages of DD species once studied will also be threatened.

For *K. angustipons*, currently listed as Vulnerable, the principal threats likely include wetland drainage, pollution, and agricultural conversion, especially extensive pineapple cultivation, which is abundant across the regions of Costa Rica where the species occurs. The species' limited distribution along the Caribbean lowlands of Central America coincides with some of the fastest rates of deforestation and hydrological alteration in the Neotropics (Aide et al., 2013; Lopez-Carr et al., 2021). These pressures suggest *K. angustipons* may warrant a higher threat category once additional research is completed and the species is reassessed.

Long-term mark-recapture and occupancy studies at both historical and newly identified sites will be essential for establishing robust population baselines and detecting changes in abundance or distribution over time. These monitoring efforts will provide valuable insights into survival, recruitment, and habitat use, allowing researchers to fill knowledge gaps and to better understand population dynamics and the effects of environmental change or management actions. Complementing these field studies, genetic analyses using blood samples will assess connectivity among populations, providing information on gene flow, genetic diversity, and potential inbreeding risks. Together, these approaches will offer a comprehensive view of population health and resilience, informing conservation strategies and guiding future management decisions regarding this knowledge gap species. Unfortunately, there are few historical data for this species, so conservation actions will need to be based on newly acquired knowledge of the species' biology and habitat usage. Once studies are completed for the species, and there is an understanding of population and habitat use, it will be important to update the IUCN status.

Limitations. During our field efforts, sampling was temporally and spatially constrained, which, coupled with cryptic behaviour and unseasonably low rainfall, may have reduced detection. Nesting and recruitment data are lacking, so future studies should focus on potential different bait types or trapping in associated or alternate habitats to see if ontogenetic shifts in habitat or food preference are present in this species. Nonetheless, the rediscovery of the species at Legler's site after six decades provides strong evidence of its persistence, albeit with only one capture, even though this site has been heavily modified and is visibly under threat of encroachment and infilling of some of the wetland habitats.

The rediscovery of *K. angustipons* at its historical site, along with new data from multiple habitats, provides the first real updates on this species in over half a century. Our findings may underscore recruitment limitations and demographic vulnerability, highlighting the need for targeted surveys, research, and likely conservation action. More broadly, this work demonstrates that knowledge gap species does not mean they are safe and that even neglected, and forgotten species may face silent decline.

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