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Range-Wide Demographic Collapse and Extinction Dynamics of the Endemic Burmese Roofed Turtle, *Batagur trivittata*, in Myanmar

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Range-Wide Demographic Collapse and Extinction Dynamics of the Endemic Burmese Roofed Turtle, *Batagur trivittata*, in Myanmar

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Abstract. – The Burmese Roofed Turtle (*Batagur trivittata*) is endemic to the major rivers of Myanmar. Once widespread and abundant, by the late 1990s *B. trivittata* was considered extinct until "rediscovered" in the Dokhtawady and Chindwin rivers during the early 2000s; the Dokhtawady has since been greatly altered by construction of the Yeywa Hydropower Dam and Reservoir (YHDR). Although a combination of *ex-* and *in-situ* conservation measures has averted biological extinction, *B. trivittata* remains critically endangered in the wild. We conducted a multi-year (2009–2019) investigation into the conservation status of *B. trivittata* with the following objectives: 1) determine the fate of the species in the Dokhtawady River and YHDR; 2) determine its conservation status in rivers not previously surveyed; and 3) query individuals with first-hand knowledge of the species to understand the processes that resulted in its near-extinction. Our investigation included Dokhtawady and YHDR, and the Shweli, Chindwin (including tributaries and headwaters), and Sittaung rivers. Our investigation relied heavily on the traditional ecological knowledge of villagers living along these rivers. We visited 243 villages, towns, and encampments, interviewed ca. 1433 persons, identified six vernacular names applied to *B. trivittata*, and accompanied villagers to 26 sandbanks used by nesting turtles (5 active and 21 former nesting sites). We determined that *B. trivittata* is no longer extant in the Dokhtawady River and YDHR, Sittaung, Shweli, and lower Chindwin rivers, or the Chindwin tributaries of Myitthar River, Nam Thalet Chaung, and creeks of Htamanthi Wildlife Sanctuary. The year of the last known occurrence of *B. trivittata* varied among rivers, ranging from the early 1990s to 2012. Residents along the Sittaung River had no knowledge of *B. trivittata* and the most recent museum specimen was collected in 1961. The Thanlwin is the only major river in Myanmar that remains unsurveyed for *B. trivittata*. A small number of turtles in the upper Chindwin River constitute the only surviving—and reproducing—wild population. Here *B. trivittata* is confined to a 21-km stretch of the river (based on active nest sites), i.e., approximately 1.7% of its historical distribution in the Chindwin. Our results and previous surveys of other rivers suggest an overall reduction of >99% in the historical geographic range of *B. trivittata*. Based on extensive interviews along the Chindwin River, we propose the following extirpation scenario. First, long-term, chronic over-harvesting of eggs created a "decadent" population composed largely of reproductively mature adults. Despite the traditional practice of leaving *in-situ* a small number of eggs from each clutch to complete incubation, low juvenile survival meant that few hatchlings attained adulthood. However, because *B. trivittata* is long-lived, the number of nests produced each year was not perceived to diminish over time and traditional practices therefore appeared effective in ensuring a sustainable crop of eggs. Second, nylon (and later monofilament) fishing nets introduced in the 1960s resulted in an increasing number of adults being drowned as fisheries by-catch. Transient fishers from elsewhere moved onto the Chindwin in the 1980s, failed to respect traditional proscriptions protecting turtles, and greatly increased mortality rates by killing adults and harvesting eggs. With no juveniles to replace adults, *B. trivittata* populations declined rapidly to near-extinction by the 1990s and early 2000s. The extinction scenario in the Dokhtawady River and YDHR is somewhat different. This area was formerly a war zone between an Ethnic Armed Organization (EAO) and the Myanmar Government, where fishers could venture only at great personal risk. As such, the war zone functioned as a *de facto*

protected area, where *B. trivittata* was able to persist until being rediscovered in 2001. Population declines began with the cessation of hostilities, which was followed by a sudden influx of fishers. Completion of the YDHR intensified fishing pressure on the now rapidly declining *B. trivittata* population and inundated the only nesting sandbank. With the extirpation of *B. trivittata* in the Dokhtawady, the few turtles surviving in the upper Chindwin became the sole remaining known wild population of this species.

Introduction

The Burmese Roofed Turtle, *Batagur trivittata* (Duméril and Bibron 1835) (Fig. 1A–C), is a large aquatic turtle endemic to the major river systems of Myanmar (Fig. 2), including the Ayeyarwady (formerly Irrawaddy), Chindwin, Sittaung (formerly Sittang), and Thanlwin (formerly Salween) (Theobald 1868; Maxwell 1911; Smith 1931; Iverson 1992; TTWG 2021). Historic sources suggest *B. trivittata* was widespread and abundant in Myanmar as late as the 1930s to 1940s (Theobald 1868; Maxwell 1911; Smith 1931; Morris 1936; Fergusson 1952), but populations declined precipitously in the years following World War II (1939–1945). This downward population spiral went largely unchronicled because fieldwork by domestic and foreign researchers was actively discouraged by a succession of reclusive military governments that ruled Myanmar from 1962 until 2015 (Steinberg 2001; Thant Myint-U 2008; Rao et al. 2011). Chronic egg collection, loss of sandbank nesting habitat, and subsistence harvesting are generally assumed to be the primary drivers of population declines, although the relative impact of each factor remains poorly understood (Thorbjarnarson et al. 2000b; Platt et al. 2005; Kuchling et al. 2006a, 2006b; Platt et al. 2017a). By the late 1990s *B. trivittata* was considered a candidate for Extinct status by the IUCN (Bhupathy et al. 2000).

Fears of extinction proved unfounded, however, when in March 2001 a field survey obtained the complete, intact shell of a freshly killed female *B. trivittata* at a village along the Dokhtawady River (Platt et al. 2005). In January 2002, a living *B. trivittata* purchased at a wildlife market in southern China came into the possession of an American turtle collector (Platt et al. 2005; Kuchling et al. 2006a). Shortly thereafter (2002–2004), further investigations into the occurrence of *B. trivittata* in the Dokhtawady River were conducted and a nesting sandbank identified, and a larger remnant population was "rediscovered" in the upper Chindwin River (Kuchling et al. 2006a, 2006b). Intense *ex*- and *in-situ* recovery efforts were launched shortly thereafter and continue today (Kuchling and Tint Lwin 2004; Çilingir et al. 2017; Platt and Platt 2019a; Platt et al. 2022).

As a first step towards recovery, an assurance colony (defined as demographically and genetically viable captive-breeding groups of imperiled taxa maintained as a hedge against the extinction of wild populations; TCF 2002) of *B. trivittata* was established in 2004 at the Yadanabon Zoological Gardens in Mandalay, with eight turtles (five females and three males) rescued from ponds at a Buddhist temple ($n = 2$) and others ($n = 6$) obtained from fishers or confiscated from wildlife traffickers (Kuchling and Tint Lwin 2004; Kuchling et al. 2006a, 2006b; Kuchling, *in litt.*). Of the eight founders, three turtles each originated from the Chindwin and Dokhtawady rivers, while the provenance of two turtles could not be reliably established (Kuchling and Tint Lwin 2004; Kuchling et al. 2006a, 2006b; Kuchling, *in litt.*). Four additional assurance colonies (Lawkanandar and Htamanthi wildlife sanctuaries, Yangon Zoological Gardens, and Wildlife Reserves Singapore) were established in subsequent years and stocked with captive-bred turtles and others hatched from wild-collected eggs, with F_1 offspring first being produced in 2021 (Platt and Platt 2021a; Platt et al. 2022).

The ultimate objective of the assurance colonies is to produce offspring for head-starting and eventual

Figure 1A,B. Burmese Roofed Turtle (*Batagur trivittata*). After attaining sexual maturity, females (**A**) are almost 50% larger than males (**B**) and lack the conspicuous coloration of males. These turtles were photographed in the assurance colonies at the Yangon Zoological Gardens (A) and Lawkanandar Wildlife Sanctuary (B). Photos by Steven G. Platt (A) and Kalyar Platt (B).

Figure 1C. Burmese Roofed Turtle (*Batagur trivittata*) male in breeding coloration at the Yadanabon Zoological Garden (Mandalay). Photo by Rick Hudson.

translocation into secure wild habitat. To this end, >100 head-started *B. trivittata* have been released into the upper Chindwin River since 2015 (Horne et al. 2022). Other on-going complimentary conservation efforts include the monitoring and protection of known nesting sites along the Chindwin River, collection of eggs from these sandbanks for artificial incubation, and the head-starting of hatchlings for eventual release (Kuchling and Tint Lwin 2004; Çilingir et al. 2017; Platt and Platt 2021a; Horne et al. 2022). With a captive population now (late 2023) exceeding 1000 (total population consists of 1110 individuals, including 320 breeding adults in assurance colonies and 790 hatchlings and juveniles being head-started for release) and >200 hatchlings being produced each year (Platt and Platt 2021a), *B. trivittata* is no longer considered at high risk of biological extinction.

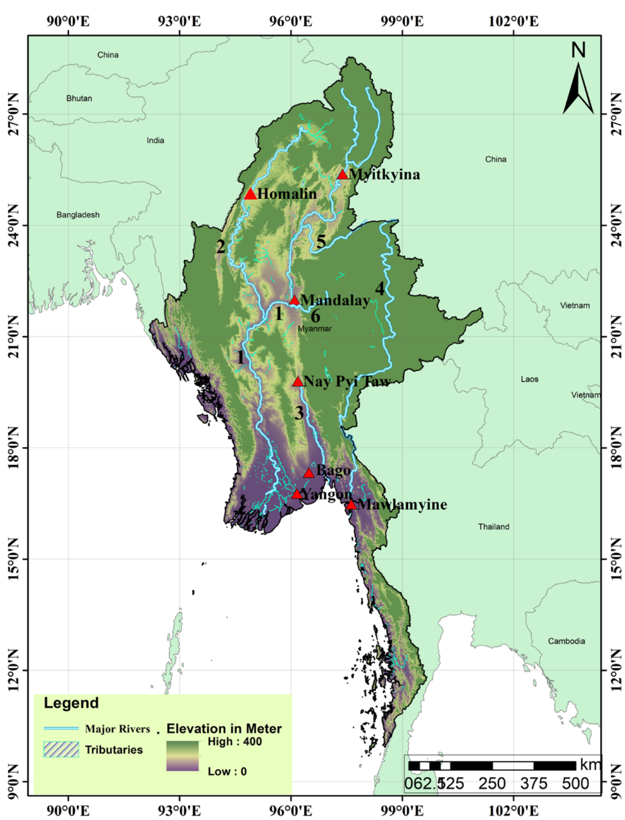

Figure 2. Map of Myanmar showing population centers (red triangles) and major rivers. 1 = Ayeyarwady River [formerly Irrawaddy], 2 = Chindwin River, 3 = Sittaung River [formerly Sittang], 4 = Thanlwin River [formerly Salween], 5 = Shweli River, and 6 = Dokhtawady River.

Despite this apparent numerical buffer against biological extinction, the conservation status of *B. trivittata* in the wild is nonetheless tenuous (Platt, K. et al. 2019). The population in the upper Chindwin River consists of <10 breeding adults and hence, continues to be at grave risk of extinction from stochastic demographic and genetic processes (Platt et al. 2015a; Platt and Platt 2016; Çilingir et al. 2017). For example, in 2014 and again in 2015, females in this population failed to produce viable eggs, most likely because the few remaining males perished after becoming entangled in fishing gear (Platt et al. 2015a; Çilingir et al. 2017). Production of viable eggs in this population only resumed after head-started males were released into the river (Platt and Platt 2016; Çilingir et al. 2017). The continued survival of *B. trivittata* in the Dokhtawady River remains unresolved as there was no follow-up to the initial (2001–2004) population assessments (TCC 2011; Horne et al. 2012), and the only stretch of the river known to be inhabited by *B. trivittata* was submerged beneath the reservoir of the Yeywa Hydropower Dam in 2010. Furthermore, with the exception of the Ayeyarwady (Thorbjarnarson et al. 2000b; Platt et al. 2005; Kuchling et al. 2006a), the possible occurrence of *B. trivittata* in other rivers in Myanmar has not been investigated. In light of these concerns, *B. trivittata* continues to be ranked among the most critically endangered turtles in the world (TCC 2018; Platt, K. et al. 2019; Horne et al. 2022).

We here report the results of a multi-year investigation (2009–2019) into the conservation status and biology of *B. trivittata* in Myanmar. We first determined the fate of *B. trivittata* in the Dokhtawady River and Yeywa Hydropower Reservoir, a task deemed critical in successive conservation action plans (TCC 2011; Horne et al. 2012). Second, we searched for *B. trivittata* in rivers not investigated during previous surveys (Thorbjarnarson et al. 2000a; Platt et al. 2005; Kuchling et al. 2006a, 2006b) to determine if populations of *B. trivittata* amenable to *in-situ* conservation were present, or if *in-situ* conservation was deemed unlikely to succeed, to capture surviving turtles and incorporate these individuals (and their allelic diversity; Çilingir et al. 2017) into existing assurance colonies. Third, we sought out and queried individuals with first-hand knowledge of *B. trivittata* to better understand the processes that ultimately resulted in the near-extinction of this species in Myanmar. Determining the indigenous distribution of a species, identifying the drivers of population declines, and developing a thorough understanding of the extinction process is fundamental to conservation biology (Kéry et al. 2006; Redford et al. 2011; Lanman et al. 2013) and a crucial first-step when attempting to engineer effective strategies for species recovery (IUCN 2013; Seddon et al. 2014; Haddad 2019; Somaweera et al. 2019; Wray 2019).

Overview of the Biology of *Batagur trivittata*

Descriptions of *B. trivittata* are provided by Theobald (1868) and Smith (1931). The maximum reported carapace length (CL) is 620 mm with females being almost 50% larger than males (Platt et al. 2019b). In a sample of 179 subadult and adult *B. trivittata* (95 females, 84 males) the mean ± 1 SD CL of females and males were 417 ± 76 mm (range = 234–620 mm) and 280 ± 21 mm (range = 224–331 mm), respectively (Platt et al. 2019b). Coloration is sexually dichromatic, with differences becoming apparent when CL exceeds 120 mm; males exhibit a brilliant green-yellow head and neck with dark carapacial stripes, contrasting markedly with the drab gray-black body and shell coloration of the female

Figure 3. Sandbanks along the Chindwin River used as nesting sites by *Batagur trivittata*. Na Maine Thaung (**A**) and Sin Naing (**B**) sandbanks along the lower Chindwin River are no longer used for nesting by turtles. Active nesting sites along the upper Chindwin River include Sein Naing (**C**), Mein Naung (**D**), and Pagoda Island (**E**) sandbanks. Most of the surviving females now nest on Pagoda Island (**F**). Photos by Steven G. Platt.

(Fig. 1A–C; Platt et al. 2017c). In captivity females can attain sexual maturity and successfully reproduce when 14 years old with a CL of approximately 400 mm (Platt et al. 2022). However, given that turtles generally grow more rapidly in captivity (Ritz et al. 2010; Jones et al. 2011), females almost certainly require longer (perhaps >20 years) to attain sexual maturity in the wild (Platt et al. 2022). Based on the development of breeding coloration, males are probably capable of reproducing at a younger age than females, although this difference has yet to be empirically confirmed, as when males attain sexual maturity remains unknown.

Because *B. trivittata* was pushed to the brink of extinction before field studies could be undertaken, very little is known concerning its natural history (Platt et al. 2017a). Historic accounts indicate *B. trivittata* inhabited estuaries, coastal mangrove swamps, and larger rivers with extensive sandbanks, but apparently were absent from rocky, swift-flowing tributaries (Theobald 1868; Maxwell 1911; Smith 1931). Although courtship and mating have yet to be described, the extreme sexual size dimorphism in *B. trivittata* suggests mating is based on female choice rather than forced insemination by males (Platt et al. 2019b). Nesting occurs from late December through March when sandbanks are exposed by falling river levels (Maxwell 1911; Smith 1931; Morris 1936; Platt et al., unpubl. data). The steep-sided sandbanks used as nesting sites are composed of coarse-grained sand and usually adjacent to deep pools known as aikes (Fig. 3A–F; Platt et al. 2017a).

Nesting occurs at night and females deposit clutches of 25–50 large eggs (70–75 mm long × 40–42 mm wide) in multiple holes (Fig. 4A,D–E; Maxwell 1911; Smith 1931; Morris 1936; Platt et al., unpubl. data). Conspicuous trackways are left by nesting females on sandbanks (Fig. 4B–C). In the past, villagers followed these trackways and then probed the sand with thin bamboo wands to locate buried eggs (Fig. 4E).

Hatchlings emerge from late April through June at the onset of the wet season, when river levels are beginning to rise. The mean (±1 SD) CL and body mass recorded for a sample of 392 hatchlings were 55.3 ± 4.0 mm (range = 43.0–65.0 mm) and 47.7 ± 4.4 g (range = 36.3–60.0 g), respectively (Platt et al. 2020). Monitors (*Varanus* sp.) are said to excavate nests and consume eggs (Kuchling et al. 2006a), and Platt et al. (2021) documented predation of a hatchling by a Javan rat snake (*Ptyas korros*). Adult females may have been taken by tigers (*Panthera tigris*) while nesting (Platt et al., unpubl. data). In the Ayeyarwady Delta, Maxwell (1911) listed crows (*Corvus* sp.), raptors, sharks, and large fish as predators of hatchlings. Platt et al. (2020) speculated that the prominent spines on the shell of hatchlings and small juveniles function to deter predators such as large fish and wading birds.

Similar to congeners (Moll et al. 2009, 2015), *B. trivittata* feeds primarily on aquatic vegetation and fruit, perhaps supplemented with fish or invertebrates (e.g., Som et al. 2019), although dietary information from wild populations is scant. In the past, *B. trivittata* was captured in traps baited with foliage and fruit of Indian mangrove (*Avicennia officinalis*; Theobald 1868; Maxwell 1911; Thorbjarnarson et al. 2000b) and villagers stated that figs (*Ficus* spp.) growing along riverbanks are an important component of the diet (Platt et al., unpubl. data). Fishers reported finding plants and fruits among the gut contents of turtles being butchered (Kuchling et al. 2006a). The dietary preferences of hatchling and juvenile *B. trivittata* in the wild are unknown.

Our observations (Platt et al., in press) and those of others (Maxwell 1911; Kuchling et al. 2006a) suggest that *B. trivittata* basks primarily during the cooler months (December–March) when sandbanks are exposed by low water levels. In captivity, most basking occurs from ca. 1100 to 1400 hrs during February and March (Platt et al., in press). Maxwell (1911) described large mixed "herds" of *B. trivittata* and northern river terrapin (*Batagur baska*) basking on sandbanks at the mouth of the Ayeyarwady River in the early 1900s. More recently (1990s), boatmen reported *B. trivittata* using logs, rocks, and sandbanks as basking substrates along the Dokhtawady River (Platt et al. 2005; Kuchling et al. 2006a).

Study Areas

We investigated the occurrence and conservation status of *B. trivittata* in the Dokhtawady River and Yeywa Hydropower Reservoir, Shweli River, Chindwin River and several of its tributaries (Nam Thalet Chaung, Myitthar River, three creek systems within Htamanthi

Figure 4A. Female *Batagur trivittata* deposit clutches of 25–50 large eggs measuring ca. 70–75 mm long × 40–42 mm wide in multiple holes excavated in sandbanks (see Fig. 4D–E). Photo by Steven G. Platt.

Figure 4B–E. Conspicuous trackways are left by a nesting female *Batagur trivittata* (**B–C**). Females deposit clutches in multiple holes excavated in sandbanks (**D**). Note the depth of the hole on far right. In the past, villagers followed these trackways and used bamboo wands to probe for eggs (**E**). The individuals pictured in these photographs are collecting eggs for incubation as part of a conservation project. Photos by Steven G. Platt.

Wildlife Sanctuary, and headwaters in the Hukaung Valley), and Sittaung River. These rivers are located in, or drain parts of, all five homogenous rainfall regions of Myanmar (Roy and Kaur 2000). River levels reflect the annual monsoonal cycle, with the highest levels occurring in August and September, and lowest levels during April through early June (Kondoh et al. 2004; Zaw Zaw Latt and Wittenberg 2015).

The Dokhtawady, Shweli, and Chindwin rivers are major tributaries of the Ayeyarwady, with the Chindwin River being the largest. The Dokhtawady (formerly known as the Myitnge or Namtu River) arises on the Shan Plateau of eastern Myanmar, flows through a restricted valley, and enters the Ayeyarwady south of Mandalay (Gresswell and Huxley 1965). The upper Dokhtawady is characterized by a series of rapids interspersed with deep pools, while the lower river meanders through a broad floodplain that is now largely converted to agriculture (Platt et al. 2003; Kuchling et al. 2006b). In 2010, a 30-km stretch of the Dokhtawady River, including an area inhabited by a remnant population of *B. trivittata* (Kuchling et al. 2006b), was inundated when the Yeywa Hydropower Dam was completed, creating an impoundment of approximately 23,900 ha. Water levels within the impoundment fluctuate as much as 18 m between the monsoon (highest level) and dry season (lowest level). Owing to this extreme hydrological variation, aquatic macrophytes are largely absent from the littoral zone of the reservoir.

The Shweli River arises in Yunnan Province, China, and flows southwards for 650 km before debouching into the Ayeyarwady at Inywa (Gresswell and Huxley 1965). The upper Shweli River is for the most part a high-gradient, swift-flowing river, in contrast to the lower river, which is characterized by a gentle gradient, sandbanks, and deep pools. Parts of the river are heavily impacted by gold mining and three major hydropower dams are currently under construction that will completely alter the hydrology of the river (Win Ko Ko and Platt 2012). Human settlements are sparse along the Shweli and much of the region is under control of Ethnic Armed Organizations (EAOs).

The Chindwin River is the largest tributary of the Ayeyarwady River, arising from rivers in the Hukaung Valley of Kachin State (Gresswell and Huxley 1965). The Chindwin River exits the Hukaung Valley, flows over the Nat Tha Mi Se (=Angel) and Kyauk Sein Se (=Jade) rapids, and then continues southward along the base of the Naga Hills before meeting the Ayeyarwady about 15 km upstream from Pakokku (Chibber 1933). The length of the Chindwin River from its headwaters to the Ayeyarwady confluence is approximately 1200 km (Gresswell and Huxley 1965). The Chindwin River is characterized by wide meanders with extensive sandbanks exposed during low water periods. Herein we follow local convention and refer to the river downstream from Homalin as the "lower Chindwin" and upstream from Homalin as the "upper Chindwin."

Nam Thalet Chaung and the Myitthar River are important tributaries of the Chindwin River. Nam Thalet Chaung arises in India, pierces the spine of the Naga Hills, and passes through a series of waterfalls and rapids, before eventually debouching onto a broad floodplain and entering the Chindwin River about 2 km upstream from Htamanthi (Saul 2005). The upper river flows through a deeply incised, boulder-strewn gorge, but downstream from Wa Daw, Nam Thalet Chaung becomes a relatively low-gradient river characterized by deep holes (depth to ca. 10 m at low river levels), occasional sandbanks, and an abundance of algae and aquatic macrophytes (Platt et al. 2013).

The Myitthar River originates in the Kabaw Valley, flows through a narrow corridor between the Chin and Ponnya Daung hills, and joins the Chindwin at Kalewa (Brown 1960). Upstream from Kalay, the Myitthar River is shallow and rocky, and therefore only the short section (ca. 25 km) between Kalay and Kalaywa was considered potential *B. trivittata* habitat and included in our survey. This stretch of river has a relatively low gradient, with sandbanks just upstream from its confluence with the Chindwin near Kalaywa. The heavily travelled Kalay-Kalaywa Road closely follows the river and several small communities are scattered along the road.

Htamanthi Wildlife Sanctuary (HWS) encompasses 2151 km^2 between the Uyu and Chindwin rivers, is administered by the Myanmar Forest Department, and currently ranks as the third largest protected area in Myanmar (Rabinowitz et al. 1995; Beffasti and Galanti 2011). HWS is drained by four large creek (= *chaung*) systems (Nam Pi Lin Chaung, Nam Pa Gon Chaung, Nam Ei Zu Chaung, and Nam Kwe Daing Chaung) that arise in the eastern part of the sanctuary, flow generally westward, and discharge into the Chindwin River. Nam Pi Lin Chaung forms part of the northwestern boundary of HWS; the other three streams lie completely within the protected area. Illegal gold mining was previously commonplace on these creeks, but aggressive law enforcement since 2015 has eliminated clandestine mining operations from inside the sanctuary boundaries.

The Sittaung River arises at the confluence of three streams: Paung Laung Stream flowing from the Shan Plateau, and Sinthe and Nagalyke streams arising in the Bago Yoma Range. The Sittaung River then flows southward for 420 km between the Bago Yoma Range and Shan Plateau and discharges into the Gulf of Mottama (Wilke 1934). At least seven major tributaries (Thaukyegat, Kyauk Kyi, Shwe Gyin, Swa, Kabaung, Pyu, and Yenweh rivers) enter the Sittaung along its course to the Gulf of Mottama. Downstream from Pyinmana, the Sittaung meanders through a broad, densely settled floodplain where regular overbank flooding occurs during the late monsoon (August and September). There are currently 17 hydropower dams operating, under construction, or planned on tributaries of the Sittaung River that will irrevocably alter the hydrology of the river.

Survey Methods

We relied heavily on the Traditional Ecological Knowledge (TEK; defined as the cumulative body of knowledge concerning the relationship of organisms to one another and their environment, empirically acquired, and passed down by oral tradition; Berkes et al. 2000; Huntington 2000) of fishers, bamboo cutters, farmers, and other riparian dwellers during this investigation. Although science has been slow to embrace TEK as a research methodology (Nadasdy 2003; Gagnon and Berteaux 2009), a growing body of evidence indicates indigenous peoples are keen observers of the natural world and can be reliable sources of information on local flora and fauna that often complements western science (Kuchling and Mittermeier 1993; Baird 2006; Newton et al. 2008; Meijaard et al. 2011; Nabhan and Martinez 2012; Gray et al. 2017). More specifically, our experience (e.g., Platt et al. 2015b, 2017b, 2018) and that of others working in the region (Thirakhupt and van Dijk

1995; Kuchling et al. 2004; Kanagavel and Raghavan 2012; Rahman et al. 2015) indicates many rural dwellers are especially knowledgeable about the local chelonian fauna, particularly readily identifiable, large-bodied species of cultural or economic importance, such as *B. trivittata*. Interviews of knowledgeable respondents offer a robust, cost-effective approach for assessing the conservation status of rare or elusive species across wide geographic areas (Kuchling and Mittermeier 1993; Kuchling 1997; Meijaard et al. 2011; Pan et al. 2015). Furthermore, local communities are an excellent, and often the only, source of information on the last occurrence of threatened species and therefore essential to understanding extinction processes (Gray et al. 2017). Finally, conducting interviews in local communities demonstrates respect for traditional knowledge and creates good entry points for conservationists to build awareness and support for recovery efforts (Mohd-Azlan et al. 2013).

During our investigation we visited riverside villages and encampments and conducted semi-structured, open-ended interviews (Martin 1995) of knowledgeable individuals. In accordance with the format of a semi-structured interview, we asked participants a series of questions that included standard questions prepared in advance and others that arose during the course of our conversation. We guided the discussion, but the direction and scope of each interview was allowed to follow the participants' train of thought (Huntington 1998). In practice, semi-structured interviews are more of a conversation than a typical question and answer session, and rather than rigidly adhering to a set of prepared questions, the interview provides an opportunity for collecting and discussing unsolicited and often unanticipated information (Gilchrist et al. 2005; Gagnon and Berteaux 2009).

Our questions focused on the past and present occurrence of *B. trivittata*, folk taxonomy (*sensu* Berlin et al. 1966), perceptions of former and current abundance, cultural practices surrounding the harvest of eggs and protection (if any) afforded to nests, juveniles, and adult turtles, potential threats to turtles, chronology and possible reasons for perceived population declines, location of sandbanks used (or formerly used) as nesting sites by female turtles, various aspects of natural history (to be reported elsewhere), and physical changes to riverine habitats. We incorporated the intact shell of a large adult *B. trivittata* into our interviews conducted in the Hukaung Valley Wildlife Sanctuary and along the Sittaung and Shweli rivers. We also asked to examine any shells of *B. trivittata* (or other species) that might be available in the village, measured straight-line carapace length (CL; Method D of Iverson and Lewis 2018) with a tree caliper (± 1 mm), and photographed each specimen. We accompanied informants to sandbanks used by turtles for nesting (past and present), determined the geographic coordinates, and collected physiographic data as part of an on-going study of reproductive ecology.

We conducted interviews of single individuals and groups ranging in size from two to 46 persons. Obtaining a precise count sometimes proved difficult because interviews were often conducted in a group setting ("focus group" of Jacques-Coper et al. 2019) and persons tended to wander in and out of the meeting venue, which was usually a public space (e.g., monastery, village office, domicile of the headman, etc.). One advantage of a group interview is "peer-review" whereby participants can critically assess and comment on the information being provided by other group members (Baird 2006). We began each interview session by explaining the objectives of the survey and the role of the participants in our research. Because ethnicity has potential political and security ramifications in Myanmar, in most areas (particularly eastern Myanmar) we refrained from asking participants about ethnic self-identity or tribal affiliations, although this information was often provided voluntarily. Interviews were conducted by one or more native Burmese speakers also fluent in English, and later translated into English and transcribed. Transcripts of most interviews are included in field notes archived in the Campbell Museum, Clemson University, Clemson, South Carolina, USA. Place names are in accordance with a national gazetteer being compiled by the Myanmar government, although local names are used for temporary encampments not included in the gazetteer. We determined geographic coordinates (India-Bangladesh Datum) with handheld Garmin® GPS units (see Appendix).

RESULTS

We visited 243 villages and encampments and interviewed ca. 1433 persons concerning the conservation status and decline of *B. trivittata* in eight rivers of Myanmar (Table 1). During our interviews we identified

Table 1. Approximate number of persons interviewed in towns, villages, and encampments during our surveys to determine the conservation status of *Batagur trivittata* in different river systems of Myanmar (2011–2019).

River/Location	Villages and Encampments	Persons Interviewed
Dokhtawady River (Yeywa Reservoir)	34	42
Chindwin River	31	360
Htamanthi Wildlife Sanctuary	5	74
Hukaung Valley Wildlife Sanctuary	12	68
Myitthar River	3	40
Nam Thalet Chaung	10	80
Shweli River	68	149
Sittaung River	80	620
Total	**243**	**1433**

Table 2. Vernacular names (with approximate translations) applied to *Batagur trivittata* along the rivers we surveyed in Myanmar. Note that *leik* is the Burmese word for turtle.

Vernacular Name (Translation)	River
Teik leik (Herding turtle)	Used throughout Myanmar
Leik khone (Domed turtle)	Chindwin R. and tributaries
Kham na sin leik (Seven star turtle)	Chindwin R. and tributaries
Leik ponenar (Stripe-necked turtle)	Upper Chindwin R.
Leik Pona (Indian ethnic group)	Dokhtawady R. and Yeywa Res.
Khaba leik (World turtle)	Used throughout Myanmar

six vernacular names applied to *B. trivittata* in Myanmar (Table 2). Knowledgeable individuals accompanied us to 26 sandbanks used as nesting sites by female *B. trivittata* along the Shweli River, lower and upper Chindwin River, and two tributaries of the Chindwin River (Table 3). Of the 26 sandbanks, five were active nest sites at the time of our visit and 21 had been used for nesting in the recent past; the former were restricted to the upper Chindwin River. The year of the last reported encounters with *B. trivittata* varied among rivers, ranging from 1961 to 2013 (Table 4). Below we summarize our findings for each river system.

Dokhtawady River and Yeywa Hydropower Reservoir

We surveyed the Yeywa Hydropower Reservoir and Dokhtawady River (from Reservoir upstream to Naung Cho) from 21 to 26 April 2011 (Fig. 5). Although permanent settlements are prohibited by civil authorities, we found numerous temporary encampments on the periphery of the reservoir and along tributary creeks. These encampments housed persons displaced from villages submerged by rising waters when the reservoir was filled and others that migrated into the area seeking economic opportunities. The inhabitants of these encampments were primarily engaged in illegal timber-felling and charcoal production and supplemented their income (and diet) by harvesting fish and wildlife, including turtles, with a heavy reliance on electro-fishing. We found little to suggest that *B. trivittata* persists in the Dokhtawady River or Yeywa Reservoir. One fisherman reportedly captured three *B. trivittata* during February–April 2010, but most persons we interviewed were unfamiliar with the species. Most tellingly, repeated offers (2011–2019) to purchase any *B. trivittata* that might be captured for inclusion in assurance colonies have gone unheeded, suggesting that few if any turtles survive. Finally, the Oo Gyi Sandbank where *B. trivittata* formerly nested (Kuchling et al. 2006b) and other similar habitats are now submerged beneath the Yeywa Reservoir. Thus, even if a small number of *B. trivittata* survive in the reservoir, critical sandbanks are no longer available as nesting habitat. For these reasons, we consider *B. trivittata* to be functionally, if not biologically, extinct in the Dokhtawady River and Yeywa Reservoir.

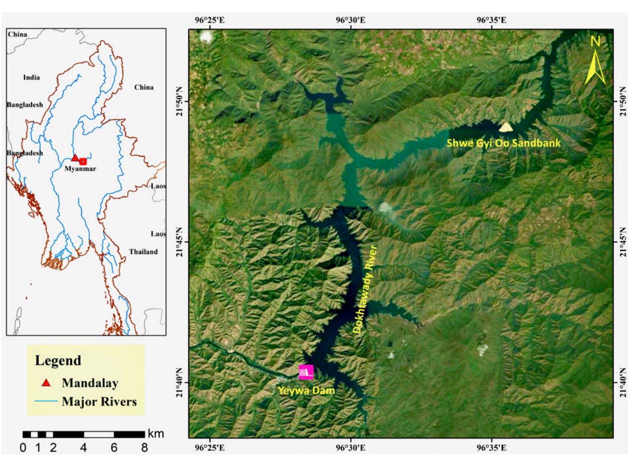

Figure 5. Yeywa Hydropower Dam and on the Dokhtawady River and former *Batagur trivittata* nesting site at Shwe Gyi Oo Sandbank now submerged beneath the Yeywa Reservoir. Inset shows the approximate location of the Yeywa Reservoir in relation to Mandalay.

Table 3. Geographic coordinates (India-Bangladesh datum) of sandbanks used for nesting by *Batagur trivittata* along the Shweli River, upper and lower Chindwin River, Nam Pi Lin Chaung, and Nam Thalet Chaung. Asterisks denotes active nesting areas as of 2012; nesting was no longer occurring on the remaining sandbanks as of 2019. Sandbanks listed alphabetically by river.

River and Sandbank	Lat. (N)	Long. (E)
Shweli River		
Bawdi Yoke Kyun	23°44.13´	96°30.32´
Kadet Thaung (Natkone)	23°39.84´	96°31.36´
Wine Lon Kyun	23°29.20´	96°35.70´
Nam Pi Lin Chaung		
Nam Khun San Sandbank	25°39.78´	96°33.50´
Nam Thalet Chaung		
Kot Tuk Sandbank	25°23.26´	95°14.75´
Nam Thalet Sandbank	25°23.58´	95°15.87´
Nam Tuk Sandbank	25°24.47´	95°12.86´
Samti Sandbank	25°22.47´	95°14.37´
Ting Tong Sandbank	25°24.43´	95°13.21´
Lower Chindwin River		
Gadu Chaung	24°02.01´	94°33.48´
Kindat	23°43.42´	94°25.53´
Taung Yadaw	22°54.48´	94°29.95´
Theyet Kone	24°12.73´	94°39.77´
Tone Nan	23°14.00´	94°19.53´
Upper Chindwin River		
Kaung Hein*	25°40.31´	95°25.11´
Kyauk Thaung*	25°43.66´	95°27.07´
Limpha Sandbank/Pagoda Island*	25°48.32´	95°31.73´
Malin	25°28.99´	95°23.01´
Mante	25°18.99´	95°17.81´
Mine Naung*	25°51.44´	95°35.50´
Na Maine Thaung	25°38.10´	95°26.00´
Nauk Pe	25°32.11´	95°24.26´
Padumone*	26°00.92´	95°52.15´
Sein Naing*	25°56.44´	95°35.50´
Sin Naing	25°15.78´	95°10.27´
Tone Lone	25°25.36´	95°23.45´
Yat Nar	25°36.60´	95°26.91´
Yedfa	25°13.85´	95°11.91´

Shweli River

We conducted interviews in villages and encampments along the Shweli River from 15 March to 29 April 2011 and 8 February to 2 April 2012. Our survey area included much of the lower (Kyusa Ywahaung to Innywa villages) and parts of the upper (Mwe Town to Monewee Village) Shweli River (Fig. 6). Fieldwork in some areas was precluded by the activities of EAOs. Of the persons we interviewed, only 20 (9.9%) had first-hand knowledge of *B. trivittata*, and notably, all of these informants were ≥60 years old. Among those familiar with *B. trivittata*, there was unanimous agreement that this species has been extirpated in the Shweli River. In the past, *B. trivittata* were eaten by villagers and occasionally offered for sale in local markets; some turtles were apparently sold to middlemen known to supply fish and turtles to markets in China. Villagers also harvested *B. trivittata* eggs from sandbanks during the dry season; these were kept for household consumption or sold in village markets. We accompanied two older fishermen (ca. 65 years old) to three sandbanks along the Shweli River where *B. trivittata* eggs were harvested in the past (Table 3). According to these persons, the last clutch of *B. trivittata* eggs was harvested "about 20 years ago" (ca. 1990). Interviewees attributed the local extinction of *B. trivittata* to the over-harvesting of adults for food and speculated their demise was due in part to the widespread use of powerful electro-fishing gear obtained from merchants in China. Hydropower development along the Shweli River played little role in the extinction process as dam construction began long after *B. trivittata* had been locally extirpated.

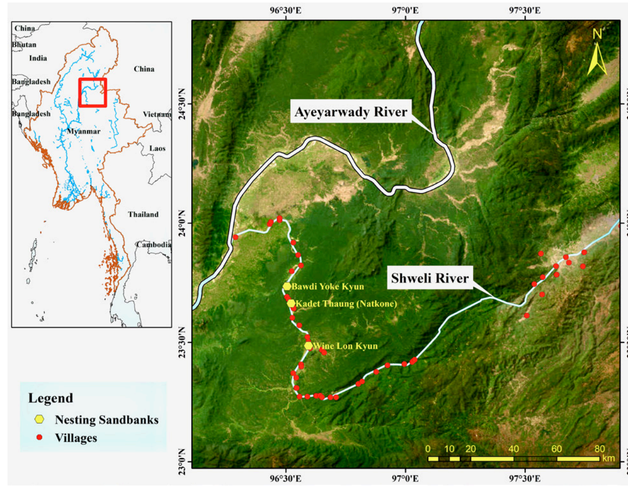

Figure 6. Map of the Shweli River showing the villages visited during our survey and three sandbanks formerly used as nesting sites by *Batagur trivittata*. Inset shows location of the Shweli River within Myanmar.

Table 4. Summary of information provided by interview respondents concerning the last reported occurrences of *Batagur trivittata* in the rivers we surveyed. BMNH = British Museum of Natural History.

Dokhtawady River and Yeywa Hydropower Reservoir
- Three adult turtles harvested by fishermen in 2010.

Shweli River
- Clutch of eggs harvested ca. 1990.

Chindwin River (lower)
- Nesting still occurring at many sandbanks 20–30 years ago (ca. 1980–1990).
- Last clutch unearthed from sandbar ca. 2002.
- Juvenile turtle captured in fish trap in either 2009 or 2010.
- Large adult turtle harvested in 2011.

Chindwin River (upper)
- Small population (<10) of *B. trivittata* persists in 21-km stretch of river between Chaung Wa (downstream) and Sein Naing (upstream). Outside of this stretch of river, nesting last occurred on four sandbanks in 2009–2011, and an adult turtle was last harvested in 2011.

Nam Thalet Chaung
- Small population (7–9 females, based on number of nests harvested) present until mid-1990s.
- Clutch unearthed from Nam Thalet Sandbank in 2010.
- Dead female turtle killed by dynamite fishing recovered in 2011.
- Trackway of nesting female found on Nam Thalet Sandbank in either 2011 or 2012.
- Forest Department staff confiscated clutch of boiled eggs in 2013.

Myitthar River
- Single turtle encountered "about 20–30 years ago" (between ca. 1985 and 1995).
- Clutch of 10 eggs harvested in 2004.
- Large hard-shelled turtle (presumably *B. trivittata*) caught in 2007.

Nam Pi Lin Chaung (Htamanthi Wildlife Sanctuary)
- Eggs harvested in 2005 and 2006 when 2–3 females nested on Nam Khun Sandbank.
- Trackway of single turtle found on Nam Khun Sandbank in 2007.

Nam Ei Zu Chaung (Htamanthi Wildlife Sanctuary)
- One or two females nested in 1990s.

Sittaung River
- No local knowledge of *B. trivittata*.
- Last in a series of museum specimens (BMNH 1961.92.94) dated 1961.

Chindwin River and Tributaries

We traveled by boat from Monywa upstream to Khamti, and conducted interviews from 4–24 February 2012, visiting 20 and 18 encampments, villages, and towns along the lower and upper Chindwin River, respectively (Fig. 7). In 2012, we were unable to continue upstream from Khamti because of an on-going, low-intensity conflict between Government forces and EAOs. However, in 2014 (24–26 February) permission was granted for us to travel upstream from Khamti to Padumone and conduct interviews at four additional riverside villages; we returned to this area again in 2019 (17–19 March). Most persons ≥50 years-old that we interviewed had first-hand knowledge of *B. trivittata*.

Our interviews suggest *B. trivittata* was common to abundant in the lower Chindwin River 40–50 years ago, but is now functionally extinct, although scattered individuals may yet persist. Villagers stated that *B. trivittata* formerly nested on sandbanks near Taung Yadaw, Tone Nan, Kindat, Gadu Chaung, and Theyet Kone villages

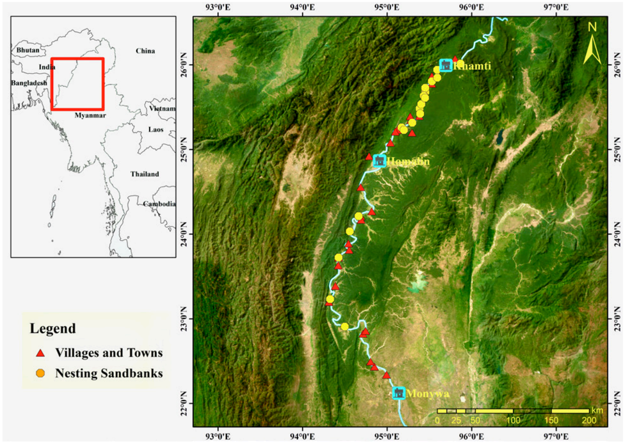

Figure 7. Map of the upper (upstream from Homalin) and lower (downstream from Homalin) Chindwin River showing towns and villages visited during our surveys and location of sandbanks used as nesting sites (past and current) by *Batagur trivittata*. Inset shows location of the Chindwin River within Myanmar.

Figure 8. Shell of an adult female *Batagur trivittata* that drowned in the early 1990s after becoming entangled in a fishing net deployed in the lower Chindwin River near Kindat. Photo by Steven G. Platt.

(Table 3). Nesting activity was last observed at most sites 20–30 years ago; however, villagers described unearthing a clutch of *B. trivittata* eggs on a sandbar near Theyet Kone "about 10 years ago" (ca. 2002). *Batagur trivittata* eggs were widely harvested in the past and either kept for household consumption or sold in local markets. Many older persons recalled regularly eating turtle eggs during the 1950s. Adult turtles were rarely eaten because of a widespread belief that consuming the flesh of *B. trivittata* could cause violent itching and other skin maladies (see below). Several persons stated that because of their unaggressive demeanor, adult *B. trivittata* were generally released unharmed when captured in fishing gear. Nonetheless, mortality frequently occurred when *B. trivittata* drowned after becoming entangled in fishing nets. We examined the intact shell of a large female *B. trivittata* (CL = 540 mm) in Kindat that drowned after becoming entangled in a fishing net in the early 1990s (Fig. 8).

Despite the apparent absence of recent nesting activity, our informants maintained that a few *B. trivittata* continue to survive in the lower Chindwin River. A juvenile was captured in a bamboo fish trap in either 2009 or 2010 near Shwe Sayay, residents of Mya Sein Kyun claimed to catch *B. trivittata* about once "every 2 to 3 years," and a large adult was captured near Hmine New Thaung in 2011. However, none of the individuals participating in our interviews was aware of any recent nesting activity along the lower Chindwin River. Villagers considered the decline and near-extirpation of *B. trivittata* in the lower river to be part of a continuing cycle of ecological degradation that has also resulted in the collapse of fish populations.

Along the upper Chindwin River, older informants (≥50 years old) characterized *B. trivittata* as common to abundant in the past and several made general statements to the effect that "hundreds of eggs" could be harvested from a single sandbank "many years ago," and that numerous nests occurred on "every sandbank" along the river. More specifically, our informants identified 13 sandbanks where *B. trivittata* nested along the upper Chindwin (Table 3); six of these sandbanks hosted active nests in 2012, but only two sandbanks were used by nesting turtles during the most recent nesting season (2021–2022). In 2012, active nests occurred along a 71-km stretch of the upper Chindwin River from Kaung Hein upstream to Padumone (Fig. 9). This range has further contracted and since 2015 active nests have been confined to a 21-km stretch of the river extending from Limpha Sandbank/Pagoda Island upstream to Sein Naing. Dates given by respondents in response to our query regarding the last confirmed nesting (trackways, nests,

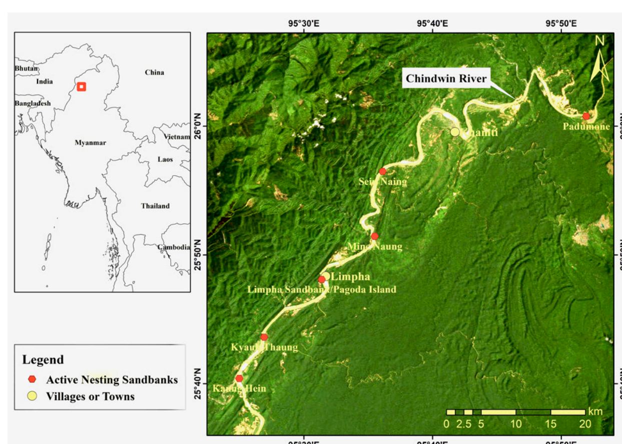

Figure 9. Location of sandbanks along the upper Chindwin River used as nesting sites by *Batagur trivittata* in 2012. During the most recent nesting season (2021–22) nests were found only at Limpha Sandbank/Pagoda Island and Sein Naing Sandbank.

Figure 10. Shells of adult female *Batagur trivittata* examined at Naung Pyin (**A**) and Limpha (**B**), villages along the upper Chindwin River. These shells were salvaged from turtles that drowned in fishing nets during the 1980s and 1990s. Photos by Kalyar Platt.

or eggs) outside of this stretch of river ranged from 1981 through 2011. Four sandbanks (Sin Naing, Yedfa, Nauk Pe, and Na Maine Thaung) were used by nesting turtles as recently as 2009–2011, but nesting activity has not since been observed at the sites.

Respondents along the upper Chindwin stated that in times past, turtle eggs (*B. trivittata* and large trionychids) were regarded as a common resource that could be harvested by anyone, although nesting sandbanks were considered the property of particular villages. In some villages, egg harvesting was treated as a festive social event and small groups of people would camp overnight on sandbanks hoping to gather eggs at first light. However, most egg harvesting seems to have occurred when villagers opportunistically chanced upon the fresh trackway left by a nesting female. Villagers described following trackways and probing the sand with a thin bamboo wand to locate buried eggs, which were then excavated by hand. Villagers typically left behind a small number of eggs from each clutch to complete incubation in the belief this practice would ensure a future generation of turtles and thereby guarantee a continued supply of eggs. Two persons claimed to translocate and rebury a few eggs at other sandbanks to prevent them from being discovered by rival egg collectors. The number of eggs said to have been left to incubate *in-situ* ranged from 1–7 or between 4.8 and 28.2% of an average clutch of 24.8 eggs (Platt et al., unpubl. data), although 2–3 eggs (8.0 to 12.1% of average clutch) was the most common answer to our question (64% of respondents). Most of the eggs harvested along the upper Chindwin River were kept for household consumption, although small numbers were sold in village markets and those of larger riverside towns, including Homalin, Htamanthi, and Khamti.

Similar to villagers living downstream, many people along the upper Chindwin believed (and continue to believe) that consuming turtle meat can induce violent itching, ringworm, and other dermatological maladies, in addition to causing reproductive problems among both men and women. Some respondents stated that consuming turtle meat can result in the recurrence of ailments a person experienced earlier in life. Large turtles are also assumed to be very old, and eating animals, especially fish and turtles, that have attained great age is believed by some to bring misfortune to the consumer. Religious significance was attached to the observation that female *B. trivittata* often nested on Buddhist days of fasting.

Along both the lower and upper Chindwin River, our respondents stated that laws protecting nesting female turtles were in effect during the British Colonial Period. Anyone intentionally killing a nesting turtle was subject to a stiff fine, equivalent to several months' wages. When Myanmar (as Burma) attained independence from Great Britain (1947), protection became the prerogative of individual Shan *Sawbwas* (hereditary rulers of Shan principalities; Sargent 1994). Colonial-era regulations protecting turtles were continued by the *Sawbwa* in Khamti Township, unlike the *Sawbwa* of Homalin Township who no longer prohibited the taking of adult turtles or controlled the harvest of eggs. After the *Sawbwas* were divested of authority by the Socialist National Government in the early 1960s (Thant Myint-U 2008), protection of *B. trivittata* and management of the egg harvest became the responsibility of individual village headmen, most but not all of whom continued the earlier protections and increased fines as the national currency decreased in value. In Mine Naung Village, persons guilty of harming a nesting female *B. trivittata* were required to strap a large *B. trivittata* carapace to their back and crawl through the village in the manner of a turtle. Our respondents maintained that proscriptions against killing turtles were honored not because people feared punishment, but instead because they considered turtle eggs a valuable resource, the continued supply of which could only be guaranteed by protecting the adult females.

In spite of these traditional protective measures, persons along both the lower and upper Chindwin River stated that *B. trivittata* was beginning to decline by the 1970s and had become extremely rare by the mid-1990s. The beginning of this downward spiral is generally attributed to the widespread introduction of nylon fishing nets in the early 1960s (1964–1965 was given by some respondents as the dates when nylon nets first became available). Prior to this time most fish were taken on baited hooks, and with *B. trivittata* being primarily herbivorous and frugivorous, this gear posed minimal danger to them. The use of nylon nets for fishing caused an increase in the incidental entanglement of turtles, and while many were released unharmed, drownings were inevitable and considered a significant source of mortality by our respondents. We examined the shells of five female *B. trivittata* that drowned in fishing nets; these included one shell in Naung Pyin (CL = 506 mm) from a turtle captured in either 1991 or 1992 (owner was uncertain), and four shells in Limpha (CL = 490 mm, 505 mm, 510 mm, 555 mm) from turtles captured "more than 20 years ago" (late 1980s to early 2000s; Fig. 10).

In the mid-1980s, the Chindwin River (particularly its upper reaches) received a large influx of immigrants from impoverished regions of central Myanmar in response to the rapidly deteriorating national economy. The livelihoods of the immigrants depended on various forms of resource extraction (fishing, bamboo harvesting, logging, and hunting for bushmeat) and fishing pressure increased many-fold. Furthermore, destructive fishing techniques such as electro-fishing, dynamite fishing, monofilament gill nets, and fish poisons came into widespread use during this time. Moreover, the newcomers exploited *B. trivittata* and their eggs, disregarding local proscriptions and traditional practices that had previously afforded some degree of protection to turtles. *Batagur trivittata* was said to have become increasingly uncommon from 1986 onwards, and by the late 1990s was considered extinct or nearly so in many stretches of the upper Chindwin River.

Industrial-scale gold mining that relied on large floating dredges began on the Chindwin River during 2002–2003. According to our respondents, gold mining ultimately sounded the death knell for the remaining *B. trivittata*. Gold mining destroyed the riverbed, caused the demise of aquatic macrophytes, smothered nesting sandbanks in mine deposits, and resulted in excessive sedimentation and dry season (low water) turbidity. When asked to describe the Chindwin River before mining began, our respondents said that a person could see 3–4 m below the surface during the dry season, and the river was narrow and deep rather than wide and shallow as is now the case.

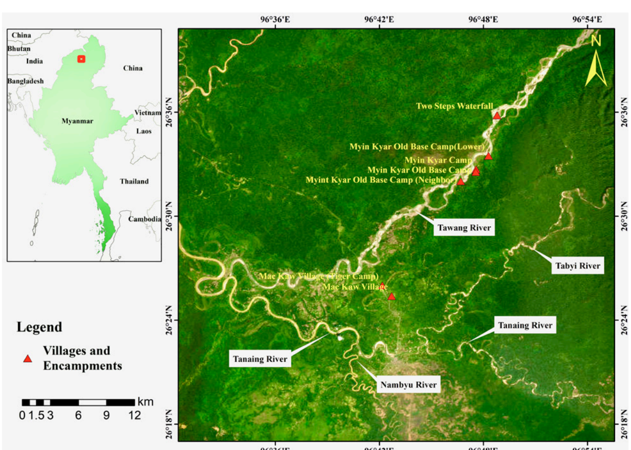

Figure 11. Map of the Hukaung Valley Wildlife Sanctuary showing rivers, villages, and larger encampments visited during our survey. Inset shows the location of Hukaung Valley Wildlife Sanctuary within Myanmar.

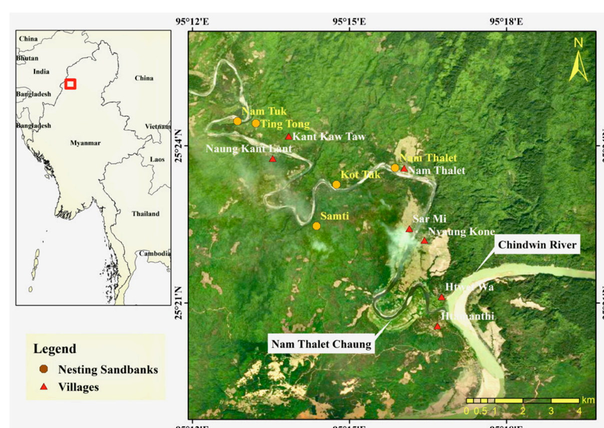

Figure 12. Map of Nam Thalet Chaung (shown as Nam Teik Leik Chaung on older maps) showing sandbanks formerly used as nesting sites by *Batagur trivittata* and some of the villages visited during our surveys. Inset shows location of Nam Thalet Chaung within Myanmar.

Hukaung Valley Wildlife Sanctuary.—We conducted interviews at villages and encampments along the Tanaing, Tawang, Nambyu, and Taby rivers within the Hukaung Valley Wildlife Sanctuary (HVWS) from 14 February to 4 April 2009 and 24–31 May 2009 (Fig. 11). Of the 68 persons interviewed, 22 (32.3%) were individual fishermen that we opportunistically encountered in the field. The Tawang River is a relatively high-gradient, shallow, braided, and rocky stream, which we judged to be unsuitable as habitat for *B. trivittata*. In contrast, the Taby and Tanaing rivers are low-gradient waterways characterized by expansive sandbanks with associated deep pools and abundant aquatic macrophytes and as such are potential *B. trivittata* habitat. We encountered large numbers of fishers on the Tanaing River. However, none of the persons we queried had first-hand knowledge of *B. trivittata* in these rivers; nor were they aware of any second-hand reports or other evidence indicating that *B. trivittata* ever occurred in the headwaters of the Chindwin River.

Nam Thalet Chaung.—We conducted interviews along Nam Thalet Chaung during visits on 2–3 March 2012, 16–20 February 2013, and 9–12 March 2014. Our survey area extended from the confluence of Nam Thalet Chaung with the Chindwin River (including Htamanthi Town), upstream to Htain Phai Yan Village (Fig. 12). We were unable to venture upstream from Nam Thalet Village during our first visit (2–3 March 2012) owing to the activities of anti-government Naga insurgents. However, a truce between the Myanmar government and Naga groups made fieldwork possible in subsequent years. We gleaned additional information during informal conversations with villagers as part of a conservation education campaign that preceded an experimental reintroduction of head-started *B. trivittata* in 2014–2015 (Platt et al. 2015a).

Our respondents maintained that *B. trivittata* formerly occurred in Nam Thalet Chaung from its confluence with the Chindwin, upstream to Nam Tuk and Ting Tong sandbanks. According to our respondents, low water temperature above Ting Tong Sandbank restricted *B. trivittata* to downstream stretches of the river. Because Nam Thalet Chaung is fed by numerous streams originating at high elevations (to 3600 m) in the Naga Hills, a thermal gradient probably exists along the course of this river. The consensus among our respondents was that *B. trivittata* was common in Nam Thalet Chaung many years ago ("during the time of our grandparents"), but has since declined to near-extinction. Interestingly, Nam Thalet Chaung is labeled "Nam Teik Leik Chaung" on British military maps dating from World War II, although no one we interviewed used this name for the river. *Teik leik* is a vernacular name widely applied to *B. trivittata* in many parts of Myanmar (Table 2).

Our respondents identified five sandbanks along Nam Thalet Chaung where *B. trivittata* nests could be reliably found each year until the mid-1990s (Table 3). These sandbanks are adjacent to deep holes, where females were said to remain during the egg-laying season. Prior to 1996, 7–9 female *B. trivittata* nested every year on Nam Thalet Sandbank, although comparable estimates from other sandbanks were unavailable. Shan villagers harvested *B. trivittata* eggs for domestic consumption, with some being sold on occasion in village markets. Respondents claimed to never kill female turtles, and as a rule, left a few eggs from each clutch to hatch *in-situ*, practices motivated by a desire to guarantee a continued future supply of eggs. The last confirmed nesting occurred in April 2010 when a clutch of 40 eggs was unearthed on Nam Thalet Sandbank. The trackway of a presumed nesting female was found on the same sandbank in either 2011 or 2012, but villagers were unable to locate the nest after a herd of water buffalo (*Bubalus bubalis*) obliterated the tracks. In 2013, Forest Department staff obtained a clutch of *B. trivittata* eggs from a villager who reportedly

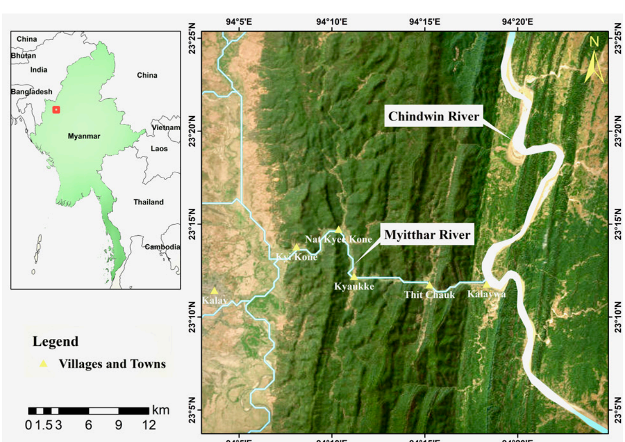

Figure 13. Map of the Myitthar River showing villages and towns visited during our survey. Inset shows location of Myitthar River within Myanmar.

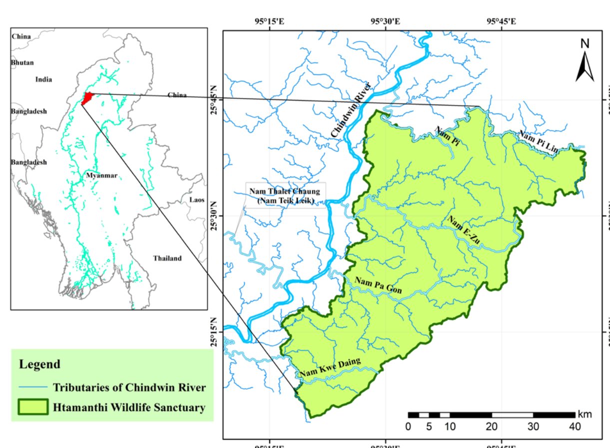

Figure 14. Map of Htamanthi Wildlife Sanctuary showing the four creeks (= chaungs) surveyed for *Batagur trivittata*. Inset shows the location of Htamanthi Wildlife Sanctuary within Myanmar.

Figure 15. Many sandbanks along Nam Pi Lin Chaung (**A**) and Nam Ei Zu Chaung (**B**) formerly used as nesting sites by *Batagur trivittata* are now buried under tailings produced by small-scale gold mining operations on these waterways. Photos by Steven G. Platt.

collected the eggs from a sandbank somewhere along Nam Thalet Chaung, although specific locality information was not forthcoming. Unfortunately, the villager boiled the eggs shortly after unearthing the clutch, precluding incubation by our conservation team. We maintain a permanent presence in nearby Htamanthi Town and to our knowledge, no further observations of *B. trivittata* or nesting activity has occurred in Nam Thalet Chaung in the years since our surveys.

According to those we interviewed, *B. trivittata* began to decline rapidly along Nam Thalet Chaung in the mid-1990s. Our respondents attributed this decline to two factors, the foremost being an influx of transient fishers from lower Myanmar (particularly the Mandalay-Monywa region) in response to the deteriorating economic situation as mentioned above. These transient fishers respected neither local customs that protected females from harvest nor traditional egg collection practices that left a few eggs from each clutch to incubate *in-situ*. Transient fishers were also said to use illegal fish harvesting strategies such as dynamite and electro-fishing, the former practice being especially devastating to turtles. Four female *B. trivittata* living in Nam Thalet Chaung in 2010 were believed to have fallen victim to dynamite fishing shortly thereafter. A dead female *B. trivittata* was recovered in 2011 by Forest Department personnel after being found floating in the river; according to villagers this turtle was killed by dynamite fishing. We examined fragments of two *B. trivittata* shells in Nam Thalet Village from turtles said to have been killed by dynamite fishing in 2001. The second factor believed responsible for the local extirpation of *B. trivittata* was an event described as a "red flood" that occurred during the wet season of either 1995 or 1996 (dates varied) and resulted in widespread flooding, excessive floodplain sedimentation, and a massive die-off of aquatic organisms. The exact nature of this phenomenon remains unclear, but a major landslide in the headwaters of Nam Thalet Chaung may have been responsible. In the years after this event, *B. trivittata* became extremely rare and sandbanks used for nesting were abandoned.

Myitthar River.—We conducted interviews at villages along the Kalaywa-Kalay Road that parallels the Myitthar River on 18–19 March 2014 (Fig. 13). We also visited three Buddhist pagodas with turtle ponds in Kalay. Most individuals we interviewed were unfamiliar with *B. trivittata*; however, one elderly fisherman told of encountering a single *B. trivittata* in the Myitthar River "about 20–30 years ago" (ca. 1985–1995). Another fisherman stated that a large hard-shelled turtle was captured on a line of baited hooks set in the river in 2007. The turtle was killed and consumed by its captor who later sold the large shell. The description of the turtle given by the fisherman was consistent with *B. trivittata*. A small number (<10) of large turtle eggs excavated from a sandbank along the Myitthar River in 2004 may have been those of *B. trivittata*. An adult *B. trivittata* that originated from the Myitthar River was kept for several years in a pond at a pagoda near Kalay, but succumbed when the shallow pond became over-heated in the dry season. We found no tradition of collecting *B. trivittata* eggs among villagers living along the Myitthar River, nor were villagers aware of any former *B. trivittata* nesting sites along the river.

Htamanthi Wildlife Sanctuary.—We conducted interviews in five villages (Chaung Wa, Hmaw Yom Myaing, Limpha, Swe Khaung Ngaw, and Tone Malaw) along the Chindwin River and within the buffer zone of Htamanthi Wildlife Sanctuary (HWS) from 24 February to 6 March 2012 (Fig. 14). The residents of these villages have traditionally harvested aquatic resources from four tributary creeks (Nam Pi Lin Chaung, Nam Pa Gon Chaung, Nam Ei Zu Chaung, and Nam Kwe Daing Chaung) within the sanctuary. Moreover, we maintain a permanent base of operations in Limpha and since 2012 have interviewed an additional 18 individuals with first-hand knowledge of *B. trivittata* in HWS.

Those persons we interviewed stated that *B. trivittata* formerly occurred in Nam Pi Lin Chaung and nested on Nam Khun Sandbank, where "25–30 years ago" (early 1980s) 300 to 400 eggs were harvested each year. The last egg harvest reportedly took place in 2005–2006, when two or three females nested on this sandbank. Trackways suggested a female returned to nest on Nam Khun Sandbank in either 2006 or 2007, although it was unclear if a clutch was actually found. Our respondents indicated Nam Khun Sandbank was located approximately 24 km upstream from the confluence of the Chindwin River and Nam Pelin Chaung. The upstream reaches of Nam Pi Lin Chaung are under the control of an EAO, therefore precluding a visit to the sandbank. *Batagur trivittata* is no longer thought to inhabit Nam Pi Lin Chaung and our respondents attributed its demise to disruption caused by widespread small-scale gold mining and poison used by miners to illegally harvest fish. Our reconnaissance of Nam Pi Lin Chaung found mine tailings now covering many sandbanks and partially occluding the channel in many places, and formerly deep holes (aikes) filled with sediment (Fig. 15A).

We found little evidence for the past occurrence of *B. trivittata* along other creeks in the sanctuary. Several respondents stated that one to two *B. trivittata* nested along Nam Ei Zu Chaung in the 1990s but could recall no further details. Our reconnaissance found the lower reaches of this creek to be heavily impacted by small-scale gold mining, with most sandbanks now buried under mine tailings (Fig. 15B). Our informants were in general agreement that *B. trivittata* never ventured up either Nam Pa Gon Chaung or Nam Kwe Daing Chaung, which our reconnaissance found to be extremely shallow (<1 m deep in most places) and lacking sandbanks with associated deep holes.

Sittaung River

We conducted interviews at villages and encampments along the Sittaung River from 6 October 2009 to 7 November 2009 and 3 March 2010 to 8 April 2010. Our survey area extended from Paung Laung Dam downstream to Kyeik Hto Town near the Gulf of Mottama (Fig. 16). Our respondents included 58 (9.3%) persons ≥60 years-old. None of the individuals we interviewed had first-hand knowledge or were otherwise familiar with *B. trivittata*. The Sittaung River is currently subject to intense fishing pressure by villagers using a variety of nets, traps, and weirs. Sandbanks are widely used for seasonal agriculture.

DISCUSSION

A thorough understanding of local folk taxonomy and vernacular nomenclature is critical when conducting

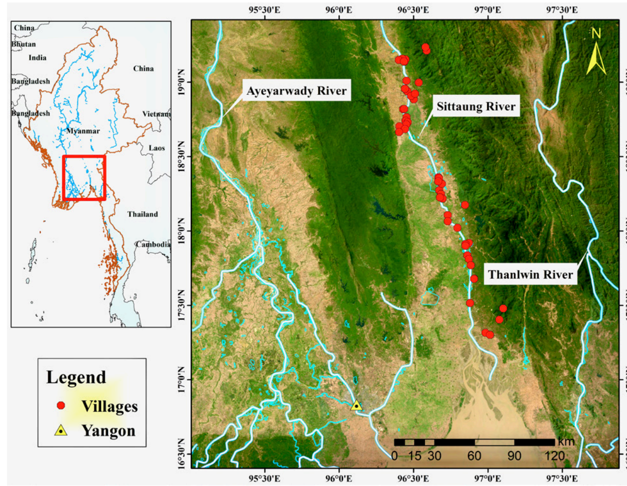

Figure 16. Map of Sittaung River showing location of villages and towns visited during our survey. Inset shows location of Sittaung River within Myanmar.

interview surveys and interpreting the results (Wilkie and Saridan 1999; Baird 2006; Das and Gupta 2015). This aspect often proves challenging owing to linguistic and cultural barriers, and because vernacular names are generally inconsistent between regions, ethnic groups, and even individuals within the same community (Wilkie and Saridan 1999; Mohd-Azlan et al. 2013). Additionally, local folk taxonomies can be under- or over-differentiated, whereby multiple scientifically recognized taxa are grouped together as a single folk species (under-differentiated) or conversely, a single scientifically recognized species is classified as multiple folk taxa (over-differentiated), the latter being especially common with economically or culturally important species (Berlin et al. 1966; Wilkie and Saridan 1999; Platt et al. 2004b). Therefore, a one-to-one concordance between folk species and scientifically recognized species cannot be assumed (Berlin et al. 1966; Baird 2006; Mohd-Azlan et al. 2013).

During our surveys, we found that multiple vernacular names are applied to *B. trivittata,* although *teik leik* (= herding turtle) appears to be used throughout Myanmar (see also Thorbjarnarson et al. 2000b; Platt et al. 2005; Kuchling et al. 2006a; Platt et al. 2018). The name *teik leik* is probably derived from the social behavior of *B. trivittata* which formerly assembled in large groups (i.e., "herds") when basking (Maxwell 1911). In coastal regions of Myanmar, *B. baska* is also referred to as *teik leik* (Maxwell 1911; Thorbjarnarson et al. 2000b) creating opportunities for confusion during interviews (K. Platt et al. 2008). *Leik khone* (= domed turtle) seems an obvious reference to the distinctive shape of the carapace of *B. trivittata*, which is also reflected in the English common name of "roofed turtle." The vernacular name *khon na sin leik* (= seven star turtle) stems from the widely held belief that nesting female *B. trivittata* only emerge from the river after midnight when a particular grouping of seven stars is evident in the night sky. Females then deposit a single clutch among multiple holes which are in turn thought to be oriented in a pattern corresponding to the alignment of these particular stars. Along the upper Chindwin, male *B. trivittata* are sometimes referred to as *leik ponenar* (= stripe-neck turtle) and recognized as a different species from female *B. trivittata* in the local folk taxonomy (over-differentiated *sensu* Berlin et al. 1966). The neck stripe is said to resemble the pattern on robes worn by religious fortune tellers known as *ponenar*, hence the vernacular name. For this reason, many fishers believe these turtles are imbued with supernatural powers and to harm one might result in ill fortune. Consequently, male *B. trivittata* were generally released unharmed when accidentally captured in fishing gear. In communities along the Dokhtawady River and Yeywa Reservoir, *B. trivittata* is known as *leik Pona* in reference to an Indian ethnic group residing in Myanmar. Members of this group paint multi-colored stripes on their faces as part of certain religious festivals. The brilliant head coloration exhibited by male *B. trivittata* during the breeding season is said to resemble the painted faces of the Pona ethnic group, giving rise to the vernacular name. Occasionally, *B. trivittata* is referred to as *khaba leik* (= world turtle), an oblique reference to large body size and perceived old age (i.e., "as large or as old as the world"). *Khaba leik* can be used in reference to any large turtle, but the name is most commonly applied to several species of large trionychids (Kuchling et al. 2004; Platt et al. 2004a; Kuchling et al. 2006a; Platt et al. 2017b).

Similar to our results, Kuchling et al. (2006a) reported that villagers along the upper Chindwin River used the vernacular names *kaba [khaba] leik*, *leik khone*, and *leik khawe* in reference to *B. trivittata*. According to Kuchling et al. (2006a), *khawe* refers to a "fruit with lines and ridges." Along the Ayeyarwady River, *B. trivittata* is also known as *yengyii leik* (= algae-covered turtle) (Platt et al. 2005). However, respondents during our surveys used neither *leik khawe* nor *yengyii leik* in reference to *B. trivittata*.

Our surveys confirm the critically endangered global conservation status of *B. trivittata* and highlight the importance of the only remaining known wild population in the upper Chindwin River. To briefly summarize our survey results, we determined the remnant population of *B. trivittata* in the Dokhtawady River is no longer extant and found nothing to suggest the continued survival of *B. trivittata* in the Sittaung and Shweli Rivers. A nesting population of *B. trivittata* no longer occurs in the lower Chindwin River, although a few surviving turtles may yet persist. *Batagur trivittata* likewise no longer survives in the Chindwin tributaries of the Myitthar River, Nam Thalet Chaung, and streams draining Htamanthi Wildlife Sanctuary. Only within the upper Chindwin River does a small population of *B. trivittata* continue to survive and most importantly, reproduce (Kuchling et al. 2006b; Çilingir et al. 2017). Here *B. trivittata* is confined to a 21-km stretch of the river (based on nest locations) or approximately 1.7% of its historical geographic range in the Chindwin River (see below). Previous surveys by us and others indicate that *B. trivittata* has also been extirpated in the Ayeyarwady River (Thorbjarnarson et al. 2000b; Platt et al. 2005; Kuchling et al. 2006a; Platt et al. 2017b, 2018). Taken together, these data suggest an overall reduction in the indigenous range of *B. trivittata* of >99% over the last several decades.

The only major river of Myanmar that remains unsurveyed is the Thanlwin (formerly Salween) where *B. trivittata* was historically reported to occur in abundance (Theobald 1868). Much of the Thanlwin is now under the control of anti-government EAOs, hence our inability to visit this area. Should the security situation along the Thanlwin River improve in the future, surveys for *B. trivittata* in that watershed should be considered a high priority.

Because a sample size of 10 respondents is likely to provide a near-saturation of relevant perceptions and experiences for respondent groups (Guest et al. 2006; Pan et al. 2015), the number of persons who participated in our interviews would seem more than adequate to assess the conservation status and population trends of *B. trivittata* in the rivers we surveyed. That said, we recognize that confidently determining if a species is locally extinct is challenging, owing to the low probabilities associated with detecting the last few surviving individuals (Brocke and van Dyke 1985; Guynn et al. 1985; Roberts and Kitchener 2006). As noted by van Dyke et al. (2019), the absence of evidence (detection) does not necessarily translate into evidence of absence when sampling turtle populations.

Nonetheless, for several reasons we consider it unlikely that—if present—a surviving population of *B. trivittata* would escape detection by villagers; i.e., the probability of detecting even a small number of surviving turtles is very high. First, adult *B. trivittata* are large turtles and if present in an area, would be readily observed when basking on riverbanks or logs (Theobald 1868; Maxwell 1911; Platt et al. 2005; Kuchling et al. 2006b). Second, female *B. trivittata* leave conspicuous trackways on sandbanks when nesting and because egg-laying takes place in the dry season when rainfall is scant to none, these trackways can persist for weeks (S.G. Platt et al., unpubl. data). Finally, turtle eggs are an economically and culturally important resource actively sought by riverside dwellers who would take notice of trackways left by nesting females. In effect, even at very low densities, *B. trivittata* (and probably other large river turtles) has a high detection threshold (Roberts and Kitchener 2006). Given these caveats, we therefore feel confident in assuming that if *B. trivittata* was present in the areas we surveyed, their occurrence would be well-known to those participating in our interviews.

The results of our survey strongly suggest that *B. trivittata* is now functionally, if not biologically, extinct in the Dokhtawady River and Yeywa Hydropower Reservoir. According to Kuchling et al. (2006b), declines of *B. trivittata* in the Dokhtawady River began following a ceasefire between the Myanmar Government and the Shan United Army, an EAO that long contested government control of this area. Prior to the ceasefire, the lower Dokhtawady River was a war zone (*sensu* Martin and Szuter 1999) where government control was tenuous and fishers from central Myanmar could venture only at great personal risk (Kuchling et al. 2006b). As such, the war zone functioned as a *de facto* protected area where *B. trivittata* was able to persist until being rediscovered in the early 2000s (Platt et al. 2005; Kuchling et al. 2006b). The cessation of hostilities between warring factions resulted in a sudden influx of fishers and by 2004 *B. trivittata* was declining rapidly in the Dokhtawady River, although juvenile and subadult turtles could still to be found (Kuchling et al. 2006b). Our survey suggests that completion of the Yeywa Dam in 2011 intensified fishing pressure on the few remaining turtles and inundated the only remaining nesting site (Shwe Oo Gyi Sandbank). With the apparent extirpation of *B. trivittata* in the Dokhtawady, the few turtles surviving in the upper Chindwin became the sole known remaining wild population of this species.

The extirpation of *B. trivittata* from the lower Chindwin (including the tributary Myitthar River) and Shweli Rivers, and near-extirpation in the upper Chindwin (and tributaries), appears to be the result of years—perhaps even centuries—of over-harvesting turtles and their eggs for domestic consumption and sale in village and occasionally urban markets (e.g., Maxwell 1911). As long-lived vertebrates with delayed sexual maturity and high adult survivorship, river turtle populations are especially sensitive to mortality among the larger size classes (Moll and Moll 2004; Zimmer-Shaffer et al. 2014) and even small increases in annual mortality rates of adults can lead to eventual demographic collapse (Congdon et al. 1993, 1994; Thorbjarnarson et al. 2000a; Spencer 2018). When coupled with egg harvests that effectively precluded recruitment, demographic collapse of *B. trivittata* was inevitable. The timing of this near-extinction roughly coincides with the reported demise of *B. trivittata* in the Ayeyarwady River (Platt et al. 2005; Kuchling et al. 2006a); turtles were rare by the late 1980s, with a few scattered individuals persisting into the 1990s and early 2000s.

Our survey sheds little light on the disappearance of *B. trivittata* from the Sittaung River as none of those we interviewed—including older individuals—had knowledge of these turtles. There is little doubt that *B. trivittata* formerly occurred in the river: Theobald (1868) reported *B. trivittata* in the Sittaung estuary and six specimens in the British Museum of Natural History (BMNH 1867.9.28.1; 1867.9.28.3; 1868.5.11.10; 1947.3.4.85; 1947.3.4.86; 1961.92.94) from "Pegu" (now Bago) almost certainly originated from the nearby Sittaung River. Collection dates of these specimens range from 1867 to 1961, suggesting *B. trivittata* survived in the river until at least the early 1960s. The Sittaung River valley has long supported a dense human population that relies on agriculture and fishing for sustenance (Allen 1973) and we assume that like elsewhere in Myanmar, *B. trivittata* and their eggs were exploited for food by villagers dwelling along the river. The Sittaung River is a relatively small and isolated river system, which would heighten the extinction risk for *B. trivittata*, and demographic collapse probably occurred more rapidly and at an earlier date (1940s–1950s with extirpation by mid-1960s) than in the much larger Ayeyarwady-Chindwin River system. The lack of local knowledge about *B. trivittata* is unsurprising as Turvey et al. (2010) demonstrated that knowledge of even charismatic aquatic megafauna rapidly disappears from the collective memory of a community once these species cease to be encountered on a regular basis.

Only in the upper Chindwin River (including Nam Thalet Chaung and tributary creeks in Htamanthi Wildlife Sanctuary) did *B. trivittata* continue to survive until recently, albeit at extremely reduced densities (Kuchling et al. 2006b; Çilingir et al. 2017). We found nothing to indicate that *B. trivittata* ever occurred in the Hukaung Valley headwaters of the Chindwin River; to our knowledge there are no museum specimens or references in the historical literature and none of our respondents in that area were familiar with *B. trivittata*. Given the apparent absence of *B. trivittata* from the Hukaung Valley, we speculate the Nat Tha Mi Se and Kyauk Sein Se rapids functioned as biogeographic barriers to upstream dispersal. The Irrawaddy Dolphin (*Orcaella brevirostris*) exhibited a similar distribution pattern in the Chindwin River as do some species of fish (Thein 1977; Smith and Mya Than Tun 2007).

Kuchling et al. (2006b) attributed the survival of *B. trivittata* in upper Chindwin River to traditional proscriptions that protected juvenile and adult turtles, while allowing an annual harvest of eggs. Protecting reproductive females is no doubt critical to the long-term survival of turtle populations (Thorbjarnarson et al. 2000a), but high rates of egg removal ultimately reduce recruitment and are implicated in population declines of other turtles (Martinez et al. 2007; Tomillo et al. 2008; Eisemberg et al. 2015). Based on our interviews, we are unable to quantify what percentage of nests along the upper Chindwin were harvested in the past; however, because trackways left by nesting female *B. trivittata* are conspicuous and readily detected and clutches easy to find and unearth, we consider it likely that >90% of nests were depredated by humans each year. Comparable levels of egg off-take resulted in the collapse to near extirpation of some leatherback (*Dermochelys coriacea*) populations in Malaysia (Chan and Liew 1996; Chan 2006; Tomillo et al. 2008).

Given these considerations, we propose the following scenario to explain the near-extirpation of *B. trivittata* from the upper Chindwin River. First, long-term chronic over-harvesting of eggs created a "decadent" population consisting largely of reproductively mature adults (Lovich et al. 2018). Despite the traditional practice of leaving behind a minimal number of eggs in each clutch (ca. 12%) to complete incubation, the low juvenile survival rates typical of most turtle populations (Thorbjarnarson et al. 2000a; Moll and Moll 2004) meant that few hatchlings ever attained adulthood. Nonetheless, because *B. trivittata* is long-lived (lifespan unknown but >80 years in a congener; Platt et al. 2019a) relative to humans, the number of nests found along the Chindwin River were not perceived to diminish from one year to the next and therefore traditional practices appeared to be effectively ensuring a sustainable crop of eggs, i.e., there was the "perception of persistence" described by Lovich et al. (2018). The situation changed rapidly in the 1960s when increasing numbers of adult turtles began to drown in the nylon nets recently adopted by fishers in Myanmar. Then in the 1980s, transient fishers from central Myanmar invaded the upper Chindwin, and not respecting the traditional proscriptions that had formerly protected turtles, intensified background mortality rates by killing adults and harvesting eggs. With no juveniles to replace those adults lost to fishing, populations declined rapidly to near-extinction by the 1990s and early 2000s.

The extirpation of *B. trivittata* in the Dokhtawady River and Yeywa Reservoir highlights the danger posed by large hydropower projects to the continued survival of river turtles in Myanmar and elsewhere in the world. The construction of dams and reservoirs converts lotic to lentic systems and can have varied and often site-specific impacts on turtles, with specialized riverine species (such as *Batagur* spp.) being the most vulnerable to negative effects (Moll and Moll 2004). Dams disrupt natural hydrological cycles by dampening or eliminating seasonal flood pulses, alter the geomorphology of river channels, decrease water quality and increase turbidity, and reduce the overall heterogeneity of aquatic habitats (Moll and Moll 2004; McCartney 2009; Alho 2011; Tornabene et al. 2017; dos Santos et al. 2021). Turtles are negatively impacted when nesting habitat is inundated, migratory routes are blocked, causing populations to become fragmented and vulnerable to stochastic demographic processes, and aquatic macrophytes that provide food and cover for turtles are reduced or eliminated (Kitimasak et al. 2005; Alho 2011; Ghaffari et al. 2014; Norris et al. 2018). Presumably, the negative impacts of run-of-the-river dams on the aquatic biota (including turtles) are less drastic than more traditional dams (Anderson et al. 2015; Campos et al. 2017, but see Norris et al. 2018 and Bárcenas-Garcia et al. 2022 for opposing views). That said, dos Santos et al. (2021) cautioned that even for fish (the group most frequently studied when evaluating dam impacts), the impacts of run-of-the-river dams are poorly studied and often speculative.

Specific actions proposed to mitigate the negative impacts of dams on river turtles include constructing artificial nesting sites to replace those inundated by reservoirs and manipulating water levels to mimic natural flow regimes and favor aquatic macrophytes that provide food to turtles (Alho 2011; Norris et al. 2018; Schneider and Vogt 2018; Vashistha et al. 2021). These measures have shown promise in South America where *Podocnemis unifilis* has attained high densities in hydropower reservoirs (Alho 2011), but to our knowledge remain untested elsewhere. Encouragingly, some riverine turtles appear to adapt well to lentic environments created by dams (Lindeman 2000; Moll and Moll 2004; Alho 2011; Vogt 2018). However, Schneider and Vogt (2018) caution that effects of dam construction on turtles remain poorly understood and warrant further study. In light of these concerns, mitigation measures must be regarded as experimental until these techniques can be further evaluated (McCartney 2009).

Despite the loss of the Dokhtawady population, we concur with Kuchling et al. (2006b) and recommend that hydropower reservoirs in Myanmar be considered as potential, albeit experimental translocation sites for captive-bred and head-started *B. trivittata*. We see no *a priori* reason to assume that translocations of *B. trivittata* into reservoirs are necessarily doomed to failure. Indeed, under captive conditions at assurance colonies in Myanmar, *B. trivittata* fare well in expansive earthen ponds and readily use artificial sandbanks for nesting (Kuchling and Tint Lwin 2004; Platt and Platt 2019; Platt et al. 2021, 2022). Although extrapolating from zoo conditions to the wild must be undertaken with caution, we suggest that given appropriately tailored management practices, habitat suitable for *B. trivittata* can be created in reservoirs. Appropriate management practices include constructing artificial sandbanks that are similar to natural nesting sites (Platt et al. 2017a) along the shoreline or on islands (Ewert 1976; Norris et al. 2018; Vashistha et al. 2021) and manipulating water levels to ensure that artificial sandbanks are exposed above-water during the nesting season (December through March). If possible, reservoir levels should also be managed in such a way that a relatively stable littoral zone is established to foster the growth of aquatic macrophytes that are important for turtles as food and cover. In this regard, run-of-the-river dams would seem more likely to prove suitable as translocation sites than traditionally managed hydropower dams (Anderson et al. 2015).

Hydropower reservoirs in Myanmar offer several other advantages to translocated *B. trivittata*. For instance, the invasive floating plants (*Eichhornia crassipes* and *Ceratophyllum* spp.) that often become established in tropical reservoirs (Junk 1977; Thirakhupt and van Dijk 1994; Villamagna and Murphy 2010) are an abundant, protein-rich food source (Boyd 1969; Men et al. 2006; Mahmood et al. 2018) that is readily consumed by *B. trivittata* in captivity (S.G. Platt, pers. obs.) and could be a significant component in the diet of translocated turtles. Furthermore, because fishing is banned on hydropower reservoirs in Myanmar (admittedly enforcement is often weak), turtles released into these habitats are at little risk from entanglement in fishing gear, provided regulations are enforced. If fishing is permitted in reservoirs, the use of large-mesh gill nets should be prohibited to lessen the likelihood of incidental mortality.

Our suggestion to translocate *B. trivittata* into reservoirs is not without precedent, as large numbers of captive-bred and head-started *Batagur affinis* (Southern River Terrapin) were released into reservoirs in Thailand with the ultimate objective of restoring wild populations (Thirakhupt and van Dijk 1994; Moll and Moll 2004). To our knowledge however, no assessment of this large-scale translocation has ever been undertaken and its outcome remains unknown. This situation is lamentable because even if unsuccessful, evaluating these efforts using a Lessons Learned approach (Waliński 2015) would inform plans for future translocations of *B. trivittata* (and other river turtles) into reservoirs, making these efforts more likely to succeed.

Finally, with the completion of our range-wide survey (except Thanlwin River), hopes that a remnant population of *B. trivittata* might yet survive in an unsurveyed river now seem increasingly remote. Nonetheless, single turtles could still persist (the "living dead" of Rosenzweig 2003; i.e., a population composed of a single or few, long-lived individuals ultimately doomed to extinction because of the continued lack of reproductive success) and become available to conservationists from fishers or during confiscations of illegally trafficked wildlife (Platt and Platt 2021b). Unless these turtles are known to have originated from the upper Chindwin River, we strongly recommend such wild-caught individuals be incorporated into one of the existing assurance colonies after a health assessment (Calle et al. 2021) and appropriate quarantine period, rather than simply released back into the wild. Such turtles would be particularly important from a genetic standpoint, because the assurance colonies were founded with fewer than 10 individuals and consequently, are genetically impoverished (Çilingir et al. 2017). Ultimately, some allelic diversity could be restored to the wild population by the release of captive-bred offspring from these turtles with potentially significant benefits to the long-term viability of the wild population (Çilingir et al. 2017)..

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Appendix

Geographic coordinates of towns, villages, and encampments visited during our surveys of *Batagur trivittata* in Myanmar. Place names are in accordance with a national gazetteer being compiled by the government of Myanmar; local names are given for locations not included in the gazetteer. Geographic coordinates (India-Bangladesh Datum) were determined with handheld Garmin® GPS units. Place names are listed alphabetically by river or wildlife sanctuary.

River and Location	Lat. (N)	Long. (E)
Chindwin River (lower)		
Bin Chun Kyun	22°49.52´	94°42.84´
Hmine Nwe Thaung	24°12.64´	94°41.33´
Homalin	24°51.73´	94°54.65´
Kani Town	22°26.18´	94°50.92´
Kindat	23°43.42´	94°25.53´
Maedin	22°29.81´	94°48.21´
Mawleik	23°37.96´	94°25.29´
Monywa	22°07.33´	95°07.48´
Mya Sein Kyun	24°10.27´	94°41.52´
Naung Sun Kyin	24°55.37´	94°47.12´
Phaung Pyin	24°16.22´	94°49.06´
Se Gyi	23°23.34´	94°23.27´
Shwe Sayay	22°20.48´	95°59.58´
Taung Yadaw	22°54.48´	94°29.95´
Thanthar	23°48.96´	94°33.02´
Theyet Kone	24°12.73´	94°39.77´
Thin Daw	22°51.49´	94°44.71´
Tone He	24°33.41´	94°41.20´
Tone Nan	23°14.00´	94°19.53´
Ye Wa	23°53.50´	94°32.51´
Chindwin River (upper)		
He Zoon	25°52.01´	95°31.73´
Htamanthi	25°12.06´	95°17.64´
Hwet Wa	25°21.01´	95°16.84´
Kaung Hein	25°40.76´	95°27.15´
Kauk Thaung	25°43.66´	95°27.07´
Limpha	25°48.32´	95°31.73´
Malin	25°28.99´	95°23.01´
Mante	25°18.99´	95°17.81´
Mine Naung	25°50.87´	95°35.60´
Moakhan	25°04.87´	95°02.31´
Na Maine Thaung	25°38.10´	95°26.00´
Nam Pha	26°04.36´	95°48.21´
Nam Pha Khone	25°23.70´	95°22.83´
Nauk Pe	25°32.11´	95°24.26´
Naung Pin	25°13.88´	95°07.25´
Ohnbet	25°12.73´	95°05.83´
Padumone	26°00.92´	95°52.15´
Sein Naing	25°56.44´	95°35.50´
Sin Naing	25°15.66´	95°10.21´
Tone Lone	25°25.36´	95°23.45´
Yat Nar	25°36.60´	95°26.91´
Yedfa	25°13.85´	95°11.91´
Htamanthi Wildlife Sanctuary		
Chaung Wa	25°46.70´	95°31.72´
Hmaw Yom Myaing	25°12.06´	95°09.99´
Limpha	25°48.35´	95°31.70´
Swe Khaung Ngaw	25°22.36´	95°21.64´
Tone Malaw	25°10.39´	95°09.97´
Hukaung Valley Wildlife Sanctuary		
Kyan Kha – Ta Wang (Confluence)	26°37.673'	96°51.314'
Mac Kaw	26°25.399'	96°42.700'
Mac Kaw (Tiger Camp)	26°26.013'	96°42.165'
Myin Kyar Old Base Camp (Lower)	26°33.488'	96°48.288'
Myin Kyar Old Base Camp (Neighbor)	26°32.024'	96°46.691'
Shi Pat Kha – Ta Wang Junction	26°37.585'	96°50.692'
Tawang	26°38.789'	96°51.456'
Tawan Kha	26°28.044'	96°42.037'
Two Steps Waterfall	26°35.828'	96°48.778'
Myitthar River		
Kalay	23°11.44´	94°03.67´
Kalaywa	23°11.78´	94°18.32´
Kyaukke	23°12.20´	94°11.19´
Kyi Kone	23°13.78´	94°08.09´
Nat Kyee Kone	23°14.73´	94°10.35´
Thit Chauk	23°11.74´	94°15.25´
Nam Thalet Chaung		
Htain Phai Yan	25°25.23´	95°12.45´
Letpanthar	25°23.90´	95°13.79´
Mol Dun Phai	25°25.21´	95°11.83´
Nam Thalet Village	25°23.52´	95°16.34´
Naung Kent Lent	25°23.86´	95°13.79´
Nyaung Khone	25°22.23´	95°16.49´
Sami	25°22.41´	95°16.43´
Sone Inn Yan	25°25.20´	95°13.23´
Sun Malin Pi	25°22.89´	95°13.57´
Wa Daw	25°25.66´	95°12.91´
Shweli River		
Bamboo Camp	23°16.21´	96°42.59´
Bawdiyoke Kyun	23°44.13´	96°30.32´
Bibin	23°38.95´	96°31.80´
Bogone Camp	23°40.00´	96°31.25´
Chaungwa	23°55.10´	96°31.85´
Choipu Camp	23°25.99´	96°02.86´
Hankan	23°49.19´	97°37.77´
Hpalai Camp	23°26.39´	96°03.91´
Hutlon Camp	23°16.21´	96°41.16´
Inngyi	23°47.94´	96°31.47´
Innhlaw	23°24.50´	96°33.81´
Innywa	23°56.46´	96°17.37´
Kadetthaung	23°39.84´	96°31.36´
Kaungkat	23°47.03´	97°37.93´
Kaungwing	23°52.33´	97°33.99´
Khotha	23°31.39´	96°35.39´
Kinekwingyi Camp	23°40.87´	96°30.66´
Konemakhan	23°27.43´	96°39.62´
Kyaukhtanpoe Camp	23°16.57´	96°37.60´
Kyetyoebin	23°34.30´	96°33.40´
Kyinehon	23°21.16´	96°32.60´
Kyusa	23°25.34´	97°01.89´
Kywunchaung	23°49.35´	96°33.79´
Mabein	23°28.55´	96°36.06´
Mahalingkone	23°23.97´	96°33.87´
Mahugone	23°38.53´	96°31.98´
Man Me	23°24.28´	96°55.50´
Manntha Camp	23°19.58´	96°48.17´
Manpu	23°42.06´	97°34.30´
Mantat	23°42.29´	97°30.58´
Menyo	23°51.98´	96°33.09´
Moemeit	23°06.63´	96°39.95´
Monewee	23°36.76´	97°30.45´
Muse	23°59.32´	97°54.15´
Myitsone	23°16.37´	96°33.44´
Nan Nwe	24°00.30´	96°26.24´
Nanhkam	23°50.07´	97°41.01´
Nantponepone	23°28.15´	96°39.00´
Naryoke	23°20.20´	96°49.11´
Naungkhan	23°52.66´	97°44.83´
Naungli	23°16.65´	96°38.58´
Naung Taung	23°51.46´	97°40.27´
Ngaoh	24°01.24´	96°28.42´
Ngateelay	23°59.78´	96°25.95´
Nyang Bintha	23°36.20´	96°31.62´

Pankhu	23°46.43´	97°34.43´
Panlo	23°49.13´	97°44.54´
Phatpansaung	23°16.21´	96°39.05´
Plantation Camp	23°16.39´	96°35.41´
Pwaytu	23°18.59´	96°32.62´
Pwaytu (old village)	23°18.57´	96°32.73´
Pyaewa Camp	23°44.01´	96°29.89´
Pyindaunglay	24°00.78´	96°28.41´
Pyinlahar	23°30.15´	96°35.64´
Saelon	23°44.68´	97°32.32´
Shweli Bridge	23°16.61´	96°37.56´
Tazinmyaing Kyun	23°41.49´	96°30.26´
Tonebaw	23°22.28´	96°31.87´
Turtle (Leik) Sandbank	23°29.20´	96°35.76´
Whuman Camp	23°25.67´	97°02.33´
Winelone	23°28.82´	96°35.46´
Wipepupan Camp	23°25.10´	97°01.70´
Yaypu Camp	23°24.57´	96°59.71´
Sittaung River		
Aungtha	18°44.49´	96°26.78´
Baganchaung	18°41.13´	96°26.55´
Dawnmo	18°13.55´	96°40.67´
Donsayit (West)	17°46.20´	96°53.13´
Hleseik	17°54.04´	96°50.92´
Kachaung	18°56.30´	96°27.58´
Kanyinkyo	18°06.45´	96°43.81´
Kawhtin	17°19.00´	96°59.01´
Khabaung	18°54.50´	96°28.99´
Kinpunsakan	17°24.28´	97°04.63´
Kuseik	17°40.78´	96°54.49´
Kyauktaga	18°10.49´	96°50.75´
Kyaungywa	17°48.70´	96°52.31´
Kyeepin Pauk	18°16.41´	96°40.38´
Kyeikhto	17°18.10´	97°00.83´
Kywepwe	18°39.94´	96°24.20´
Kyweyinepyin	19°08.36´	96°26.14´
Leiktho	19°12.78´	96°35.30´
Madauk	17°54.72´	96°50.92´
Makethalin	18°21.68´	96°40.05´
Myabago	18°20.02´	96°39.95´
Myoso	18°42.29´	96°24.30´
Nannamake	18°21.30´	96°40.30´
Natthankwin	18°14.90´	96°41.11´
Ngoketaw	19°00.61´	96°27.15´
Ohnbin	18°49.16´	96°25.81´
Okepho	19°14.18´	96°34.81´
Peinnebin	19°09.24´	96°26.73´
Pidauksan	19°09.00´	96°24.11´
Pyinyaygyi	18°01.29´	96°47.72´
Sapakyi	18°42.98´	96°27.11´
Seven Mile Camp	18°59.91´	96°32.13´
Shwegone	18°43.89´	96°27.67´
Shwekyin	17°55.17´	96°52.38´
Tar Oo	17°50.18´	96°51.71´
Taungtha	19°08.30´	96°26.33´
Tawkyaungpauk	18°13.07´	96°41.71´
Thaungyi	19°09.51´	96°25.53´
Thee Phyu	18°55.38´	96°30.60´
Theinzayat	17°30.97´	96°52.82´
Thuyethumein	17°40.71´	96°54.41´
Uyinyatkwet	18°53.13´	96°30.11´
Yayle	18°19.04´	96°41.50´
Yaytwingon	18°03.94´	96°43.84´
Zeepyuthaung	18°45.95´	96°27.15´