Chelodina oblonga Gray 1841 – Northern Snake-Necked Turtle*

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Summary. – The Northern Snake-necked Turtle, *Chelodina* (*Macrochelodina*) *oblonga* (Family Chelidae), until very recently known as *C.* (*M.*) *rugosa*, is a fairly large freshwater turtle (carapace length to 360 mm) with a broad distribution in tropical northern Australia and southern New Guinea. Its preferred habitats are seasonal wetlands on the coastal floodplains and adjacent hinterlands. These habitats undergo extensive flooding during the tropical wet season, with declining water levels during the following dry season; many waterholes dry completely. The species survives the dry season by migrating to permanent water or by estivating under the mud of dried waterholes. It is a highly prized food item among Aboriginal people, and turtles are collected each year in a harvest that has occurred for many millennia. The species is exclusively carnivorous and feeds on a range of fast-moving aquatic invertebrates, tadpoles, and fish. It is a highly fecund, fast-growing, and early-maturing species in comparison to most other Australian chelids. Its habit of nesting underwater makes it unique among all turtles. Nesting commences in the wet season (February) and is mostly complete by July (mid-dry season), though gravid females can be found as late as September if waterholes remain inundated. Eggs are laid in holes dug in mud under shallow water in the littoral zone of flooded waterholes. Embryonic development remains arrested while the nest remains flooded, but recommences when floodwaters recede and the ground dries. Embryonic development proceeds during the dry season and hatchling emergence coincides with the heavy rainfall or flooding in the following wet season. The species remains common in all the major river systems across northern Australia and southern New Guinea, and is sustainably harvested for traditional consumption in Australia, but is under some threat there from pig predation.

Distribution. – Australia, Indonesia (Papua), Papua New Guinea. Floodplains and adjacent hinterland of northern Australia, ranging in the west from the Victoria River of the Northern Territory and extreme northeastern Western Australia; in the east to the rivers draining east and west on Cape York, Queensland, south to the Normanby drainage; also in coastal tea tree swamps of southern New Guinea.

Synonymy. – *Chelodina oblonga* Gray 1841, *Chelodina rugosa* Ogilby 1890, *Chelodina oblonga rugosa*, *Macrochelodina rugosa*, *Macrochelodina rugosa rugosa*, *Chelodina* (*Macrochelodina*) *rugosa*, *Chelodina siebenrocki* Werner 1901, *Chelodina oblonga siebenrocki*, *Macrochelodina siebenrocki*, *Macrochelodina rugosa siebenrocki*, *Chelodina intergularis* Fry 1915, *Macrochelodina billabong* Wells and Wellington 1985 (*nomen nudum*), *Chelodina billabong*, *Chelodina kuchlingi* Cann 1997, *Macrochelodina kuchlingi.*

Subspecies. – None currently recognized.

Status. – IUCN 2013 Red List: Not Listed (Least Concern, LC, assessed 1996), TFTSG Draft Red List: Near Threatened (NT, assessed 2011); CITES: Not Listed; Australian EPBC Act: Not Listed; All State and Territory legislation: Not Listed.

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* Until very recently this species was known as *Chelodina rugosa* Ogilby 1890. See full discussion under Taxonomy.

Figure 1. Female *Chelodina oblonga* from Tonda Creek, Morehead River, Western Province, Papua New Guinea. Photo by Arthur Georges.

Taxonomy. — Taxonomic confusion regarding what scientific name to use for the Northern Snake-necked Turtle has recently arisen. Though this species has been referred to as *Chelodina rugosa* Ogilby 1890 for over 45 years, the holotype of *Chelodina oblonga* Gray 1841 is actually a specimen of a Northern Snake-necked Turtle (Thomson 2000). As a result, Thomson (2006) petitioned the International Commission on Zoological Nomenclature to use its plenary powers to preserve prevailing usage of *C. rugosa*, instead of recognizing *C. oblonga* as having priority, and Kuchling (2010) provided a detailed account of the history and taxonomic confusion that ensued from the earlier misidentification of the holotype. Complicating the situation is that the name *C. oblonga* had for the last 45 years been used as the scientific name for the Southwestern Snake-necked Turtle. However, the ICZN (2013) recently ruled that the name *C. oblonga* is valid and has priority over *C. rugosa*, and should be used for the Northern Snake-necked Turtle, and we follow that ruling here.

Chelodina oblonga was originally described by Gray (1841) from the type locality of "Western Australia" which,

at that time, included the Northern Territory. Later, Gray (1873) stated that the collection of the British Museum of Natural History also included specimens of *C. oblonga* from the Port Essington region of what is now the Northern Territory. Gray (1856) described *Chelodina colliei* from the Swan River as a separate species from southwestern Western Australia. From this it was clear that Gray (1856, 1873) recognized *C. colliei* from southwestern Australia as a different species from *C. oblonga* of "Western Australia" and of the Port Essington region of the Northern Territory. However, this perceived distinction was not to last.

Boulenger (1889) subsequently synonymized *C. colliei* with *C. oblonga*, a view that held sway for over seven decades. A year later, Ogilby (1890) described *Chelodina rugosa* from Cape York, Queensland, and then Werner (1901) described *Chelodina siebenrocki* from "Deutsch-Neu-Guinea" (in error, actually southern British New Guinea; see Rhodin and Mittermeier 1976). Siebenrock (1909, 1915) completed the consolidation by synonymizing both these latter taxa with *C. oblonga*. For
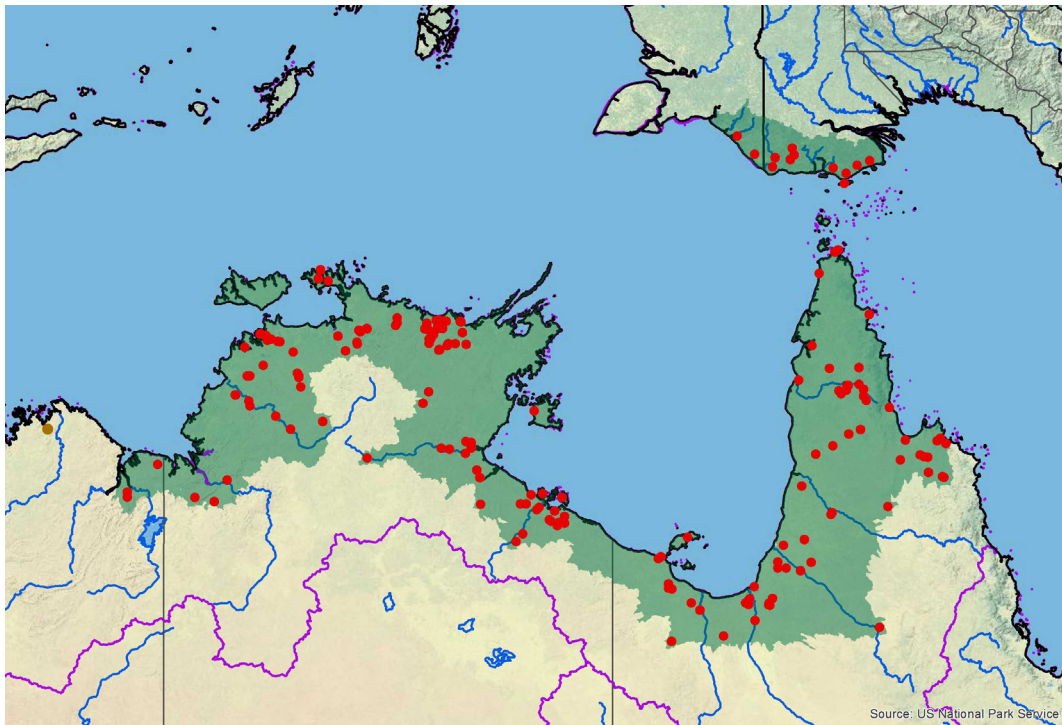

Figure 2. Ventral and dorsal views of female *Chelodina oblonga* from the Blyth-Cadel drainage, north-central Arnhem Land, Northern Territory, Australia. Photos by Arthur Georges.

Figure 3. Ventral and dorsal views of female *Chelodina oblonga* from Van Rook Creek, near Normanton, Cape York, Queensland, Australia. Photos by John Cann.

Figure 4. Distribution of *Chelodina oblonga* in northern Australia and southern New Guinea (Indonesia and Papua New Guinea). Purple lines = boundaries delimiting major watersheds (level 3 hydrologic unit compartments – HUCs); red dots = museum and literature occurrence records of native populations, based on Iverson (1992) and the addition of more recent and authors' data; brown dot = type locality of the holotype of *C. kuchlingi* in Western Australia (synonymized with *C. oblonga*), a captive animal presumably originally collected elsewhere; green shading = projected native distribution based on GIS-defined HUCs (level 10) constructed around verified localities and then adding HUCs that connect known point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs (Buhlmann et al. 2009), and adjusted based on authors' subsequent data.

a long time, *C. oblonga* was considered a single wide-ranging species from northern Australia, southern New Guinea, and southwestern Australia, through to the 1960s (Worrell 1963; Pritchard 1967).

The initial concepts of Gray (1841, 1856) were revisited when Goode (1967), in discussions with scientists of the day, recognized Gray's distinction between the southwestern form and the northern forms of *C. oblonga* and split the forms, resurrecting earlier scientific names. However, he erroneously restricted the name *C. oblonga* to the southwestern Australian form, overlooking the correct

Figure 5. Ventral and dorsal views of female *Chelodina oblonga* from Tonda Creek, Morehead River, Papua New Guinea. Photos by Arthur Georges.

name, *C. colliei*. Furthermore, he assigned the northern Australian populations to the species *C. siebenrocki*, even though he acknowledged elsewhere in his book that *C. rugosa* was an earlier name than *C. siebenrocki*. This latter error was rectified by Burbidge (1967), who recognized *C. siebenrocki* as a junior synonym of *C. rugosa*, but Burbidge followed Goode's erroneous application of the name *C. oblonga* to the form in southwestern Australia. Burbidge placed the snake-necked turtles of northern Australia into the species *C. rugosa*. The combination of *C. oblonga* for the southwestern form and *C. rugosa* for the northern Australian forms remained in consistent use for the ensuing 46 years, through 2013.

Thomson (2000) clarified the nomenclatural situation by demonstrating that the holotype of *C. oblonga* Gray 1841 is actually a specimen of what was at the time being referred to as *C. rugosa* Ogilby 1890. As a result, Thomson (2006) applied to the International Commission on Zoological Nomenclature to use its plenary powers to retain the current usage of the name *C. rugosa* for the Northern Snake-necked Turtle from northern Australia, in the interests of nomenclatural stability. However, the ICZN (2013) rejected this proposal, and did not support using *C. rugosa* over *C. oblonga* on the basis of long-standing use. We therefore follow the ICZN ruling and now refer to the Northern Snake-necked Turtle as *Chelodina*

Figure 6. Female *Chelodina oblonga* from Northern Territory, Australia; Fogg Dam, Middle Point, near Darwin (**top**), and Blyth-Cadel drainage, north-central Arnhem Land (**bottom**). Photos by John Cann (top) and Arthur Georges (bottom).

Figure 7. Male (**top**) and female (**bottom**) *Chelodina oblonga* from the southern New Guinea coast, near Daru, Western Province, Papua New Guinea. Photos by Anders G.J. Rhodin.

oblonga rather than *C. rugosa*. This ruling also leads to the required resurrection of the name *Chelodina colliei* as the valid designation for the Southwestern Snake-necked Turtle from southwestern Western Australia, until recently referred to as *C. oblonga*.

Mertens and Wermuth (1955) and Wermuth and Mertens (1961) resurrected the New Guinea species *C. siebenrocki* from the synonymy of *C. oblonga*. While several authors have since regarded *C. siebenrocki* as separate from *C. oblonga* and *C. rugosa* (Burbidge et al. 1974; Rhodin and Mittermeier 1976; Cogger et al. 1983; Rhodin and Genorupa 2000), we follow the classification of Georges and Thomson (2010) that includes the New Guinea *C. siebenrocki* populations within *C. rugosa* (now *C. oblonga*), which is supported by genetic analyses (Alacs 2008). Under this classification, *C. oblonga* is included in the subgenus *Macrochelodina*, together with *C. burrungandjii*, *C. expansa*, and *C. parkeri* (Georges and Thomson 2010), characterized by relatively broader heads, longer necks, and narrower plastra than species in the subgenus *Chelodina*. *Chelodina oblonga* hybridizes with *C. burrungandjii* in the escarpment country of Arnhem Land, producing fertile offspring, and extensive introgression (i.e., backcrossing of the hybrids with their parental species) occurs in some areas (Georges et al. 2002; Alacs 2008). Hybridization is predominantly unidirectional via matings between *C. burrungandjii* males with *C. oblonga* females, and not vice versa (Alacs 2008). *Chelodina oblonga* also hybridizes with *C. canni* where their ranges overlap, principally in the rivers draining into the Gulf of Carpentaria (Georges et al. 2002).

Chelodina oblonga forms two distinct genetic lineages across its range, based on 867 bp from the mitochondrial ND4 and control region. One lineage is comprised of haplotypes from the Gulf of Carpentaria, Cape York, and southern New Guinea, and the second lineage is comprised of haplotypes from the Northern Territory and northeastern Western Australia (Alacs 2008). If determined to be distinct at the species level, these two lineages would be known, respectively, as *C. rugosa* in Cape York and New Guinea, and *C. oblonga* in the Northern Territory and northern Western Australia. The relationships among mitochondrial haplotypes suggest that the New Guinean and Cape York Australian forms are not distinct taxa (Alacs 2008), and refute the designation of southern New Guinea specimens as *C. siebenrocki* (Rhodin and Mittermeier 1976); however, more genetic and morphologic work is needed. Past connectivity of southern New Guinea and Queensland *C. oblonga* populations is likely to have been facilitated by the formation of the Torres Strait land bridge and Lake Carpentaria in the Pleistocene, as recently as 8000 yrs ago (Jones and Torgersen 1998; Reeves et al. 2007, 2008).

Description. — *Chelodina oblonga* is characterized by an extremely long neck that may be as long as its carapace. The carapace is dark brown to black and is egg-shaped in younger specimens, tapering anteriorly, becoming broadly oval with age. The plastron is white or yellowish and is markedly narrower than the width of the carapace. The robust neck is black above and white or cream below and the head is broad and moderately flattened. The head is retracted sideways when disturbed and is not fully protected by the edge of the carapace and barely at all by the plastron. When disturbed it releases yellow fluid from inguinal and axillary scent glands, but the secretion lacks the pungent odor typical of some other species of *Chelodina* (Eisner et al. 1978; Kool 1981; Kennett et al. 1994a).

Chelodina oblonga is the second largest of the Australian chelids. The species is sexually dimorphic in body and tail size, with females achieving larger sizes and males possessing distinctly longer, thicker tails. Maximum adult body sizes recorded in populations around Darwin in the Northern Territory are about 310 mm in carapace length (CL) and 4 kg in mass for females and 265 mm and 3.3 kg for males (Kennett 1994a). Larger specimens of about 350 mm CL occur in the Mary River in the Northern Territory and individuals of up to 360 mm have been reported from the Gulf of Carpentaria region (Cann 1998).

Hatchlings from the Maningrida region (Northern Territory) have masses of 7.1 ± 0.1 g on average (range, 3.2–10.3 g; n = 116) with a mean maximum CL of 33.3 ± 0.25 mm (range, 22.9–38.6 mm; n = 112) and a midline plastron length of 25.6 ± 0.20 mm (17.7–29.2 mm; n = 112) (Fordham et al. 2007a). Hatchlings from the Darwin region (Northern Territory) have masses of 7.9 ± 0.17 g on average (5.1–11.2 g; n = 75) with a mean CL of 32.2 ± 0.31 mm (27.3–36.9 mm; n = 75) (Kennett 1999).

Distribution. — Floodplains and adjacent hinterland of northern Australia, ranging in the west from the Ord River and Victoria River drainage, in the east to the rivers draining east and west on Cape York, south to the Normanby drainage, and in the coastal tea tree swamps of southern New Guinea. Isolated populations occur on the larger islands of the Torres Strait. In Australia, occurs in sympatry with *C. novaeguineae* on the Cape York Peninsula and in the Gulf of Carpentaria region, but does not occur as far south as that species. In Papua New Guinea, occurs in the Morehead and Bensbach drainages, and in broad sympatry with *C. parkeri* in the Fly and Bamu systems, but not in microsympatry, owing to habitat differences. In Indonesian Papua, the species occurs in the southern coastal regions in the Merauke River drainage.

Figure 8. Hatchling *Chelodina oblonga* from Sigabaduru, near Saibai, Western Province, Papua New Guinea. Photos by Fred Parker.

Figure 9. Hatchling *Chelodina oblonga* from Fogg Dam, Middle Point, near Darwin, Northern Territory, Australia. Photos by John Cann.

Habitat and Ecology. — *Chelodina oblonga* occurs in a broad range of swamps, waterholes, and slow flowing rivers throughout tropical northern Australia and southern New Guinea, but it occurs in highest densities in seasonally ephemeral swamps and waterholes on coastal floodplains and adjacent hinterlands (Kennett 1999; Fordham et al. 2007b; Georges et al. 2006). These habitats are characterized by extensive flooding, often covering hundreds of square kilometers during the monsoonal wet season (about December to April), and rapidly falling water levels during the intervening dry season when little or no rain falls. Many waterholes dry completely, and turtles survive the dry season by moving to permanent water or digging into the muddy substrate of drying swamps and estivating underground (Grigg et al. 1986; Kennett 1994a). During estivation, metabolic rate drops to about 25% of standard metabolic rate at the same body temperature, and this reduced metabolic rate enables turtles to conserve fat and water stores through many months of estivation (Grigg et al. 1986; Kennett 1994a). Inside their underground climate refugia, turtles are protected from daytime soil surface temperatures that often exceed 60°C; temperatures inside the refugia rarely exceed 31°C (Kennett 1994a; Kennett and Christian 1994).

Population densities of *C. oblonga* are much lower in permanent than in ephemeral waterholes (Kennett 1994a; Fordham et al. 2007b). For example, of over 800 captures of turtles in the permanently-flowing Douglas River (Northern Territory), only one was *C. oblonga*, whereas seasonally ephemeral swamps associated with the nearby Daly River supported high densities of *C. oblonga* (Kennett 1994a). However, high densities of *C. oblonga* have been observed during the late dry season in permanent water upstream of the drying Adelaide River (NT) floodplain, suggesting that *C. oblonga* may move to permanent water refugia under some circumstances.

Chelodina oblonga is a carnivorous turtle that feeds on a range of aquatic invertebrates and fish and has evolved a suite of feeding adaptations that enable it to specialize on fast-moving prey. These include an extremely long neck, a broad flattened head, a large hyoid apparatus, and binocular vision (Pritchard 1984). The long neck and binocular vision enable a fast strike at moving prey, which is engulfed by the large mouth; prey is effectively sucked into the mouth by a vacuum created when the hyoid is lowered.

Extensive flooding during the wet season opens up new feeding grounds for *C. oblonga*, and individuals move from deeper waterholes to occupy contiguous shallowly-flooded wetlands to feed on abundant tadpoles and aquatic invertebrates. Typical prey items for *C. oblonga* occupying seasonally ephemeral waterholes near Darwin included odonate nymphs, adult coleopterans (especially the black water beetle *Cybister tripunctatus*), adult belostomatids, freshwater shrimp (*Macrobrachium* sp.), and fish (Kennett

Figure 10. Typical habitat of *Chelodina oblonga* in northern Australia. The waterholes of the lowland floodplains are highly productive during the wet season; they contract dramatically in the dry season, and many waterholes dry completely. Photo by Damien Fordham.

Figure 11. Dam-dam Billabong in Arnhem Land of northern Australia, showing the extensive ephemeral wetlands occupied by *Chelodina oblonga*. Note the fyke net used to capture the turtles. Photo by Damien Fordham.

Figure 12. Gid-da-dilla Billabong in Arnhem Land of northern Australia, which is typical floodplain habitat of *Chelodina oblonga*. Note the snorkel trap used to capture the turtles. Photo by Damien Fordham.

Figure 13. Imimbar Billabong in Arnhem Land of northern Australia showing the tea tree (*Melaleuca* sp.) inhabited by *Chelodina oblonga* in both northern Australia and southern coastal New Guinea. Photo by Damien Fordham

and Tory 1996). The composition of the diet differs seasonally at some sites, with proportionally more fish being consumed during the dry season and proportionally more odonate nymphs during the wet season. Increased fish consumption reflected the crowding of fish into shallow water as water levels fell, making the fish more accessible to turtles, whereas the increased consumption of odonate nymphs in the wet season probably reflected their greater abundance. The mass emergence of odonate adults, and hence a decline in the numbers of nymphs, is widely considered to herald the start of the dry season in northern Australia. The availability of fish at sites that are more isolated from permanent waters depends on whether the region experienced above-normal rainfall in the previous wet season, leading to extensive flooding.

Chelodina oblonga is the fastest growing of the Australian chelid turtles. For populations in the Darwin region, males reach sexual maturity at a CL of about 165 mm and 4 yrs of age, whereas females do not mature until about 210 mm and 6 yrs of age (Kennett 1996). In the Maningrida region of Arnhem Land, males mature at about 148 mm and females at 183 mm; growth models for some sites predicted age of maturity for females at just

Figure 14. *Chelodina oblonga* typically occupies ephemeral wetlands, but can also be found in permanent riverine habitat, albeit in lower densities. Shown here is the Daly River (nr. Oolloo Crossing) in the Northern Territory of Australia, where the species can be found in the log jams, tree roots, and beneath undercut banks. Photo by Arthur Georges.

3.3 yrs (Fordham et al. 2007b). These ages at maturity are less than half those reported for other long-necked turtles in temperate Australia (Parmenter 1976; Chessman 1978; Parmenter 1985).

Onset of maturity is marked by a dramatic slowing of growth rate, and many adults do not grow at all for several years. This slow growth prohibits age estimates for adults based on plastral growth rings (Stott 1988) or

recapture growth analyses (Kennett 1994a, 1996), and data on longevity in natural populations are unavailable. Although slow adult growth rates suggest that some large individuals may be quite old (> 30 yrs?), the low annual rates of survival of *C. oblonga* (50–83% for adults in ephemeral waters [Kennett 1994a; Fordham et al. 2007b]) compared to most other freshwater turtles (mean of 88%, see Iverson 1991 for a review), suggests that *C. oblonga* in ephemeral waters does not commonly reach the ages suggested for other chelid turtles (Georges 1982). Yet, at low density sites that dry infrequently, *C. oblonga* survival rates are similar to other turtles (Fordham et al. 2007b). This is because turtle survival is strongly negatively correlated with frequency of drying (Fordham et al. 2009). In the Maningrida region, post-maturity growth was higher than in the Darwin region, up to 10 mm per year CL and annual survival rates tended to be lower (at least for turtles in ephemeral habitats; Fordham et al. 2007b, 2009). In fact, survival rates as low as 24% (13–40%) were recorded in years where turtle predation by feral pigs was particularly severe (Fordham et al. 2006a).

Estimates of high rates of natural annual mortality (based on mark-recapture studies of populations where introduced predators do not occur [Kennett 1994a]) are supported by observations of large numbers of dead animals on drying floodplains each year. Major sources of mortality at sites with low pig densities are dehydration and overheating of turtles walking overland, and predation by goannas (*Varanus* spp.), Dingos (*Canis familiaris*), and raptors such as the White-breasted Sea Eagle (*Haliaeetus leucogaster*) that catch turtles in shallow water or on land. Large piles of turtle shells are often located beneath sea eagle nests. Indeed, the abundance of dried turtle shells on desiccated floodplains each year has prompted investigation into developing permit conditions to allow the collection and use of shells as artifacts in the Aboriginal art industry (Kennett 1994b). Although *C. oblonga* will eat cane toad eggs and tadpoles in captivity (Greenlees and Shine 2011), and suffer some mortality as a result, there is no evidence that the introduced cane toad has caused declines in this species. It remains abundant throughout the rivers draining into the Gulf of Carpentaria where cane toads have been present for some time.

Where feral pigs are present in high densities, they are a major source of turtle mortality before, during, and immediately after the turtles enter estivation as waters recede (Fordham et al. 2006a, 2007b). The predation pressure is particularly acute at demographically isolated populations (where turtles tend to aestivate in response to waterholes drying rather than dispersing overland [Fordham et al. 2006a]) with a high density of *Eleocharis* sp. The bulbs and tubers of *Eleocharis* sp. are primary dietary items for pigs in the late dry season (Fordham et al. 2007b) and substantial alteration of wetland habitat occurs where feral pigs are abundant (Doupe et al. 2009).

Chelodina oblonga populations can rebound rapidly following reductions in density, and so is resilient to a level of harvest and predation by pigs. Kennett (1996) demonstrated significantly faster growth rates in a *C. oblonga* population following an experimental population reduction of approximately 55% and a consequent reduction in age at maturity from 4 to 2 yrs for males and from 6 to 3–4 yrs for females. Fordham et al. (2009) found that turtle abundance took as little as one year to recover from an experimental population reduction of > 50% in adult density. This was achieved through an increase in hatchling recruitment and survival into larger size classes. However, even when accounting for strong compensatory responses to mortality using demographic simulation models, future predictions on *C. oblonga* population persistence are not encouraging if feral pigs are not controlled (Fordham et al. 2008).

Nesting commences in the wet season (February) and is largely completed by July in the mid-dry season, but gravid females have been captured as late as September in years following good wet season rains, when waterholes retained water longer, and food availability is high. All mature females appear to reproduce every year, laying between 2 to 4 clutches per year.

Clutch size ranges from 9 to 21 eggs with a mean clutch size of 12 eggs. Eggs are hard-shelled and ellipsoid in shape with masses of 14.9 ± 0.07 g (range, 10.6–20.0 g) and are 34.6 ± 0.07 mm (range, 29.0–41.7 mm) in length and 26.9 ± 0.05 mm (range, 24.0–30.2 mm; n = 745 for all measurements) in width (Kennett 1994a, 1999).

Incubation period at constant 30°C ranges from 76 to 163 days with a mean of around 103 days, and there is considerable variation in development rate and hatching times both within and between clutches (Beynon 1991; Kennett et al. 1999; Fordham et al. 2006b). Embryonic survival is greatest at 26°C, steadily declining as temperature increases to 32°C (Fordham et al. 2007a). A similar increase in incubation temperature decreases incubation period by approximately 40 days; however, almost half of this variation is attributed to the increase in incubation temperature from 26 to 28°C.

Hatchling growth in *C. oblonga* is characterized by two phases: an initial phase of relatively slow growth under the partial influence of initial egg size and incubation duration, followed by a second phase of relatively rapid growth under the partial influence of water temperature and mass at hatching.

In contrast to all other known chelonians, *C. oblonga* nests underwater and its eggs can survive long periods of immersion of up to 25 weeks (Kennett et al. 1993a, 1993b, 1998; Fordham et al. 2006b). The principal adaptation of this

species for protracted embryonic developmental arrest under water is a vitelline membrane of such low permeability to water that the expansion of the yolk compartment (ultimately leading to embryo death) is about 10 times slower than for other turtles (Seymour et al. 1997).

Eggs are laid in holes dug in mud under shallow water in the littoral zone of flooded waterholes (Kennett et al. 1993a). Embryonic development is arrested while the nest remains flooded, but proceeds when floodwaters recede and the ground dries (Kennett et al. 1993b). Eggs in nests that are immersed after embryonic development commences die (Kennet 1994a). Hatchling emergence coincides with the heavy rainfall or flooding in the following wet season. Whether the eggs hatch in the nest and await conditions conducive to emergence, or hatch and emerge immediately is not known. Hatchlings would be unlikely to survive if they emerged when little or no standing water was present, and substantial rain may be required anyway, to soften the ground before hatchlings can emerge.
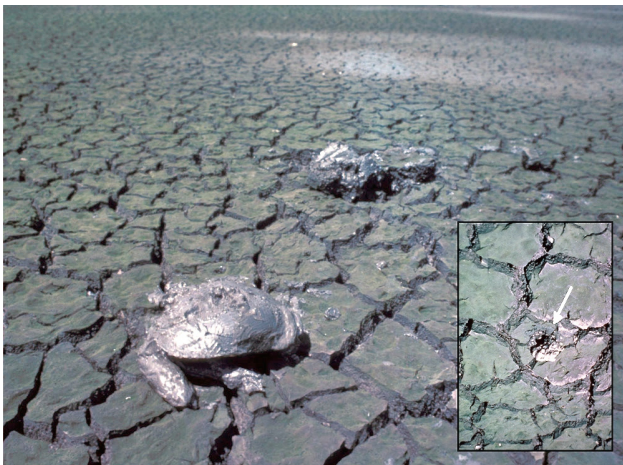
Kennett et al. (1998) demonstrated that embryonic survival was unaffected by the period of immersion (0, 2, 7, and 10 weeks; survivorship range, 61–71%). Fordham et al. (2006b) found that non-immersed eggs suffered the same mortality as eggs inundated for 25 weeks (ca. 30% survivorship), but with clear optimal inundation duration of 6 weeks (ca 70% survivorship) and concluded that underwater nesting is not a facultative capacity but, rather, inundation is essential for optimal survivorship of embryos. Eggs immersed longer hatch sooner (Kennett et al. 1998; Fordham et al. 2006b), reducing incubation period by up to nine weeks over what would be expected for non-immersed eggs at a given temperature (Fordham et al. 2006b). Eggs

Figure 15. *Chelodina oblonga* estivate beneath the mud when their waterhole dries in the wet-dry tropics of northern Australia and the southern Trans-Fly region of Papua New Guinea. When they do so, they use a breathing hole (inset, see arrow), which is used as a cue by Aboriginal people in northern Australia to locate the turtles. Feral pigs turn the soil over as the waterholes dry, so that locating the turtles by this method is then very difficult. Photo by Peter Wellings.

experimentally inundated for up to seven weeks completed incubation faster than if they had been laid at the same time in dry ground (Fordham et al. 2006b).

Nesting underwater and laying multiple clutches, coupled with high levels of inter- and intra-clutch variation in incubation period (Beynon 1991; Kennett et al. 1993b), shorter incubation periods with increasing inundation periods, and embryonic estivation (Ewert 1985; Beynon 1991; Rafferty and Reina 2012), are likely adaptations to the highly variable timing of wet season rains and flooding in the wet-dry tropics (Fordham et al. 2006b; Shine and Brown 2008). Collectively they allow turtles to: 1) start and complete nesting during periods of high food availability when waterholes are full (and so also to accumulate fat stores for dry season estivation); 2) to avoid the need to find dry nesting sites in mostly flooded habitats that extend for thousands of square kilometers and that may later be flooded; 3) to select nest sites that will be closer to the water's edge when waterholes refill and so increase hatchling survivorship; and 4) to increase the probability that their eggs will complete incubation and be ready to emerge when aquatic habitats re-flood. Nesting underwater may not be without ecological cost, however, as longer inundation results in smaller hatchlings, possibly because calcium is leached from immersed eggs, thereby reducing the calcium available to developing embryos (Kennett et al. 1998).

There are no data on thermoregulation by *C. oblonga*, but field observations indicate that individuals do not leave the water to bask (Fordham, pers. obs.). Possible explanations include avoidance of exposure to predation by aerial predators that often occur in high densities near floodplain habitats, or a paucity of aerial basking sites in many habitats. Surface water temperatures in shallow, heavily vegetated swamps often exceed 35°C (Fordham, unpubl. data); hence, basking while floating at the surface may be sufficient to elevate the body temperature to desired levels. Webb (1978) showed that other *Chelodina* bask only occasionally.

Indigenous Harvest. — Estivating *C. oblonga* contain large stores of fat and are readily caught by hand in shallow drying waterholes, dug from estivation burrows or less commonly caught on a handline. This makes them highly prized as a food item by indigenous people throughout northern Australia (Jackson et al. 2012) and southern New Guinea (Georges et al. 2006). Hauls of up to 60 estivating turtles in a single day from one area have been recorded in recent times (R. Pengilley, unpubl. data), while historical accounts from Aboriginal people in Arnhem Land suggest even larger hauls. Often surplus turtles were stored for months on end in underground pits surrounding waterholes, remaining in a state of torpor until the onset of the wet season and providing a food source for people passing by these harvest sites.

Figure 16. *Chelodina oblonga* is favored for traditional consumption by Aboriginal people of northern Australia (**left**) and villagers of the southern Trans-Fly region of Papua New Guinea (**right**) because of the large fat stores the turtles accumulate to carry them through estivation. Photos by Damien Fordham (left) and Arthur Georges (right).

Estivating turtles are located by the appearance of a characteristic breathing hole (created as the turtle pushes its head to the surface when the mud is still wet) and by probing the ground with a digging stick. Steel bars have replaced wooden sticks but little else about this traditional harvest has changed over time.

The timing and extent of drying of waterholes limits harvesting today as in the past—in wetter years billabongs do not dry, turtles do not need to estivate and people do not harvest turtles. Cultural practices such as the closure of waterholes to hunting when the owner passes away, and ceremonial obligations that coincide with turtle harvesting time, also limit the harvest.

The cultural importance of *C. oblonga* is reflected in its widespread appearance in Aboriginal rock art, some examples of which date back at least 8000 years (Chaloupka 1993). The species has been found among food items at several archaeological sites (Brockwell 2006), and it is likely that turtles have been hunted since Aboriginal people first arrived in Australia more than 40,000 years ago (Hiscock and Kershaw 1992). This annual harvest represents one of the oldest sustained harvests of a reptile species in the world.

The rapid expansion of feral pigs across northern Australia has upset the long established dynamic between people and turtles because pig predation significantly reduces turtle numbers. Pig rooting and wallowing behavior also negatively impacts the habitat and makes it difficult for hunters to locate estivating turtles.

Population Status. — *Chelodina oblonga* is common in all the major river systems across northern Australia and southern New Guinea. Much of its favored habitat on the coastal floodplains remains intact, and *C. oblonga* can be regarded as abundant across a broad geographic range. Although inter-annual population estimates and juvenile densities are available for a number of sites in Arnhem Land (Fordham et al. 2007a, 2009), estimates of total population densities range from 2.4 to 13.4 turtles per ha (Kennett 1994a; Fordham et al. 2009). These biomasses are within the range reported by Iverson (1982) for carnivorous freshwater turtles.

Threats to Survival. — Predation by feral pigs (*Sus scrofa*) on estivating adults as well as (potentially) nests and eggs currently poses the most serious threat to *C. oblonga*. Despite the resilience of *C. oblonga* to harvest, modelling predicts that pig predation will overwhelm density-dependent increases in hatchling survival and that populations in woodland savanna environments will decline rapidly and local extinction of affected populations can be expected within 50 years (Fordham et al. 2008). This modelling does not take into account the potential indirect impacts on turtle populations of habitat degradation by pigs (Doupe et al. 2009). The effects of such habitat degradation is compounded by changes

in vegetation arising from altered fire regimes – in the absence of regular burning, the turtles may estivate in grass and associated litter rather than underground, and so are more susceptible to fire when it does occur (McGregor et al. 2010).

Introduced Water Buffalo (*Bubalis bubalis*) have been reported by Aboriginal residents in Kakadu National Park to cause short-term localized declines in *C. oblonga* populations by trampling and killing large numbers of estivating turtles at drying waterholes (I. Morris, pers. comm.). Buffalo numbers have begun to increase in remote areas of the Northern Territory since a large-scale disease control program, Brucellosis and Tuberculosis Eradication Campaign (Freeland and Boulton 1990), ceased in the 1980s. Buffalo have also been implicated in saltwater intrusion to low lying floodplain habitat with attendant dramatic changes to wetland structure and function.

There is evidence of barter trade in freshwater turtles among indigenous communities across the species' range in Australia as refrigeration facilities and transport have become more readily available (Georges and Kennett 1988), but the impact of this trade on natural populations is unknown. There are no observable impacts from traditional harvesting with frequently harvested populations retaining similar moderate to high levels of genetic variation compared to unharvested populations (Alacs 2008). Using an empirical based modelling approach, Fordham et al. (2008) showed that if turtle predation by pigs is minimized, and subsistence harvesting is forfeited, commercially harvesting *C. oblonga* is ecologically sustainable, even if the harvest focuses on adult turtles. Impacts of commercial harvesting, particularly loss of genetic diversity and inbreeding, can be ameliorated by maintaining connectivity (and hence dispersal opportunities) between populations (Alacs 2008).

There is increasing evidence of a gradually developing international pet trade in this and other species of chelid turtles from southern New Guinea, with animals from Papua New Guinea and the Indonesian province of Papua being traded and exported from Merauke via Jakarta to international markets (Rhodin and Genorupa 2000; Lyons et al. 2013).

Impacts on habitat related to climate change are medium to long-term threats to *C. oblonga*. Large areas of favored habitat on coastal floodplains are less than 0.5 m above sea level and hence will be subject to sea level rise and saltwater intrusion under even optimistic climate change scenarios. This is likely to lead to a substantial contraction of available floodplain habitat (Traill et al. 2010), as occurred during the relatively higher sea levels in the region, perhaps as recently as 2000 yrs ago (Nott 1996), with an associated impact on *C. oblonga* range and abundance.

Conservation Measures Taken. — Because *C. oblonga* is considered a common species throughout its range, specific conservation plans to ensure its survival are not a high priority and have not been formulated. However, *C. oblonga* is currently protected under both state and federal legislation which prohibits the taking and killing of native wildlife by all except Aboriginal people and Torres Strait Islanders. It is regarded as a common species by all States and Territories where it occurs, and individuals may be kept without a permit provided they are not collected from the wild and are obtained from a legal source. Overseas export of native animals is regulated by the Environment Protection and Biodiversity Act 1999 administered by the Australian government. Commercial trade in *C. oblonga*, other than for an approved trade in hatchlings for pets, is prohibited.

The life history parameters of *C. oblonga* make it a suitable candidate for aquaculture (Webber and Riordan 1976; Kennett 1994a) and a commercial harvest has been operating under license in the Northern Territory since 2000 to meet domestic demand for pet hatchlings. This small-scale industry creates employment for Aboriginal people in a remote community in northern Australia, provides opportunities for people to visit and manage remote areas of habitat and a commercial incentive to protect habitat, and supports research and a training program. Fencing of wetlands is part of their overall Caring for Country program, funded by the Australian Government. Turtles are caught in baited hoop traps and fyke nets when waterholes are full. Turtles are marked, measured and weighed for ongoing monitoring; eggs are induced from gravid females and all turtles are released. Egg incubation and hatchling husbandry procedures follow Fordham et al. (2007a). Hatchlings are sold under license to pet retailers across the Northern Territory of Australia. Between 500 and 1000 eggs have been harvested each year since 2000 (Fordham et al. 2010a,b).

The species was assessed as Least Concern by the IUCN Red List in 1996, and was provisionally reassessed as Near Threatened by the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group in 2011, specifically because of the increasing threat from feral pigs. It is not listed on CITES.

The species occurs in many protected areas in Australia, including Kakadu and Litchfield National Parks in the Northern Territory, and Err Oykangand and Rinyirru National Parks in Queensland. In New Guinea it occurs in Tonda Wildlife Management Area in Western Province of Papua New Guinea and also in the contiguous Wasur National Park in Papua Province of Indonesia.

Conservation Measures Proposed. — There are national contingency plans to cull feral pigs in the event of a Foot and Mouth Disease outbreak because of the

economic impact on the Australian pastoral industry, but no active coordinated pig control program exists for environmental reasons across north Australia. Some localized control of pigs by shooting, trapping, poisoning, and exclusion fencing occurs, such as in national parks (e.g., Kakadu National Park) and is also undertaken by indigenous ranger programs (Baker et al. 2001). The growth of these ranger programs in both size and as a network across north Australia in recent years, and their commitment to reducing pig numbers to meet cultural and conservation 'looking after country' objectives represents the most optimistic scenario for addressing the conservation threat predation by pigs. As with feral pigs, control measures by indigenous Ranger programs are the most optimistic scenario for buffalo control in areas outside national parks.

Lyons et al. (2013) have recommended that this and other chelid species from New Guinea be considered for listing on the CITES appendices due to the growing international pet trade developing there.

Captive Husbandry. — *Chelodina oblonga* is hardy in captivity, and thrives on a balanced diet of fish, tadpoles, invertebrates, and prepared food. Eggs can be readily obtained by hormonal injections to induce oviposition, and the capacity of the eggs to remain in arrested development while immersed allows for the safe transport of eggs over long distances without the usual mortality that occurs when turtle eggs are transported.

Current Research. — Ecological studies on *C. oblonga* are largely limited to the southerly part of its range and were conducted as doctoral (Kennett 1994a; Fordham 2007; Alacs 2008) or honors theses (Beynon 1991) with subsequent publications (most cited above). Information on *C. oblonga* prior to these works was scant or fragmented. Grigg et al. (1986) examined the blood chemistry of estivating turtles, Cann (1980) and Legler (1985) presented limited data on egg and clutch size and incubation, and Legler (1980, 1982) presented some ecological data, principally diet, in unpublished reports. A study of the molecular phylogeography of *Chelodina oblonga* and the related *C. burrungandjii*, is underway at the University of Canberra.

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