

Saltwater Crocodile *Crocodylus porosus*

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Common Names: Saltwater crocodile, saltie, Estuarine crocodile, Indo-Pacific crocodile, Buaya muara (Indonesia), Baya, Pukpuk, Kone huala (Papua New Guinea), Jara Kaenumkem (Thailand), ius (Palau)

Range: Australia, Bangladesh, Brunei, Cambodia (extinct?), China (possibly historically), India, Indonesia, Malaysia, Myanmar, Palau, Papua New Guinea, Philippines, Seychelles (extinct), Singapore (extinct?), Sri Lanka, Solomon Islands, Thailand (extinct?), Vanuatu, Vietnam (extinct?)

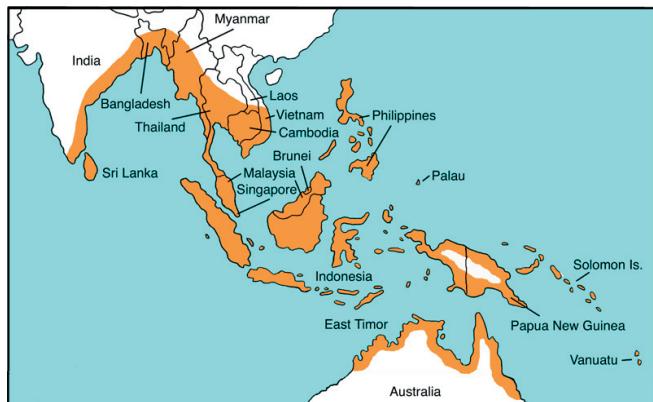


Figure 1. Distribution of *Crocodylus porosus*. The species is considered to be extinct in Thailand, Singapore and possibly Cambodia, and confined to a small reintroduced population in Vietnam.

Conservation Overview

CITES:

Appendix II: Australia and Papua New Guinea

Appendix II: Indonesia (Ranching Resolution Conf. 3.15, with special conditions applying to Papua Province pursuant to Resolution Conf. 8.22)

Appendix I: All other countries

2009 IUCN Red List: LRlc (Lower Risk, least concern; IUCN 2009). Total wild population is estimated to be in excess of 400,000 non-hatchlings, with secure populations in Australia, Papua New Guinea and Indonesia (Papua Province). Range is extensive. Seriously depleted in most other Range States, and probably extinct in the wild in Thailand, Cambodia and Vietnam. (Last assessed in 1996).

CSG Action Plan:

Availability of population survey data: Variable, ranging from “good” in Australia, limited in Papua New Guinea and Papua Province (Indonesia) and generally “poor” elsewhere.

Need for wild population recovery: High in some countries, although constrained by high human population and low habitat availability.

Potential for sustainable management: High in countries where sufficient habitat remains.

Principal threats: Habitat destruction, illegal hunting, removal as pests and predators on people and livestock.

Ecology and Natural History

Crocodylus porosus is considered the largest of the living crocodilians, with reported lengths of up to 6-7 m (Webb and Manolis 1989, 2009; Whitaker and Whitaker 2008). Although accounting for far less human fatalities than the Nile crocodile (Caldicott *et al.* 2005), *C. porosus* preys on people when given the opportunity. It is one of the most widely distributed of all crocodilians, ranging from southern India and Sri Lanka, throughout southeast Asia, east through the Philippines to Micronesia, and down through Indonesia, Papua New Guinea and the Solomon Islands to northern Australia.



Figure 2. Adult male *C. porosus*. Photograph: Grahame Webb.

A great deal of ecological research was carried out in the 1970s and 1980s, particularly in Australia and Papua New Guinea. Contrary to its common name “Saltwater crocodile”, which implies a marine existence, the species commonly inhabits non-tidal freshwater sections of rivers, and inland freshwater lakes, swamps and marshes. Indeed, it thrives in freshwater environments. In the marine environment it mostly inhabits tidal rivers and creeks, where salinity changes with different seasons and distance upstream, but they regularly move around the coast between rivers and occupy offshore islands.



Figure 3. Tidal creek habitat of *C. porosus* in northern Australia. Photograph: Grahame Webb.

Long-distance voyages at sea occur (Allen 1974; Manolis 2005) with unknown frequency (eg Cox 1985; Jelden 1985; Webb *et al.* 1984, 1987; Messel and Vorlicek 1989; Webb and Manolis 1989, 2009). Some of the highest densities of *C. porosus* have been reported from heavily vegetated freshwater swamps without any tidal influence (Webb *et al.* 1977, 1984). Breeding and recruitment take place principally in rivers with significant freshwater input, or in freshwater swamps (Jelden 1981; Webb *et al.* 1983; Cox 1985).



Figure 4. Adult male *C. porosus*, Arnhem Land. Photograph: Tom Dacey.

In the tidal waterways of northern Australia the movement of *C. porosus* between river systems appears to be related sex

and ontogenetic changes in social status. Radio and satellite tracking of large, male *C. porosus* are now providing insights into the pattern of movement out of rivers onto the coast, between river systems, and within tidal and non-tidal habitats, including homing associated with relocated individuals (Read *et al.* 2007; Kay 2004; Brien *et al.* 2008; WMI *et al.*, unpublished data).

In the Northern Territory of Australia, the recovery of wild *C. porosus* populations following protection (1971) was carefully documented, providing new information on population dynamics. Increasing numbers of large crocodiles over time have been accompanied by decreasing numbers of small crocodiles (Webb and Manolis 1992), which are predated or excluded from rivers and sometimes forced into marginal habitats, including upstream freshwater areas used for recreation by people (Letnic and Connors 2006).



Figure 5. Aggressive social interaction between sub-adult *C. porosus*. Photograph: Grahame Webb.



Figure 6. Mud-crabs are a common food item for *C. porosus* in tidal, saline areas. Photograph: Grahame Webb.

Female *C. porosus* mature at around 2.2-2.5 m (12+ years of age in the wild). They lay their eggs in a mound of vegetation during the annual wet season (October-May; Webb *et al.* 1977, 1983). Mean clutch size in Australia is around 50 eggs at 113 g per egg (Webb *et al.* 1983), whereas in Papua New Guinea it is around 60 eggs at 100 g per egg (Cox *et al.* 2006). Incubation is typically 80-90 days (depending on temperature). As nesting is a wet season activity, loss of nests

due to flooding is typically very high (Webb *et al.* 1983; Cox 1985). Some wild females actively defend their nests. Loss of eggs to non-human predators is exceptionally low. Lizards (varanids) take eggs, but usually when the eggs are dead, rotten and can be located by smell. The loss of very small numbers of eggs to rodents has been recorded (WMI, unpublished data). Wild pigs have been reported to raid *C. porosus* nests but the significance of this has not been demonstrated. In parts of northern Australia and Papua New Guinea wild eggs are collected for commercial ranching programs.

Conservation and Status

Consolidating and improving the conservation and management of *C. porosus* in each of the countries within its range is a highly challenging problem. The species is both widely distributed and occupies a wide range of wetland habitats, from the sea (including thousands of islands) to hundreds of kilometres inland. Throughout most of this region they are considered dangerous animals by those who share the environment with them. Quantifying status through regular surveys involves daunting logistics, beyond the reach of most national wildlife agencies. The species has the most commercially valuable hide of any crocodilian (Fuchs 2006), and was intensively hunting for skins historically throughout their range, particularly from the mid-1940s to the 1970s. Depleted populations have the biological capacity to recover reasonably quickly if: (1) habitats are intact; (2) they are given the opportunity through effective protection; and (3) people are prepared to tolerate expanded populations. However, these three preconditions are rarely met. Habitat loss continues to be a major problem in many areas occupied by *C. porosus*, and they are frequently killed as pests regardless of whether their skin is used commercially or not. Unless incentives are provided, in most parts of their range people are not prepared to tolerate increases in *C. porosus* abundance, particularly the 10- and 20-fold increases that are biologically achievable. Information on the current status of *C. porosus* in each Range State is summarised as:

Australia: Surveys by Professor Harry Messel and colleagues established the baseline for crocodile monitoring in northern Australia in the early 1970s (eg Messel *et al.* 1978-1987). The population was protected (1969-74 in different States and Territories) after intensive unregulated hunting since 1945-46. The recovering Australian population was transferred to CITES Appendix II (for ranching) under Resolution Conf. 3.15 in 1985 (Webb *et al.* 1984), and was given an unqualified Appendix-II listing in 1994. This was under the old Berne Criteria, as Resolution Conf. 9.24 was only agreed at the 9th CITES meeting.

In the Northern Territory, spotlight surveys carried out since the early 1970s indicate that in some rivers the population continues to increase, whereas in others numbers have stabilised (Fukuda *et al.* 2011), despite high levels of legal egg harvest (the ranching program) in almost all river systems (Letnic 2004). The size structure is now biased towards larger animals (>2 m), and total crocodile biomass continues

to increase even in rivers where numbers have stabilized (Fukuda *et al.* 2011). The total population in the Northern Territory is considered to be approaching pre-exploitation levels (Webb *et al.* 2000; Letnic 2004). A sustainable use program based on ranching of wild eggs forms the basis of management (see Leach *et al.* 2009), combined with a program of problem crocodile removal (Letnic 2004; Nichols and Letnic 2008), a limited wild harvest by landowners, and public education to reduce HCC (Letnic 2004). Six farms are currently in operation in the Northern Territory (PWSNT 2005). The degree to which introduced cane toads (*Bufo marinus*) have impacted on *C. porosus* is unknown, but is not generally considered significant.



Figure 7. Female *C. porosus* at nest. Photograph: Grahame Webb.

In Western Australia, major populations in the northwest of the state are in protected areas. The monitoring program is based on an annual aerial survey, with spotlight surveys carried out less regularly in some areas (Mawson 2004). Helicopter count surveys, which target larger animals in the population, in the Ord River and West Arm indicate mean rates of increase of 5.1% p.a. (2000-2008) and 4.1% p.a. (1999-2008) respectively. Spotlight surveys of the Ord River carried out in 2008 indicate that the overall rate of increase, based on all size classes, is 8.2% p.a. (1992-2008) in the tidal section and 5.5% p.a. in the non-tidal section of the river. Harvesting of juveniles, sub-adults, adults and eggs has been undertaken at various times in West Arm. Crocodile farms operate in Wyndham and Broome.

In Queensland, there is a high human population on the east coast and significant habitat alteration for agriculture. The abundance of *C. porosus* varies between river systems, with the highest densities reported from north-west Cape York Peninsula (Read *et al.* 2004a,b). Size structure varies between biogeographical regions. Recent surveys (2007) of 47 major waterways (767 km surveyed) along the east coast of Queensland revealed a relative density of 0.36 NH/km (Queensland Parks and Wildlife Service 2007). Crocodiles ranged in size from hatchlings to 5 m, with the majority, for which length could be estimated, less than 2 m (61.6%). Hatchlings comprised 38% of all crocodiles sighted, while "eyeshines" comprised 27.7%. Conversely, surveys based on 10 key river systems in western Cape York Peninsula in

2008 showed a relative density of 0.85 NH/km with moderate breeding populations (Big Gecko, pers. comm. 2009). Identifiable threats to breeding include feral pests (toads) and invasive weeds.

Based on comparisons with previous survey work (since 1996) in the same areas (Kofron and Smith 2001; Read 2002), the population of *C. porosus* on the east coast of Queensland has been increasing marginally since XXXX for the majority of waterways north of Cooktown (Read *et al.* 2004). How this relates to the historical population remains unclear. Over the last few years authorities have been under increasing public pressure to deal with increasing numbers of crocodiles in urban areas, and this seems to be in response to a general increase in the human population and intensive publicity about crocodile reporting procedures following the implementation of the Trial Intensive Management Area for Crocodiles (TIMAC) management program in 1998 and the “Croc-Wise” campaign in 2001. Following a review of Queensland Environmental Protection Agency’s (EPA) crocodile management program (Brien 2008), the recommendations adopted in February 2009 were incorporated into a new Estuarine Crocodile Management Manual, which informs EPA staff of revised policies, delegations, guidelines and procedures now in place (see Manolis 2009).

The utilization of crocodiles on Queensland farms is currently restricted to captive breeding, with some farms importing large numbers of ranched crocodiles from the Northern Territory and Western Australia. The situation with wild egg harvesting is presently under active review (Adam Britton, pers. comm. 2009).

Australia is considered the most secure long-term stronghold for *C. porosus* throughout its range.

Bangladesh: Saltwater crocodiles occur in the Sunderbans (Ganges delta), but no recent population data are available. The population, estimated to be 150-200 individuals in 1985, is believed to have been reduced to less than 100 due to a variety of reasons, including an increasing human population,

habitat alteration and illegal killing by people (eg fishermen believe crocodiles compete with them for fish) (Manik 2009). One commercial farm, based on production through captive breeding, acquired adult stock from Malaysia. A license for a second farm was approved by Government in late 2008 (Sharma 2008). The Karamjal Crocodile Breeding Centre, established in 2000, had one pair of adults and 125 hatchling/juveniles in stock in early 2009. One of the goals of the centre is to make animals available for release into the wild, when they have reached 2 m in length - no crocodiles have been released to date (Manik 2009).

Brunei: Little information is available on the status of *C. porosus* in Brunei. Cox (2006) reported low numbers in most rivers and creeks in Brunei Bay (relative density of 0.33 ind./km). Habitats are largely undisturbed, so the biological potential for a recovery exists if incentives for the local population to accept increased numbers of crocodiles can be provided (Ibrahim and Cox 2006). The extent of HCC is unknown, although attacks have been recorded recently (Tom Dacey, pers. comm. 2009).

Cambodia: Preliminary reports from Cambodia (Thuok and Tang 1994) suggest *C. porosus* may still occur in small numbers, although no further details are available. The majority of crocodiles in Cambodia, in the wild and in farms, are *C. siamensis*. It is believed that *C. porosus* was extirpated from Tonle Sap Lake about 30-50 years ago (Platt *et al.* 2006), but some may possibly occur in coastal areas of the country (Jelden *et al.* 2005). Very few *C. porosus* are held on the 900+ crocodile farms in Cambodia (Jelden *et al.* 2005). Hybridization with *C. siamensis* in Cambodian farms is mainly with *C. rhombifer* (introduced from Cuba to Vietnam in 1985, and then from Vietnam to Cambodia more recently) rather than *C. porosus* (Starr *et al.* 2009).

China: The presence of *C. porosus* in southern China remains to be verified. Various farming operations on mainland China and Hainan Island have some *C. porosus*, imported from Range States such as Thailand (Chen 2001; Geng 2001; Li 2001).



Figure 8. *Crocodylus porosus*. Photograph: Grahame Webb.

East Timor: The population status of *C. porosus* in East Timor is unknown. A reasonable population may exist in Lake Iralalaro, which is being assessed as a national park and also for a hydroelectric scheme (Manolis 2006). At least 1-2 fatal attacks are reported to occur each year. Crocodiles are culturally very important to local people, and *C. porosus* is the national animal (Anon 2008c). A small number of *C. porosus* are held in captivity in the capital, Dili. Political unrest since independence has hampered efforts to assess the *C. porosus* population in the country. Aerial surveys of marine coastal habitat undertaken in 2008 resulted in some opportunistic sightings of *C. porosus* (Kiki Dethmers, pers. comm. 2009). A CSG mission visited East Timor in September 2009 with a view to initiating dialogue with Government (Webb 2009).

India: Saltwater crocodiles remain in the northeast coastal region of mainland India and the Andaman Islands (Singh and Kar 2006). A restocking program in Bhitarkanika National Park (BNP), Orissa State, has released more than 2300 captive-reared juveniles (approximately 1 m long) between 1977 and 2009. Some have matured and several released females are now reported to be nesting successfully in the wild (Kar 2007a, 2009). The *C. porosus* population in BNP has been increasing since the reintroduction program started, from 95 sightings in 1976/77 (relative density= 0.87/km) to 1596 sightings in 2009 [1484 individuals in the park (relative density= 13.5/km), and a further 112 in areas surrounding the park] (Kar 2009). Almost 74% of crocodiles are found in the Kanika Range. The number of nests has increased from around 55 in 2004 to 65 in 2009 (Kar 2009). This population increase has led to increased dispersal and human-crocodile conflict (HCC). Local fishermen are now employed to capture problem crocodiles and relocate them back to BNP (Anon 2008b). Recently, groups of captive-bred *C. porosus* were released by the Forest Department in the southern-most part of BNP, but primarily as a strategy for deterring human activities in the mangrove forest (Kar 2007b).

The proposed development of several seaports along the coast near BNP and the development of the Rengali Canal, which will reportedly starve BNP of 95% of its fresh water, may both have a detrimental effect upon BNP and the *C. porosus* population that it sustains (Janaki Lenin, pers. comm. 2009).

In the Andaman Islands, crocodiles are widely distributed but population expansion through intrinsic breeding appears to be constrained by the lack of suitable breeding habitat (freshwater swamps). Human occupation is displacing crocodiles (Andrews and Whitaker 1994) and a recent study has examined HCC in this area (Whitaker 2008).

Indonesia: An extensive survey program was conducted by FAO and the CITES Management Authority (PHKA - Direktorat Jenderal Perlindungan Hutan dan Konservasi Alam) in the 1990s, but it did not provide an estimate of the total population of *C. porosus* within Indonesia, nor its distribution across the archipelago nation. The stronghold for *C. porosus* is Papua Province, particularly the Mamberano River drainage in the north. Past human exploitation and habitat alteration have reduced the population of *C. porosus*



Figure 9. *Crocodylus porosus*. Photograph: Grahame Webb.

throughout much of Indonesian, although localities in Sumatra and the extensive rivers and lowlands of Kalimantan clearly support wild populations. With the exception of Papua Province, only captive breeding of *C. porosus* is supposed to be permitted elsewhere in Indonesia (eg Java, Sumatra, Kalimantan, Sulawesi), however ranching (collection of wild juveniles) remains widespread and commonplace in Sumatra and Kalimantan, an issue that needs to be resolved by CITES. In July 2007 there were 15 registered farms in Indonesia (Manolis 2007; Manolis and McInnes 2007). The last intensive review of crocodile conservation and management in Indonesia was in the early 1990s (Webb and Jenkins 1991).

Despite a self-imposed hunting moratorium between 1994 and 1996, it seems that by 1997 many crocodile farms in Papua Province had stockpiles of wild *C. porosus* skins collected during this time. Based on these stockpiles, the management plan was revised in 1997 (Directorate General of Forest Protection and Nature Conservation 1997) (Hellen Kurniati, pers. comm. 2009). A system of ranching (juveniles) and wild harvest (sub-adults), similar to that established in neighbouring Papua New Guinea, is now well established in Papua Province.

Annual export quotas are established by the CITES Scientific Authority (LIPI - Lembaga Ilmu Pengetahuan Indonesia) based on monitoring results, and the CITES Management Authority (PHKA) regulates the quotas. Spotlight surveys, which form the basis for monitoring the wild *C. porosus* population (Kurniati and Rumbarar 1999), were not undertaken between 1998 and 2008, and a zero export quota for the species was put in place. However, in 2007, it was reported that about 10,000 hatchlings were taken through ranching (Hellen Kurniati, pers. comm. 2009). Industry is also interested in an egg harvest, which was undertaken on a trial basis with *C. novaeguineae* in the early 1990s under the FAO project (Manolis and McInnes 2007), but costs of collection in the remote swamps of Papua Province were considered prohibitive (Hellen Kurniati, pers. comm. 2009).

Industry recently raised concerns that the harvest quotas in Papua Province could be increased, and that the system of

allocation of the quotas between farms may not be equitable (Manolis and McInnes 2007). Although minimum and maximum size limits for wild *C. porosus* skins (25 cm and 51 cm belly width respectively) are established, large skins are still purchased illegally by buyers. It is difficult for hunters to distinguish between the two species of crocodiles around the maximum size limit.

It is widely recognized that the crocodile industry in Indonesia (as in Papua New Guinea) is an important, and sometimes the only, source of cash income for many rural communities in remote areas.

Malaysia: In Peninsular Malaysia, *C. porosus* is considered rare. Sebastian (1993) listed 10 localities where *C. porosus* had been reported and suggested that the Setui-Chalok-Bari basin on the east coast near Trengannu may the most significant population, but it has not been confirmed with surveys. A preliminary survey of *C. porosus* in Rembau Estuary, undertaken in 2009, indicated a relative density of 2.9 NH/km; the presence of hatchlings indicating successful nesting the previous season (Nazli and Hashim 2009).

In Sabah, *C. porosus* is reportedly common in the Kinabatangan River and associated wetlands. Stuebing and Mohammed Sah (1992) surveyed the Klias River and found a small but viable population of around 50 individuals, while Cox and Gombek (1985) reported uniformly low densities throughout Sabah. More recently, Kaur (2006) reported the relative density of *C. porosus* in the Segama River had increased from around 0.04 ind./km in 1981 (Whitaker 1984) to 1.42 ind./km in 2005. Stuebing *et al.* (2002) reported a mean density of 1.1 non-hatchlings/km in Sabah rivers: 22 times that reported by Whitaker in 1984 (0.05 NH/km).

The *C. porosus* population in Sabah has recovered significantly over the last 20 years due to: legal protection (since 1982); a decline in the timber industry which decreased habitat/river disturbance; siltation leading to the alteration of downstream river habitats; stabilization of oil palm estates and secondary growth along river banks; opening of closed canopy swamp and riverine forest; the El Niño-Southern Oscillation episode



Figure 10. *Crocodylus porosus* in tidal, coastal habitat.
Photograph: Grahame Webb.



Figure 11. Female *C. porosus* with hatchlings. Photograph: Grahame Webb.

of 1997-98 which reduced flooding of nests and led to high recruitment that year; and, a dramatic decline in the harvest of wild crocodiles for skins during the late 1990s due to both lower prices and the implementation of CITES (Steubing *et al.* 2002).

The University of Malaysia Sabah is planning to quantify the current status of *C. porosus* in Sabah through wide-ranging surveys. The increase in HCC in recent years is of major concern to authorities (Webb 2008a), with 28 attacks (11 fatal, 17 non-fatal) reported between 2000 and 2008 (mean 3.1 attacks per year) (Andau *et al.* 2004; Look Fook Soon Trading, unpublished data). Problem crocodiles have been captured and removed to farms (Tom Dacey, pers. comm. 2009; Look Fook Soon Trading, unpublished data). A management/action plan drafted in 2002 is being reassessed in light of increased numbers of *C. porosus* and HCC. A sub-regional meeting planned for June 2010 will allow discussion of these issues with regional neighbors and other experts.

Like Sabah, in Sarawak *C. porosus* occurs in most major rivers and large individuals are sufficiently common to be a serious threat to people. Surveys undertaken in the early 1980s found uniformly low densities of crocodiles throughout Sarawak (Cox and Gombek 1985), but more recent surveys indicate that numbers have increased markedly in many rivers. Surveys conducted in 28 rivers since 1996 indicate an overall relative density of 0.62 NH/km (Engkamat Lading, unpublished data), but the data are insufficient to allow trends over time to be quantified. Surveys undertaken in 2008 in five rivers reported a mean density of 0.87 NH/km (range= 0.60 to 2.07) (M.K.B. Zaini, unpublished data).

Attacks on humans in Sarawak have increased from a mean of 0.9/year (1980-1985) to 3.3/year (1986-2004) (Lading 2004). Authorities now undertake culling operations in areas where fatal attacks have taken place. In May 1992, a notorious and distinctively marked (white back) *C. porosus*, Bujang Senang, was killed after 30 years in which it is reported to have eaten 13 people (Ritchie and Jong 1993).

Myanmar: Once widely distributed throughout all coastal areas, *C. porosus* is now largely restricted to the lower Ayeyarwady (= Irrawaddy) River, and coastal Rakhine and Tanintharyi States. The only viable population is in Meinmahla Kyun Wildlife Sanctuary and adjacent forest reserves of the Ayeyarwady delta, where nesting and recruitment were documented in 1999 and 2003 (Thorbjarnarson *et al.* 2006). Hatchlings from the sanctuary were collected for captive rearing and released back to the wild when up to 1.2 m long (TL); 68 were released between 1998 and 2001 (Thorbjarnarson *et al.* 2006). A farming/ranching program was implemented by Government in 1978, and a farm established in 1979 (Aung Moe 1994). Juvenile *C. porosus* collected from the wild (4097 between 1978 and 1999) and captive-bred individuals (3087 hatchlings between 1983 and 1999) were used to stock the farm. Exports were mainly of live animals to Thailand and Singapore, but since 1990 have been minimal. The farm was reported as suffering from a range of technical problems (Thorbjarnarson *et al.* 2006), and was proposed for registration as a CITES captive breeding facility in early 2008 (see AC24 Doc. 5.2; www.cites.org/eng/com/AC/24/index.shtml).

Palau: Crocodiles were extensively hunted in Palau for their skins between the 1960s and 1980s. The first systematic survey of crocodiles undertaken in 1991 by Messel and King (1992b) recorded 42 crocodiles in 112 km of waterway, concentrated in two small populations at North Estuary on Belilou and Ngerdok Lake on Babedaob. Brazaitis *et al.* (2009) estimated the total population to be 500-750 individuals, based on a 2003 survey. The Bureau of Marine Resources has run a crocodile program since 2004, with annual, country-wide surveys undertaken since 2005. The most recent surveys revealed relative densities of 0.41 to 1.48 ind./km in coastal mangrove habitat and 0.41 to 2.81 ind./km in creeks, with the majority of individuals estimated to be 0.6-3.0 m TL. The survey results available (2003, 2005-2008) suggest that the population has not increased significantly since the early 1990s, and is probably stable (Joshua Eberdong, pers. comm. 2009). Most of the 46 past/present crocodile hunters interviewed in 2002/2003 felt that there were more crocodiles now than 5, 10 or 50 years ago (Matthews 2003, 2005).

The Palau program also focuses on ‘problem’ crocodile complaints and public awareness, with 21 problem crocodiles reported between 2005 and 2008, mostly from the north of the country (Joshua Eberdong, pers. comm. 2009). Despite concerns about the genetic integrity of *C. porosus* in Palau due to past importation of different crocodile species (*C. novaeguineae*, *C. mindorensis*, *Alligator mississippiensis*; Brazaitis *et al.* 2009), an analysis of 39 blood samples from wild *C. porosus* confirmed no hybridization (Russello *et al.* 2007). A CSG review in 2005 highlighted the fact that crocodiles are not currently protected by law, and that the public generally “dislike” them, and consider them pests (Anon 2006a). At times crocodiles are killed and eaten as food. A few adult *C. porosus* are maintained in Koror, and some captive-bred hatchlings have been released back into the wild. A management recovery plan is being drafted with assistance from the US Fish and Wildlife Service.



Figure 12. Juvenile *C. porosus*. Photograph: Grahame Webb.

Papua New Guinea: *Crocodylus porosus* is widely distributed throughout the lowlands of Papua New Guinea and on New Britain, New Ireland, Bougainville and Manus. Current management of the wild population involves ranching (eggs, hatchlings, juveniles) and wild harvest (with size limits to protect breeding stock). A monitoring program has included regular nest surveys of representative habitats in the middle Sepik River since 1977, with a review of the program carried out in 1995 and subsequent revision of nesting indices (Manolis 1995). Nesting surveys indicate that the *C. porosus* population is increasing, with more recent increases in the Sepik River area attributed to a conservation awareness campaign and conservation incentives generated from an expanded *C. porosus* egg harvest (Wilken and Langelet 2004; Sine and Kula 2006). Mean rate of increases in “landowner secure” areas is much higher than that in “landowner-disputed” areas.

Introduced fish [Pacu (*Piaractus brachypomum*), Java carp (*Puntius gonionotus*)] are now threatening nesting habitat (Cox *et al.* 2006). Given the very large area of inaccessible and undeveloped habitat and the incentives for local traditional landowners to maintain crocodiles, *C. porosus* seems secure in Papua New Guinea. It is unclear whether an apparent increase in crocodile attacks over the last few years is linked to increasing *C. porosus* populations or better communication with remote areas with mobile telephones (David Wilken, pers. comm. 2008) so that knowledge of attacks is more easily spread. Recent reports from New Britain suggest that increasing numbers of attacks on people and livestock are due to increasing numbers of *C. porosus* (PNG National Newspaper, 28 August 2009).

Philippines: Saltwater crocodile populations and habitats are greatly reduced throughout the Philippines and no large populations of *C. porosus* remain (Ortega *et al.* 1994). Today they exist as relatively few single individuals and small groups, scattered through remaining wetland habitats. Areas with the highest numbers of *C. porosus* are thought to be on the island of Mindanao (eg Ligawasan Swamp), and in rivers and

estuaries around Palawan and northeastern Luzon. A recent survey (2008) found evidence of nesting in the Agusan River basin which may represent the best remaining population of *C. porosus* in the Philippines (Charles Ross, pers. comm.). Northern Sierra Madre National Park in Isabela may also be home to a small population of *C. porosus* (Rainier Manalo, pers. comm.), but they are threatened by killing as pests, by-catch in fishing nets, and by agricultural encroachment into the remaining habitats (Manalo 2004).

In the late 1980s and early 1990s, the majority of the remaining wild adult *C. porosus* population on Palawan (141 individuals) were caught and relocated to the Crocodile Farming Institute, where they formed the nucleus of a captive breeding population. The progeny of these animals were later relocated to private establishments, some of which have begun commercial farming based on captive breeding (Mercado 2007). Between 2006 and 2008, five reported (eg Anon 2006b, 2008a) and numerous unreported crocodile attacks on humans occurred in southern Palawan (Rainier Manalo, pers. comm. 2009), despite the remaining population consisting of very few individuals. Crocodiles that threaten the safety of people and livestock are usually killed.

In February 2007, a forum was convened to address conservation, management and sustainable use of crocodiles in the Philippines (Anon 2007). This led to an exchange of information and experience between organisations in Luzon (Mabuwaya Foundation) and Mindanao (University of Southern Mindanao) (USM Crocodile Research Team 2007; Mabuwaya Foundation Inc. 2007), and closer liaison with the developing crocodile farming industry. The Ligawasan Marsh Wild Crocodile Research Program was launched in 2007, with assistance from the fledgling industry. The initial aim is to quantify the status of wild *C. porosus* and *C. mindorensis* in Ligawasan Marsh and the surrounding central Mindanao River basin area (Pomares 2007). An interview survey of local residents suggested that *C. mindorensis* is much more commonly sighted than *C. porosus* (Pomares *et al.* 2009).

Solomon Islands: The only survey of crocodiles in the Solomon Islands was undertaken in 1989 by Messel and King (1990), who identified survey sites based on knowledge from local people and crocodile hunters. Suitable habitat is restricted by the terrain and further reduced by human occupation and agriculture, and most sightings were from three localities - Lauvi Lagoon (Guadalcanal), Lake Tatae (Russell Islands) and Ghahirahobo (Santa Isabel). With the cessation of hunting for skins in 1989, the *C. porosus* population has increased greatly and obviously, resulting in increased HCC and fatalities in different parts of the country. The situation may have been exacerbated by the banning of guns following civil unrest and the arrival of the Australian-led Regional Assistance Mission (RAMSI) in 2003, such that local people were unable to deal with problem crocodiles themselves. Planning is currently underway to assess the current status of the population, and to investigate options for ongoing management based on sustainable use (Josef Hurutarau, pers. comm. 2009). A small number of *C. porosus* were being held in captivity in Honiara in mid-2008.

Sri Lanka: The status of *C. porosus* in Sri Lanka is considered serious, with no conservation or management programs in place. A breeding population is known to exist in Muthurajawela Swamp (Devapriya 2004; Jayawardene 2004), although sporadic breeding is occasionally reported at other locations (de Silva and de Silva 2008; Gramentz 2008).

Recent surveys (2007-2008) of the Bentota River revealed a small breeding population, with the population size structure strongly biased towards hatchlings (35 cm) and yearlings (<70 cm) (93%) (Gramentz 2008), which is indicative of a depleted population attempting to recover. Devapriya (2001, 2004) observed 20 individuals along a 2.8-km stretch of the Dandugam Oya and 2-9 individuals in 1.7 km of adjacent marsh. *Crocodylus porosus* were reported recently in the Madu Ganga (de Silva and de Silva 2008).

De Silva (2008) reported an estimated population of 50 individuals in a 5-km stretch of the Nilwala River, and listed the destruction of eggs, habitat loss and the killing of hatchlings, juveniles and sub-adults as by-catch in fishing nets as major threats. Local communities along the river use a variety of crocodile exclusion enclosures for bathing, washing, etc., in response to attacks by *C. porosus* (de Silva 2008).

The entire country-wide population of *C. porosus* was estimated to be around 375 non-hatchlings in 1978, with the majority (250) confined to the southwest coast of the island (Whitaker and Whitaker 1979). Despite limited survey data, there is no indication that the current *C. porosus* population is much larger.

Thailand: Crocodile surveys undertaken in the early 1990s (Ratanakorn *et al.* 1994) revealed sightings of one or two *C. porosus* on Phuket Island, but the majority of suitable habitat in this area has been destroyed or occupied by people. No viable population exists. Occasional reports of crocodiles by local fisherman in the Ranong River, adjacent to the Myanmar border, and a report of a newly hatched clutch in 2007 (Yosapong Temsiripong, pers. comm. 2009) suggest a few individuals may still exist in this area. The species is considered to be extinct in other parts of Thailand. The number of *C. porosus* contained within Thailand's extensive crocodile farms is unknown, but could number in the thousands (12 farms were registered as CITES captive breeding operations at 1 May 2009). Thai farms contain mainly *C. siamensis*, and hybridization between *C. siamensis* and *C. porosus* is well established.

Vietnam: Saltwater crocodiles persisted in southern Vietnam and the Mekong delta until 10-20 years ago, but extensive habitat degradation and the direct capture and killing of crocodiles greatly reduced the population. By the mid-1940s no more than 100 *C. porosus* were thought to survive in the wild (Cuc 1994). It is unlikely that viable populations exist in the wild today, although with no survey data, the situation remains unclear. A re-introduction and recovery program for *C. porosus* in remaining suitable habitat was proposed by a recent CSG-led review mission (Jelden *et al.* 2008). Of the

374,775 crocodiles reported on Vietnamese crocodile farms in late 2007, the vast majority are *C. siamensis* with very few *C. porosus* (Jenkins and Sung 1998; Jelden *et al.* 2008). Nonetheless, hybridization of *C. porosus* with either *C. siamensis* or *C. rhombifer* (imported into Vietnam from Cuba in 1985) is a possibility (Jelden *et al.* 2008).

Vanuatu: The eastern-most population of *C. porosus* is recorded from eastern Vanua Lava in Vanuatu (New Hebrides and Banks Islands). The locality was surveyed in 1992 by Messel and King (1992a), who concluded that crocodiles were on the verge of extinction. Only two adult crocodiles were seen in the wild and the population is no longer breeding. In 2003, Australia Zoo was asked by the Vanuatu Government to capture and relocate a 3.6 m *C. porosus* from the heavily populated island of Maewo to Vanua Lava, where it is believed to have originated.

Other: Stray *C. porosus* have been encountered considerable distances from their normal range. For example:

- In 1971, a 3.8 m *C. porosus* was captured in southern Pohnpei, Eastern Caroline Islands, around 1360 km from the nearest population (Allen 1974; Buden and Haglelgam 2010).
- In late 1986, a crocodile, assumed to be *C. porosus*, was reported from Woleai Atoll, Yap State (Eldredge 1994; Buden and Haglelgam 2010).
- Around 1959, a 1.0-1.5 m long crocodile, assumed to be *C. porosus*, was killed at Eauripik Island, Yap State. Although not reported in the literature, many residents sighted the animal after it was killed and buried (Buden and Haglelgam 2010).
- In October 2004, an individual *C. porosus* was captured in the Marshall Islands, some 2000 km from the nearest population in Papua New Guinea (Manolis 2005).
- Takashima (1955) reported three crocodiles from Japanese territory; one from Iwo Jima (in 1744), one from Amami-Oshima at the northern end of the Ryukyu Islands (in 1800), and a third from Toyama Bay, on the main Japanese island of Honshu. All three were presumably specimens of *C. porosus*.
- A vagrant crocodile was reported on Nauru Island, 1160 km from the nearest population (Webb 1994).
- Re-examination of skeletal material from the Seychelles suggests that the species that occurred there at the time of European discovery, and subsequently extirpated by the 1800s, was *C. porosus* and not *C. niloticus* as previously assumed (Gerlach and Canning 1993).
- In 2007, a crocodile, assumed to be *C. porosus*, was captured in the Maldives, and in April 2009, suspected crocodile tracks were investigated at Gaafu Alifu Atoll (Anon 2009).

Saltwater crocodile populations are legally protected in most countries, but protection alone may be ineffective. Management programs based on sustainable use have been successfully implemented in Papua New Guinea, Australia and Indonesia (Table 1), the three countries that contain the majority of the global population of the species. Ranching,

wild harvest and captive breeding are all undertaken to varying degrees in each country.

In the remaining Range States, populations have been greatly reduced as a result of historical hunting and ongoing habitat loss. Nonetheless, protection has resulted in population increases in a number of countries (eg Sabah/Sarawak, Solomon Islands), to the extent that attacks on humans have increased and become a serious problem. Protection alone is unlikely to offer long-term security in these cases, because if it works, and wild populations increase, the crocodiles start to attack people again, creating incentives to eradicate them. Management options that allow recovered populations to be used sustainably, for the commercial benefit of landowners have particular utility with *C. porosus*.

Table 1. Types of legal use of *Crocodylus porosus*. E= eggs,

H= hatchlings, J= juveniles, S= sub-adults, A= adults.

¹Unclear whether previous ranching program has continued since late 1990s; ²Stock imported from Malaysia; ³Stock imported from elsewhere (eg Thailand); ⁴Farms mainly stock *C. siamensis*, with few *C. porosus* in captivity (Jelden *et al.* 2005, 2008). Numbers in brackets for “Captive Breeding” indicate numbers of CITES-registered captive breeding operations (www.cites.org/common/reg/e_cb.html; at 1 May 2009).

Country	Ranching	Wild Harvest	Captive Breeding
CITES Appendix II			
Australia	E, H, J	S, A	Yes
Indonesia	H, J	S	Yes
Papua New Guinea	E, H, J	S	Yes
CITES Appendix I			
Myanmar ¹	?	-	Yes
Bangladesh ²	-	-	Yes (1)
China ³	-	-	Yes
Malaysia	-	-	Yes (5)
Philippines	-	-	Yes (1)
Singapore	-	-	Yes (2)
Thailand	-	-	Yes (12)
Vietnam ⁴	-	-	Intended
Cambodia ⁴	-	-	?
Brunei	-	-	-
East Timor	-	-	-
India	-	-	-
Palau	-	-	-
Solomon Islands	-	-	-
Sri Lanka	-	-	-
Vanuatu	-	-	-

Farming of *C. porosus*, based on captive breeding is undertaken in Bangladesh, China, Thailand, Singapore, Malaysia, Myanmar, Philippines, Indonesia, Papua New Guinea and Australia. Stocks produced through captive breeding are

added to significantly through ranching programs (eggs, hatchlings and/or juveniles) in Indonesia, Papua New Guinea and Australia. Ranching is not possible in much of the former range of *C. porosus* because wild populations are severely depleted or extinct.



Figure 13. Captive breeding based on *C. porosus* is carried out in many Range States where the wild populations are depleted. Photograph: Grahame Webb.



Figure 14. Sustainable use programs have created positive incentives for the conservation of *C. porosus*. Photograph: Grahame Webb.

As a species, the global population of *C. porosus* is secure, because of large populations, extensive habitat and effective management in Australia, Papua New Guinea and to a lesser degree Indonesia. There are increasing *C. porosus* populations in the Solomon Islands, Sarawak and Sabah, due to effective protection measures, and management may require incentives derived from sustainable use to counter negative public attitudes towards them. Reintroduction and protection efforts in Bhitarkanika National Park, India, have been successful to the point that increasing HCC is being reported. Re-establishment of large populations in India outside protected areas may never be possible due to the large human population and lack of suitable habitats. Likewise, re-

establishment of wild populations of *C. porosus* in Singapore, Thailand, Vietnam and Cambodia, where the species is essentially extinct, is unlikely, although in some cases it may be possible in pockets of protected areas.

Ironically, *C. porosus* in the wild is most secure in the countries where the wild population is subject to sustainable use.

Priority Projects

High priority

1. **Status surveys:** Recent quantitative and qualitative assessments of the current status of wild *C. porosus* populations in the majority of Range States are lacking. This requires a national coordinator, who can assess whatever historical data are available, and who can ideally undertake qualitative and quantitative surveys with a view to determining whether status is improving or declining. Status overviews are required for most countries, but in some even basic data are missing [Bangladesh, Brunei, Cambodia, East Timor, Indonesia (outside Papua), Myanmar, Sri Lanka, Vietnam].
2. **Management:** Population surveys planned for Sabah, Sarawak and the Solomon Islands, where all indications are that the wild populations of *C. porosus* are increasing, are needed to better inform management. The conservation problem appears to have been largely solved (depleted populations are now increasing). However, as a consequence HCC is on the increase, and if realistic management programs tailored to local circumstances are not developed and implemented, there will be no public or political will to tolerate the expanded population. Sustainable use may be one means through which economic incentives can be generated (eg Whitaker 1984), but the probability of success depends on many factors. In Sarawak and Sabah, captive breeding operations based on *C. porosus* are established (Table 1), and some provide an avenue for housing problem crocodiles (Look Fook Soon Trading, pers. comm. 2008). The degree to which the wild population may be able to be used sustainably has not been investigated fully, in part due to a lack of information on the status of the wild population (see above).
3. **Crocodile management in Indonesia:** Population monitoring of *C. porosus* in Papua Province has not been undertaken since 1998 (Kurniati and Rambarar 1999), but may restart in 2009/2010 (Tonny Soehartono, pers. comm. 2009). Although wild harvest quotas have been reduced because of no survey data, the allocation of the quota among licensed farms located in Papua Province, Sumatra and Java, is of concern to some operators (see Manolis and McInnes 2007). The regulatory system may benefit from external review by the CSG or other competent groups. Protection is nominally afforded to *C. porosus* in areas other than Papua Province (ROI 1994), but it seems ranching is occurring in Sumatra, Kalimantan and perhaps other locations. If so, it needs to be sanctioned by CITES, through a proposal to the next Conference of the Parties.

4. Increased regional cooperation in Southeast Asia: The close association between production and trade in crocodilian products (including *C. porosus* but mainly *C. siamensis*) between Cambodia, Vietnam, Thailand and China indicates that management, conservation and regulatory activities need to be coordinated in this sub-region (see Jelden *et al.* 2005, 2008). Technical exchange (eg training), surveys, development of management programs and mutually supporting regulatory structures (eg enforcement, Customs) are recommended.

Moderate Priority

5. Crocodile conservation program in India: An evaluation of restocking and the identification of additional release sites is in need of review. There are excess animals now in captivity and insufficient release sites to take them. The issue of HCC in Bhitarkanika National Park and adjacent areas needs to be assessed in view of the increasing attacks on local people. The new port development adjacent to Bhitarkanika National Park makes a very strong and compelling case for a stringent monitoring program to be introduced.

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