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Demonstrating decline of an iconic species under sustained indigenous harvest – The pig-nosed turtle (*Carettochelys insculpta*) in Papua New Guinea

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ABSTRACT

Papua New Guinea has astonishing biological and cultural diversity which, coupled with a strong community reliance on the land and its biota for subsistence, add complexity to monitoring and conservation and in particular, the demonstration of declines in wildlife populations. Many species of concern are long-lived which provides additional challenges for conservation. We provide, for the first time, concrete evidence of a substantive decline in populations of the pig-nosed turtle (*Carettochelys insculpta*); an important source of protein for local communities. Our study combined matched village and market surveys separated by 30 years, trends in nesting female size, and assessment of levels and efficacy of harvest, each of which was an essential ingredient to making a definitive assessment of population trends. Opportunities for an effective response by local communities to these declines needs to consider both conservation and fisheries perspectives because local communities consider the turtle a food resource, whereas the broader global community views it as a high priority for conservation. Our study in the Kikori region is representative of harvest regimes in most rivers within the range of the species in Papua New Guinea, and provides lessons for conservation of many other wildlife species subject to harvest.
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1. Introduction

Papua New Guinea (PNG) is one of 17 megadiverse countries that account for 70% of global biodiversity (Mittermeier et al., 1997). The biodiversity of many of these nations is under threat, particularly in tropical countries that allow and encourage aggressive mining, forestry and agricultural practices driven by immediate financial imperatives rather than longer term sustainable economic considerations (Laurance et al., 2001; Sodhi et al., 2004). Papua New Guinea has remarkable species diversity and high levels of endemism. Its biodiversity is of international concern, and attracts considerable conservation funding in support of government initiatives to prevent overexploitation of their biological assets (Connell, 1997).

Charting a path to a sustainable future is complicated by the equally astonishing cultural diversity of the Papuan human population, many of whom still live traditional lives in villages distributed through the New Guinea highlands and coastal plains (Foley, 1986). This cultural diversity coupled with a strong community reliance on the land and its biota for subsistence, presents a number of challenges for monitoring and managing wildlife populations. Wildlife management is complicated by a shift from subsistence to a cash economy, increasing human population size and the introduction of modern fishing and hunting techniques (Bennett and Robinson, 2000). These changes can intensify the pressures placed on natural resources (Dudgeon et al., 2006; Groombridge and Wright 1982; Rosser and Mainka, 2002) and the outcome is often the decline and extinction of wildlife populations.

Exploitation of long-lived species brings additional problems for conservation management (Marsh et al., 2004; Romero et al., 2002). They generally exhibit slow growth and late maturity. Reproduction is usually characterized by low fecundity (e.g. large cetaceans) or variable and infrequent recruitment (e.g. sea turtles) (Musick, 1999). These characteristics make long-lived species particularly vulnerable to excessive adult mortality (Broderick et al., 2006; Frazer, 1992, but see also Fordham et al., 2007, 2009). Furthermore, the impact of exploitation younger life stages and trends toward population collapse may be masked because absence of recruitment can be concealed by the presence of long-lived senescing adults. Declines may progress for many years before it is detected and overcome (Browne and Hecnar, 2007; Musick, 1999).

Long-lived animals are important sources of protein for indigenous communities and have been for many centuries (Milner-Gulland and Bennett, 2003; Smith, 1979). The pig-nosed turtle (*Carettochelys insculpta*), an iconic species from the Kikori region, is no exception (Georges et al., 2008a). It is of conservation

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concern because it is the sole survivor of a once widespread family (Carettochelyidae), because it has a restricted distribution, and because it is subject to intense harvest pressure (Groombridge and Wright, 1982). It is one of many chelonian species of international concern (Rhodin et al., 2011).

Highly prized as food, these turtles are caught and their eggs are collected for consumption by local villagers or trade in local markets (Georges et al., 2008a). Local villagers harvest *C. insculpta* eggs with close to 90% efficiency (Pauza, 2003). Growth in human populations, a greater propensity for villages to establish on riverbanks since tribal warfare ceased, and the introduction of new technologies, particularly outboard motors, have brought added pressure to turtle populations in recent decades. This has led to the widespread view that populations of *C. insculpta* have suffered severe population declines (Georges et al., 2008b; Groombridge and Wright, 1982; Pauza, 2003). There is however, remarkably little direct evidence of these declines, and what there is remains unpublished. The International Union for Conservation of Nature (IUCN) listing of the species as vulnerable (IUCN, 2009) rests largely on a precautionary approach to evaluation of its status. This uncertainty has in turn led to reduced commitment to act to conserve the pig-nosed turtle despite its international profile as a distinctive relic species.

Assessing the impact of small-scale or artisan fisheries in remote locations of developing countries is extremely necessary because of its value to local economies (Humber et al.,, 2010; Low et al., 2009; Salas et al., 2007; Soykan et al., 2008; Townsend et al., 2005). Nevertheless, few studies have the benefit of long term data (Broderick et al., 2006; Spotila et al., 2000). Furthermore, direct evidence of decline is very difficult to obtain. Indirect evidence through market surveys typically span too few years to be of value, and in any case can underestimate the extent of harvest (Milner-Gulland and Bennett, 2003). To eliminate some of these potential biases, it is necessary to combine market surveys with surveys of households and direct surveys of wildlife populations (Milner-Gulland and Bennett, 2003). Thus, obtaining defensible evidence of decline in complex situations involving both human harvest, altering harvest practice and patterns of consumption and environmental change presents a formidable challenge.

In this paper, we meet this challenge with matched surveys of *C. insculpta* consumption via both market and village over almost 30 years in the Kikori delta, which provide the first evidence of population declines of this iconic species. We compared the nesting female size between the two periods to evaluate the effect of selective harvesting of nesting females. We monitored the nesting survivorship in natural sandbanks to access the level of harvest pressure. Finally, we identify opportunities for an effective community level response to these declines with a view to establishing more sustainable harvest practices for this important food species.

2. Material and methods

2.1. Study site

The Kikori drainage extends from the coastal region and delta to the limestone plains of the Kikori lowlands (Löffler, 1977) in the Gulf Province of Papua New Guinea (Fig. 1). The river system is highly confined within its limestone bed, and meanders and oxbows are absent. The delta is a large alluvial plain below 40 m elevation, dissected by a tributary system of river channels, and formed where thick layers of soils, principally soft silts and clays, have been deposited over the underlying limestone plain. The coast comprises the delta islands exposed to the Gulf of Papua. Wind and wave action creates coastal beaches, sand bars and sand islands in what is a very dynamic system (Enesar Consulting, 2005).

Before interaction with Europeans, the lowland upstream sections of the Kikori River were characterized by a few sparsely-distributed small villages whereas the delta region had many villages each with more than 1000 people (David, 2008). Nowadays, there are 51 villages and fishing camps, from three major language groups, distributed over much of the lowland area. The Rumu language group comprises approximately 700 people living in villages mainly in the limestone plains upstream of the main Kikori Township. The Porome language group comprises approximately 600 people residing in villages of the delta region. The Kerewo language group is the largest, comprising approximately 1500 people whose lands are in the deltas and coastal regions of the Omati and Kikori River systems. Each of these groups is subdivided into networks of clans and lineages with their own territorial estates (Busse et al., 1993).

2.2. Methods

A daily survey of pig-nosed turtle eggs passing through the Kikori (7°24′44.45″S; 144°14′51.78″E) and Sirebi markets (7°12′23 .36″S; 144°14′47.80″E) was conducted during the turtle nesting seasons (September to February) in the years 1980–1981, 1981–1982, 2007–2008, 2008–2009. Only the Kikori market operated in the years 1980–1982. A second market was established at the Sirebi Forestry Camp in 2007 and continued to operate until early 2009. We based the comparisons among years on the Kikori market in 1980–1982 versus the combined totals for both markets in 2007–2009. Data recorders comprised volunteers from local villages, who visited Kikori and Sirebi markets every day of operation and recorded the number of pig-nosed turtle eggs for sale and obtained estimates of counts of eggs that had already been sold. We regularly visited the markets to undertake spot surveys as a cross check on the veracity of the accounts from the recorders.

Two riverine villages (Kopi and Waira) and one coastal village (Dopima) were selected for intensive monitoring of egg and turtle numbers consumed in the 2007–2008 and 2008–2009 nesting seasons. These villages were selected because of comparable data collected there in the nesting season of 1981–1982. Data on household consumption was recorded by volunteer village residents. Four volunteers in Kopi, two in Waira and one in Dopima visited all village families every week to access the number of eggs harvested per day. When shells or live turtles were available, we used a flexible measurement tape to measure the curved carapace length (CCL).

Nest survival rate was recorded for the two most remote nesting areas (Turuvio island and Wau creek sandbank) in the 2007–2008 and 2008–2009 nesting seasons. Data on nest fate were collected by local volunteers and validated by direct survey every month. Nest characteristics (clutch size, egg diameter and hatchling weight) were measured in all years. To ensure comparability of data, only data from nesting females, nests, eggs, and hatchlings from nests laid in the riverine sandbanks in December were used for the *t*-test comparisons between years. Price for the pig-nosed turtle meat and eggs was also recorded from villages and markets.

Data on egg diameter and hatchling weight were averaged by clutch to avoid pseudoreplication arising from lack of independence of eggs within clutches. Statistical tests followed those recommended by Sokal and Rohlf (1981) and were performed using SAS 9.1 or by hand. Chi-square tests were performed on counts of clutches as the independent entities satisfying the underlying multinomial assumptions. Where we had only egg counts, not clutch counts, the number of clutches was estimated by dividing the number of eggs by the average clutch size of 21.3, so that these data could be included in the statistical analyses. We used the difference between the total number of eggs consumed (market and villages) in the 1981–1982 nesting season and the average from

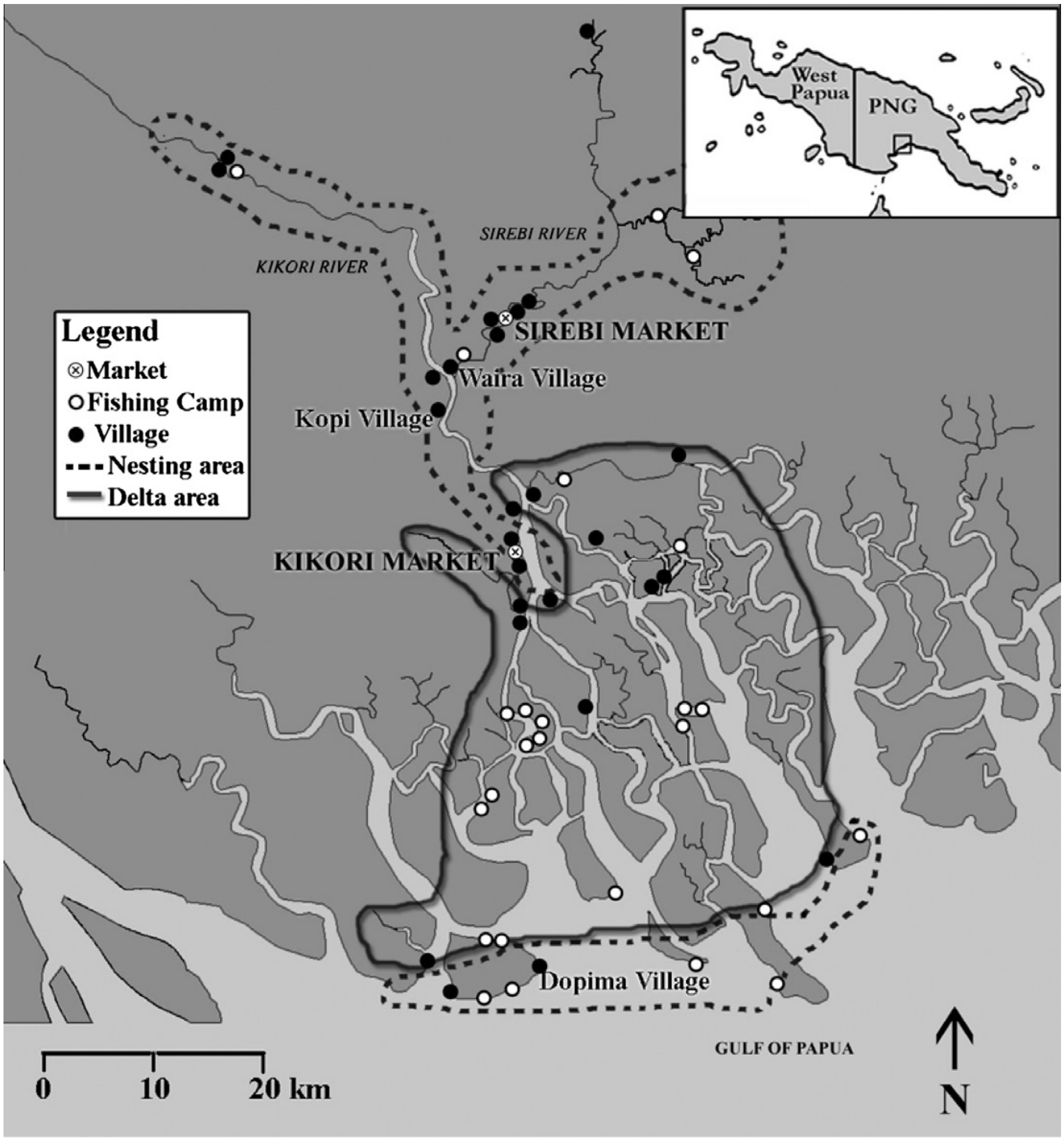

Fig. 1. Map of the Kikori region showing permanent settlements (villages), temporary settlements (fishing camps) and markets. Areas with sandbanks, where *Carettochelys insculpta* females lay their eggs, are delimited by dashed lines. The Kikori region is divided into delta, riverine (area upstream of the delta) and coast.

the total number of eggs consumed in the 2007–2008 and 2008–2009 nesting seasons to estimate the level of decline.

3. Results

The number of turtle eggs passing through the markets in 2007–2009 was substantially lower than in 1980–1982 ($X^2 = 269.04$, $df = 3$, $p < 0.0001$; Fig. 2). The proportion of eggs sold in market decreased from 28.5% (1980–1981) to 19.7.3% (2007–2008) and subsequently to 8.4% in the next year ($X^2 = 1704.29$, $df = 2$, $p < 0.00001$; Fig. 3). However, fewer eggs overall were consumed in the 2007–2008 and 2008–2009 nesting seasons in the villages of Kopi ($X^2 = 72.67$, $df = 2$, $p < 0.0001$), Waira ($X^2 = 62.65$, $df = 2$, $p < 0.0001$) and Dopima ($X^2 = 84.27$, $df = 2$, $p < 0.0001$) when compared with the numbers consumed in 1981–1982 in the same villages (Fig. 4). On the basis of these data, our best estimate of the level of decline is 57.2% since 1981.

Nest survival was exceptionally low on the nesting beaches of Turuvio Island during the nesting seasons of 2007–2008 (3.3% of 120 nests survived) and 2008–2009 (2.9% of 104 nests survived)

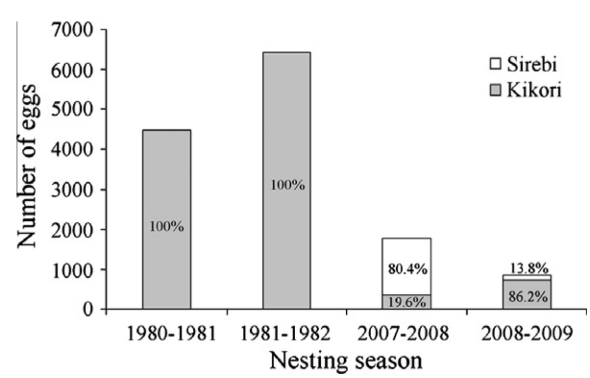

Fig. 2. Number and percentage of pig-nosed turtle eggs passing through the active markets of the Kikori lowlands (Kikori and Sirebi markets) in the nesting seasons of 1980–1981, 1981–1982, 2007–2008 and 2008–2009. There was a significant decline in trade between 1980–1982 and 2007–2009 ($X^2 = 269.04$, $df = 3$, $p < 0.0001$).

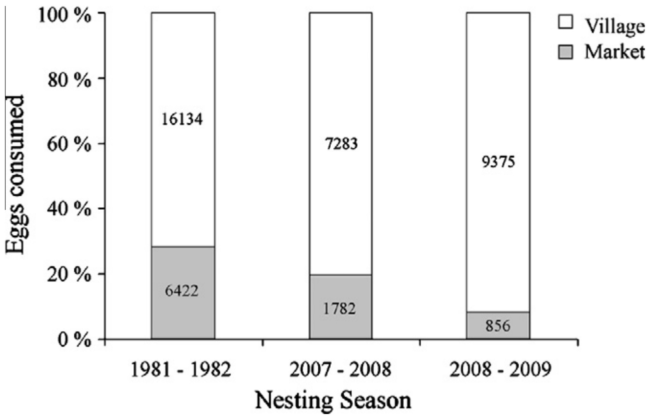

Fig. 3. Percentage and number of pig-nosed turtle eggs passing through the active markets and villages of the Kikori lowlands (Kikori and Sirebi markets) in the nesting seasons of 1980–1981, 1981–1982, 2007–2008 and 2008–2009. There was a significant increase in percentage of eggs consumed in the villages between 1980–1982 and 2007–2009 ($X^2 = 1704.29$, $df = 2$, $p < 0.00001$).

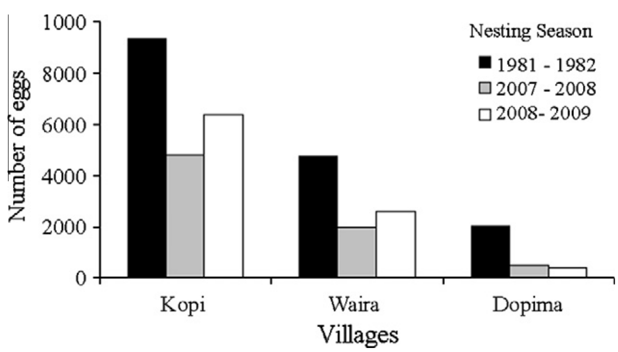

Fig. 4. Number of pig-nosed turtle eggs consumed in the villages of Kopi, Waira and Dopima in the nesting seasons of 1981–1982, 2007–2008 and 2008–2009. There was a significant decline in consumption between 1981–1982 and 2007–2009.

and Wau Creek 2008–2009 (2.0% of 100 nests) and did not differ significantly among any monitored location ($X^2 = 0.37$, $df = 2$, $p = 0.70$). Humans were the only predator responsible for nest mortality in Turuvio Island while monitor lizards (*Varanus indicus*) uncovered and removed the eggs of 65% ($n = 65$) of the 100 nests in Wau Creek, with a further 33% ($n = 33$) harvested by humans.

The average size of nesting females, clutch size and egg diameter was smaller in the 2007–2009 than in the 1980–1982 nesting season. On the other hand, egg and meat price increased and hatchlings were heavier (Table 1). However, only the size of nesting females was statistically significant ($t = 2.53$, $df = 16.2$, $p < 0.05$). Nesting females in 1980–1982 had an average curved carapace length 3.94 cm larger than in 2007–2009 (Fig. 5). Clutch size ($t = 0.91$, $df = 164$, $p = 0.36$), egg diameter ($t = 1.25$, $df = 52$, $p = 0.22$) and hatchling weight ($t = 1.22$, $df = 21.3$, $p = 0.24$) did not differ significantly between periods.

4. Discussion

Reports over the last 30 years have suggested dramatic declines in *C. insculpta* natural populations in New Guinea (Georges et al., 2008a,b; Groombridge and Wright, 1982; Pauza, 2003) but these have largely derived from anecdotal information or inference drawn from observations on the intensity of harvest. We have provided for the first time, concrete evidence of a substantive decline in these pig-nosed turtle populations. We drew this conclusion from matched village and market surveys spanning 30 years, trends in nesting female size, and assessment of levels of harvest, all of which are essential to make a definitive assessment of the population trends in this species.

Table 1
Nesting female sizes, nest and market attributes for *Carettochelys insculpta* from the Kikori region in the 1980–1982 and 2007–2009 nesting seasons.

Parameter	1980–1982	2007–2009	Trend
CCL[a] (cm)	58.2[b] ± 1.0 (52.2–61.0, $n = 9$)	54.3 ± 0.7 (46.8–57.1, $n = 20$)	Decrease
Clutch size	22.8 ± 0.5 (11–33, $n = 73$)	22.2 ± 0.6 (7–37, $n = 93$)	Decrease
Egg diameter (cm)	4.37 ± 0.02 (4.19–4.5, $n = 25$)	4.33 ± 0.02 (4.11–4.54, $n = 36$)	Decrease
Hatchling weight (g)	30.10 ± 0.88 (23.00–34.3, $n = 17$)	32.41 ± 1.10 (25.8–35.1, $n = 11$)	Increase
Egg price (Kina)	0.03 ± 0.00 (0.01–0.05, $n = 128$)	0.49 ± 0.01 (0.40–0.50, $n = 8$)	Increase
Turtle price (Kina)	3.5 ± 0.2 (1.0–5.0, $n = 54$)	23.8 ± 3.8 (10.0–55.0, $n = 12$)	Increase

[a] CCL = curve carapace length.
[b] Means are given with their SE, maximum and minimum sample values, and sample sizes.

Both village and market surveys are essential because the combined data capture consumption in the villages, exchange among local villagers, and informal sales in addition to formal trade through markets (Milner-Gulland and Bennett, 2003) and so are robust to shifts in patterns of consumption. Growth in human populations can be expected to shift the balance between village consumption and trade, and so can be expected to distort assessments made on market surveys alone. Indeed, we demonstrated an increase in the relative importance of consumption in villages over market trade between 1981–1982 and 2007–2009, illustrating the need to couple market sales with data on local village consumption.

Perhaps more difficult to assess is the effect of shifting emphasis from a subsistence economy to a cash economy as more villagers come to engage in resource development through mining, forestry industries and associated infrastructure development, or indeed employment in support of conservation efforts (Georges et al., 2008a,b). The impact of a cash economy is a double-edged sword. One cannot assume that economic development will reduce demand for wild meat. The opposite could easily happen in the short term (Milner-Gulland and Bennett, 2003). In the presence of well established transport infrastructure and legal or illegal trade networks, a cash economy can have devastating impacts on high profile species because of high returns and opportunities derived from a global market (van Dijk et al., 2000).

The impact of such trade on native turtle populations because of high demand in China arising from the combination of traditional practices and new found wealth is well documented (van Dijk et al., 2000). The initial stages of such trade in *C. insculpta* are seen in neighbouring Indonesia. International pet trade has largely driven the recently intensified egg collection in West Papua (Maturbongs, 1999; Shepherd and Nijman, 2007). The level of harvest involved is unlikely to be sustainable, but there are no rigorous monitoring programs in West Papua to assess the impact. This trade is also affecting the exploitation and conservation status of the species in PNG (Rhodin and Genorupa, 2000).

On the other hand, the global trade networks that have been established in West Papua (Samedi and Iskandar, 2000, 2002) and which extend across the border into the western province of Papua New Guinea (Georges et al., 2006; Rhodin and Genorupa, 2000) are not connected to the local networks in the Kikori region. An efficient transport infrastructure is absent in the Kikori region,

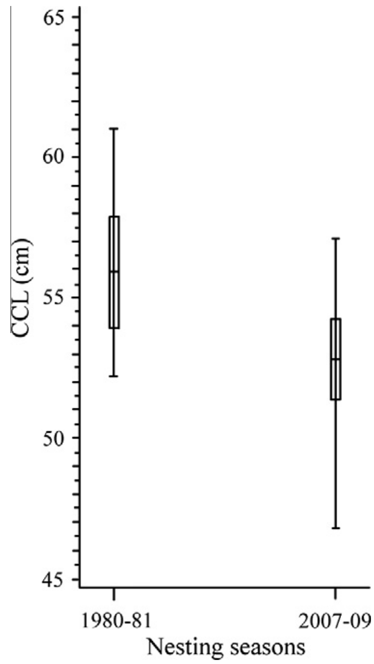

Fig. 5. Comparison of the body size of nesting females of *Carettochelys insculpta* for different nesting seasons of the Kikori. CCL, Maximum Curved Carapace Length in cm. Means are given with 95% confidence limits (boxes) and ranges (vertical bars). Nesting females were significantly smaller in 2007–2009 when compared with 1980–1981 ($t = 2.53$, $df = 16.2$, $p < 0.05$).

which can only be accessed by air or boat. Fuel is also a critical limiting factor for local villagers, which greatly limits any net returns. Georges et al. (2008a) found no evidence of trade in turtles, eggs or turtle products with markets outside Kikori, only an anecdotal report of live *C. insculpta* being shipped out of the region on logging boats for sale in the Asian market. However, we recorded crocodile skin (*Crocodylus novaeguineae* and *Crocodylus porosus*) and numerous species of shark fin being actively collected for the international trade, which demonstrates the existence of a trade system that could potentially include turtles.

In this context, a shift from a subsistence economy to a cash economy and an accompanying shift toward reliance on processed foods would be expected to reduce local demand for turtles. We assessed the impact of this possible confounding effect on our surveys by a concurrent study of the impact of harvest on nest survivorship. Our results showed an astonishing level of human harvest on eggs, which confirms an earlier unpublished report of nest harvest rates of 85.6% (Pauza, 2003). Our results demonstrated that, if there had been a reduction in harvest effort and hunting acumen by local villagers as a result of the developing cash economy, it had not yet translated to a reduction in the outcome of the harvest – the rate remained exceptionally high.

A third indication of the impact of harvest comes from the analysis of turtle body size. Human harvest can alter demographic parameters of turtle populations (Close and Seigel, 1997; Fenberg and Roy, 2008; Fordham et al., 2007; Gamble and Simons, 2004; Wolak et al., 2010). When a pristine population comes under harvest pressure, one of the first indicators is a reduction in body size (Bhupathy and Saravanan, 2006; Daza and Páez, 2007; Múnera et al., 2004), both because the larger individuals are more likely to be targeted or retained and because of reduction in life expectancy, which in a species with indeterminate growth, translates to a lower average body size in the population. We demonstrated a significant reduction in female body size in the past 30 years.

The combination of matched market and village surveys, the sustained and exceptionally high efficiency of human harvest, and the significant reduction in the body size of harvested female turtles all point to the firm conclusion that the pig-nosed turtle had suffered a substantial decline in population size in the past three decades in the Kikori region.

Such a decline is unlikely to be restricted to the Kikori delta as the species is under similar pressures elsewhere in PNG. In the Fly River also, pig-nosed turtle eggs and meat provide an important source of protein to complement agricultural produce (Georges et al., 2006) and they are heavily harvested there (Rose et al., 1982). Intensive egg harvest was also documented in the Purari River (Pernetta and Burgin, 1980), and West Papua (Cann, 1978). Around 1970, egg harvest increased substantially in the Eilanden River (West Papua), when the region became more secure (Cann, 1998). Recently, it was estimated that 1.5–2 million eggs are annually harvested in the Merauke Regency (Samedi and Iskandar, 2000). In the Vriendschap River only adult turtles were usually capture for consumption. However, egg collection has expanded massively since 1997 due to the influx of eggs harvest from outside West Papua (Maturbongs, 1999). Our data demonstrating a decline in the Kikori gave indirect substance to claims of decline throughout within its range in New Guinea and are likely to result in a re-evaluation of the status of the species in New Guinea and globally.

4.1. Conservation Icon or Fishery?

The global and local perspectives of the pig-nosed turtle are dramatically different. There is a potential for tension during the implementation of a conservation and management program for the pig-nosed turtle in the Kikori among indigenous people, wildlife managers, researches and conservationists.

Internationally, *C. insculpta* is a conservation icon. From the point of view of the local Papuan community, the pig-nosed turtle is an important and traditional source of food, particularly protein, and a source of supplementary income through trade. A conservation ethic has yet to penetrate community perspectives, and many villagers believe that the turtles are abundant, have always been abundant and will continue to be so (Carla Eisemberg and Arthur Georges, unpublished data). Those in the community who are concerned about the decline of the species are more concerned for sustainability of the resource (for future generations) rather than as an endangered species issue in the western sense. The local villagers view the species more as a fishery to be managed sustainably than a species to be conserved from the perspective of the international conservation movement.

From a fishery management perspective, decline in abundance is an inevitable consequence of exploitation, and is not of concern unless and until the decline threatens sustainability of the resource. Indeed, decline in a fishery stock ranging from 30% to 60% (depending on the resilience of the species) in relation to its virgin levels could be regarded as a normal and satisfactory outcome following the development of the fishery (Restrepo et al., 1998). From a conservation perspective, any substantial decline in abundance of a globally restricted species such as the pig-nosed turtle is likely to trigger concern.

So the two perspectives, indigenous and western, differ not in their common desire to see populations of the species persist in perpetuity, but in their response to demonstrated decline in abundance and in the level at which the population can decline and still be regarded as acceptable. This diversity in perspective is an important consideration in crafting a conservation plan for *C. insculpta* in PNG.

4.2. Achieving sustainability

Programs to manage wildlife resources should be sustainable in the long term, as well as biologically, economically and culturally acceptable (Bennett and Robinson, 2000; Campbell, 2002). Because conservation is about sustaining values, and because the value of *C. insculta* for the local population is centred on its use as food, not the more esoteric concerns of the international community, a focus on education to achieve sustainability of *C. insculta* as a fishery would seem most appropriate.

There is a potential for utilizing *C. insculpta* under a sustainable yield management to provide a valuable protein source for local inhabitants (Rose et al., 1982). The central question here is whether it is possible to achieve sustainability given the combination of life history attributes of the turtles (e.g. late maturing, slow-growing, long-lived) and harvesting practices (focus on nesting females and eggs). Organisms with these life history attributes are particularly susceptible to chronic disturbance and overexploitation (Congdon et al., 1993), especially when large reproducing females are removed (Tucker and Moll, 1997). An extreme level of iteroparity (repeated reproduction) is required in species with low seasonal probability of reproductive success (Congdon et al., 1993; Heppell, 1998). This concept promotes the perception that sustainable harvest of adult turtles is virtually impossible. However, it has been demonstrated that long-lived reptiles can be sustainably harvested when appropriate management regimes are implemented both for crocodiles (Bradshaw et al., 2006) and turtles (Fordham et al., 2007). Nevertheless, it is not known where *C. insculpta* is situated in the 'slow-fast' (recruitment, growth, maturity) continuum of life history characteristics and the question as to whether any level of harvest in the Kikori region is sustainable remains open.

Although a definitive answer to this question is not known, we do know that reptiles, especially turtle eggs and meat, are an important and seasonal source of protein for many rural populations in developing countries, and a potential source of supplementary income through trade (Klemens and Thorbjarnarson, 1995; Mittermeier et al., 1992). Complete elimination of pig-nosed turtle harvest in Kikori could potentially aggravate their already protein-deficient diet (Foley, 1986). Exclusionary and restrictive conservation practices in developing countries have often alienated local people and failed to protect the wildlife (Pimbert and Pretty, 1998). It is unlikely that any efforts to dramatically curtail the harvest of pig-nosed turtles would be acceptable to the local community and any attempt to do so could lead to counterproductive attitudes to conservation on broader agendas.

Our study in the Kikori region is likely representative of harvest regimes in most areas within the species range in PNG, from the Purari River in the east to the Fly River in the west, and provides lessons for conservation of many other wildlife subject to harvest. This type of scenario calls for a holistic approach that integrates all biological, socioeconomic and political disciplines (Campbell, 1998; Frazer, 1992; Ludwig, 1993; Marcovaldi and Marcovaldi, 1999; Milner-Gulland and Bennett, 2003). The approach needs to be adaptive, where communities continue to draw upon the resource concurrent with monitoring that is sufficiently robust to quantify trends in abundance. Without community-led action informed by applied research and environmental education, supported by wildlife protection, and adequately funded by those industries gaining most from natural resource development, the current declines may continue to yield unsatisfactory outcomes from both fishery and conservation perspectives.

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