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Last chance for dolphins in Laos:

A review of the history, threats, and status

By Gerard E. Ryan

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Executive Summary

Irrawaddy dolphins have a proud history in Laos, but their future there is now in doubt – just six dolphins remain in Lao waters, and threats continue.

Irrawaddy dolphins *(Orcaella brevirostris)* are critically endangered in the Mekong River, where their range is reduced to a small section of river in Southern Laos and Northeast Cambodia. In Laos dolphins once occurred within numerous tributaries in the Sekong River Sub-basin, and around a trans-boundary deep pool in the Mekong mainstream below the Khone Falls in Champassak. No recent records exist from the Sekong, and the trans-boundary pool is now the only location dolphins can be found in Laos (Figure I). The pool area is around 6 km^2, the core of which is a deep-water pool around 1 km^2 in area, and 40 m deep.

Figure I. The location of the trans-boundary dolphin pool on the borders of Champassak Province, Laos, and Stung Treng, Cambodia.

Dolphin watching is a major feature of tourism in southern Laos. In 2011 approximately 20,000 tourists are estimated to have visited the trans-boundary dolphins. The associated income—boat trips, meals, guesthouses, etc.—is very significant in local communities that otherwise rely heavily on fisheries for subsistence and income. Dolphins may not be the only reason tourists visit the area, but they are a certainly a major attraction and contributor to growth.

Dolphins are also an important indicator of the health of their ecosystem—here an ecosystem relied heavily upon by local communities—and declines in dolphin numbers may reflect a declining trend in broader ecosystem qualities. Several dozen dolphins may once have used the trans-boundary pool; though by the early 1990's there are thought to have been around 25 individuals. Extensive photographic surveys show that by 2007 just eight dolphins used the pool, and in 2012 only six remain. These are the last six dolphins in Lao waters.

The risk of this sub-population disappearing is assessed using several conceptual models. The trans-boundary population is predicted to continue to decline if the current conditions do not improve. It is predicted that the group will be effectively extirpated within 20 years, and none are expected to remain after 2037—though this could happen much sooner. In fact, without newborns to replace them and elimination of threats, it is very unlikely the population will survive the next 5-7 years. The sex of the dolphins remaining is unknown, though copulation observed in March 2012 shows that both males and females remain, and that if protected, the group may recover.

Despite the tiny population size and its importance to the community, threats to dolphins continue at the site. Gillnets are used intensively in some areas, posing the risk of entangling dolphins. Explosives are used to fish around the site; an extremely high risk to those fishers who use them, as well as dolphins and fisheries. Electrofishing is also known in the area. Both gillnetting and destructive fishing practices are incompatible with dolphins persisting. Regulations to reduce the risk of bycatch in the pool have been created, including a gillnet-free community conservation zone on the Lao side, and recently enacted, extensive dolphin conservation areas in Cambodia. While these are significant achievements, enforcement is needed on both sides and over a larger part of the pool to remove the threat from destructive fishing completely: a major challenge. Motorized boat traffic at the site is frequent and almost certainly increasing—a well-known, long-term threat to dolphins. Disturbance could be reduced by taking better advantage of land-based dolphin watching opportunities, increased use of paddled boats in slow water, and regulation of vessel movement across the pool. Infrastructure proposals in and around the site are a future threat to the persistence of dolphins in the trans-boundary pool, including a proposed pier sited directly in key deep-water micro-habitat.

The future for dolphins in Laos is bleak, but not hopeless. Intervention is urgently needed in the area to reverse this situation, with coordinated actions on both sides of the border. Specifically these actions are:

- **Immediate banning of gillnets** from all parts of the trans-boundary pool throughout the year,
- Concerted effort to **end illegal fishing and the use of explosives** in the area,
- Trans-boundary efforts to **regulate boat traffic** transiting the deep pool,
- **Cancellation of the proposed ramp** and pier at Anlung Cheuteal, and
- **Secure funding** to support conservation efforts at the site, including effective enforcement of the above recommendations.

1 Introduction

Freshwater Irrawaddy dolphins *(Orcaella brevirostris)* are an icon of the Mekong River. For centuries these animals have featured in the cultures of the Mekong's peoples, and they remain an important symbol of the status of the river. From one Lao legend, the dolphin was born of a man banished by the king to live forever on the periphery. In a Khmer fable, the dolphin originated from woman who threw herself into the river, escaping disgrace. It is easy to imagine that these mythologies converged at the border as the nations do—and from the mythical male and female dolphins of Laos and Cambodia, spawned the population that is the pride of the river today.

But the Mekong's dolphins are in trouble. Critically endangered on the IUCN Red List of Threatened Species (Smith & Beasley, 2004), the dolphins that once ranged from the delta in Vietnam, into the Great Lake of Cambodia, and up the Sekong River into Laos (Smith & Jefferson, 2002), are gone from most of this range and continuing to decline. The Mekong's dolphins are one of three riverine populations of the Irrawaddy dolphin, and now number around 85 individuals restricted to a small section of the mainstream Mekong in north-east Cambodia and Southern Laos (Ryan et al., 2011). As well as the Mahakam and Ayeyarwady Rivers in Borneo and Myanmar, Irrawaddy dolphins also occur in near-shore coastal and brackish areas in South and South-East Asia. The species is globally classified as vulnerable and believed to be declining (Reeves et al., 2008).

Below Khone Falls, a group of dolphins freely traverse the border in a trans-boundary deep-water pool, known alternately as Boong Pa Gooang in Lao, or Anlung Cheuteal in Khmer (Fig 1). Recent evidence suggests that dolphins using this trans-boundary pool are the only dolphins remaining in the waters of Laos. An important icon in a critical state; these dolphins are in acute need of conservation action (Ryan et al., 2011).

This report reviews the status of dolphins in Laos and makes recommendations on the most urgent conservation actions. Firstly, the benefits of river dolphins are discussed. The recent history of the trans-boundary pool and its dolphins are then examined, along with other recent and historic records of dolphins in Laos. Causes of mortality are discussed, and the population status, trend, and extirpation risk are assessed with several models. These assessments are made based on decades of conservation research at the area, including published records, unpublished data, and surveys of gillnets and interviews with local villagers conducted in early 2012. Finally, recommendations focus on urgent actions to protect the dolphins swimming below Khone Falls today, and ensure that they will not be the last dolphins ever seen in Laos.

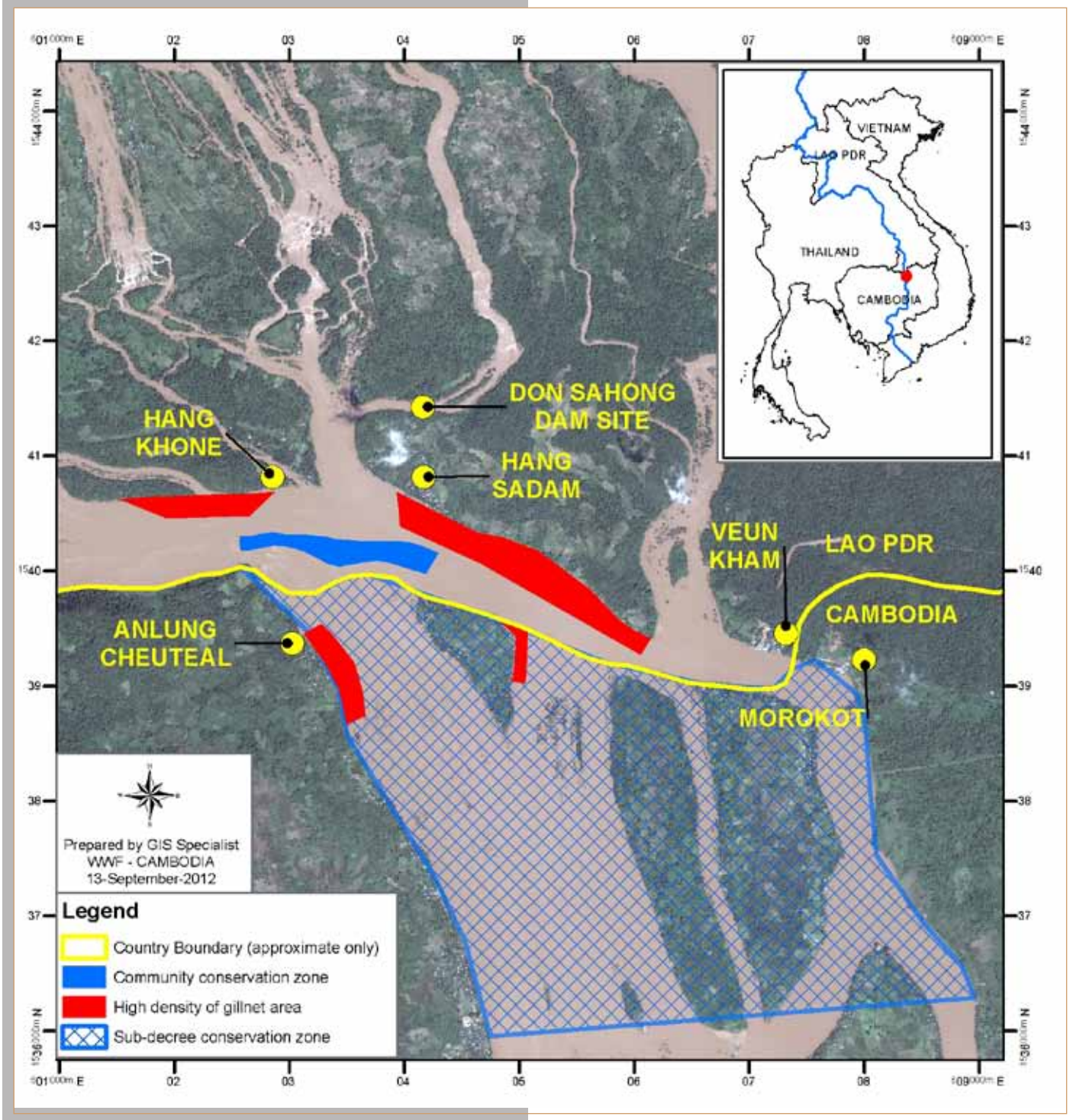

Figure 1. The trans-boundary dolphin pool and surrounds, showing areas of high gillnet use (red), key tourism sites in the surrounding villages (yellow-markers), and conservation zones on both sides of the border (solid and hatched blue). Sites for the proposed Don Sahong is also shown. Dolphins are most frequently found in the ~1 km^2 deep water between Hang Khone, Hang Sadam, and Anlung Cheuteal, approximated on the Lao side by the community conservation zone. This area is the only location where dolphins occur in Laos. The international border is approximate and indicative only; it does not represent the opinion of the author or WWF on the location of this border.

2 The benefits of river dolphins

Dolphins have long held a strong spiritual value to the peoples around them—many believe that dolphins have saved people from drowning, fended off attacking crocodiles, or consider them reincarnated humans (Baird & Mounsouphom, 1994; Baird & Mounsouphom, 1997). Today dolphins provide another very tangible benefit to the communities around the trans-boundary pool: tourism income.

Southern Laos has seen a boom in tourism numbers over the last decade (TDD, 2012). Low levels of dolphin-watching tourism occurred in Southern Laos in the early 1990's (Stacey, 1996), however in recent years numbers of tourists and the associated income, have increased dramatically. Dolphin watching tours leave from several locations around the pool, including Hang Khone and Veun Kham in Laos, and Anlung Cheuteal and Morokot in Cambodia (Fig. 1). Tours leaving Hang Khone have risen from 3,480 visitors in 2008, to 7,200 visitors in 2011, directly resulting in income of over US$15,000 for the local community in 2011 (S. Schipani, Asian Development Bank, unpublished data). Many more tourists visit dolphins from Veun Kham than Hang Khone, though direct estimates are unavailable. On the Cambodian side the popularity of watching dolphins has risen

Image 1. Tourists watch dolphins below Khone Falls in Laos. © WWF-Cambodia / Nou Chanveasna

just as rapidly from 206 visitors to Anlung Cheuteal in 2005, to 1,075 in 2008, and 6,120 in 2011 (Touch, 2012). Estimating the total number of visitors to the dolphin pool is complex, with boats originating from many sites within the broader Siphandone area and both countries to see dolphins. Many of the visitors to the Cambodian side originate from Laos, particularly Veun Kham and to a much lesser extent Hang Khone. It is unclear how many tourists from Hang Khone may be double-counted in the Cambodian figure. The total is certainly considerably higher than either of those estimates alone, as many visitors from Veun Kham would not be captured in either statistic (GER, pers. obs). In 2005, over 9,000 total visitors were estimated watching the dolphins (Asia Pacific Projects Inc. 2006, in Bezuijen et al., 2007). Even a conservative estimate for 2011, assuming significant duplicity in visitor counts would suggest well in excess of 10,000 visitors. Based on the trends in both the Hang Khone and Cambodian counts since 2005, the total is likely closer to 20,000 or more foreign and domestic tourists visiting the trans-boundary dolphins in 2011.

It is clear that dolphin-watching can be a direct source of significant income for the communities around the trans-boundary pool. Aside from the fees paid directly for boat hire, tourists drawn to the area are also patronizing restaurants, guesthouses, and home-stays, buying souvenirs, visiting waterfalls and other sites, and using other services. The income generated by these 'collateral' activities likely far exceeds the income due purely to seeing dolphins. Dolphins are not, of course, the only reason tourists visit the Siphandone, however there can be no doubt that they are a major attraction and contributor to tourism growth in the area.

Dolphins are much more than just a cultural icon or tourist attraction, however. The environmental benefits of dolphins are significant. Irrawaddy dolphins are the sole member of an entire mammalian order —the Cetacea—present in Laos, and their loss would greatly diminish the biodiversity of the nation. River dolphins are an excellent indicator of the health and management of freshwater ecosystems (Gomez-Salazar et al., 2012), where decreasing density of river dolphins indicates degradation of the river. River dolphin population trends can also be used as surrogates for the populations of other difficult-to-monitor freshwater species (Turvey et al., 2012). The trans-boundary pool, the Siphandone, and the Mekong River more generally, are very important resources for communities through fisheries, the supply of water, and other livelihood needs (Daconto, 2001). The presence of dolphins in the trans-boundary pool is a good indicator of the state of the river. Decline in this group of dolphins suggests declining health of the entire river ecosystem, and likely declines in other species too.

3 Dolphins in Laos

Irrawaddy dolphins have long been known from the trans-boundary pool below Khone Falls, which is seen as an impenetrable barrier to their dispersal upstream (Baird & Mounsouphom, 1997). The general area is around 6 km^2 of river across the base of the falls (Fig. 1), but the area most important for dolphins, and fishes, is a deep-pool of around 1 km^2 in surface and 40 m deep. For a short period during one wet-season in the 1960's dolphins were reported to have been seen around Don Dtan Village just above the falls before apparently returning downstream the same month (Baird & Mounsouphom, 1994). There is no evidence however, that dolphins were ever established permanently above Khone Falls. The trans-boundary pool and surrounding area is the only section of the mainstream Mekong River where dolphins have ever been resident in Laos.

The Sekong River is a major tributary of the Mekong River running from Southern Laos to the Mekong in Stung Treng in Cambodia. Dolphins are historically reported to have been seen upstream of Kaleum Town in Sekong Province, almost 300 km upstream of the confluence at the Mekong, and 200 km north of the Laos–Cambodia border. Dolphins are also known from a number of tributaries of the Sekong including the Xepian, Xenamnoi, and Xekhaman Rivers (Baird & Mounsouphom, 1994; Baird & Mounsouphom, 1997). Baird and Mounsouphom (1994; 1997) provide detailed accounts of historic dolphin distributions from interviews in the Sekong sub-basin. Many of these rivers are quite shallow, and dolphins were most commonly reported during the high water-levels of the wet-seasons, though individuals were historically reported as seen throughout the year

Image 2. Irrawaddy dolphins in the trans-boundary pool, photographed in 2011. © WWF-Cambodia / Tan Someth Bunwath

in some areas (Baird & Mounsouphom, 1994). By the early 1990's however, it was clear that records from the Sekong sub-basin were increasingly scarce (Baird & Mounsouphom, 1997). Conflict during the America–Vietnam war, resulting in the shooting of dolphins by Vietnamese soldiers and bombing of rivers by American aircraft is believed to have been a significant contributor to dolphin declines in the Sekong. Dolphins are no-longer believed to use the Sekong sub-basin even seasonally (Davies et al., 2006), and almost certainly no resident groups remain. The only known recent reports from the Sekong are from 2006 where a small group was seen and one animal may also have been shot (V. Cowling, pers. comm. 2012). Follow-up surveys to uncover any recent evidence of dolphin occurrence in the Sekong sub-basin should be a priority, though their presence is extremely doubtful.

Dolphins are listed under the highest level of protection in Laos, and killing of a dolphin can potentially result in a fine or prison. In the trans-boundary pool, a small community conservation area has been demarcated in the centre of the pool around the deepest areas most commonly used by dolphins (Fig 1). Gillnet fishing is banned within this area, as is high-speed boat travel. On the Cambodian side, recent protected area laws were enacted that ban gillnet fishing in the entire pool and nearby areas on that side of the border, as well as most of the other dolphin habitat downstream (Fig. 1). Dolphins are also fully protected under the highest level of Fishery Law in Cambodia. Attempts to instigate cooperative trans-boundary management of the pool have been made by a series of international development and conservation organizations over the last decade, resulting in a number of meetings on both sides of the border (e.g., Lopez, 2005; FiA & DLF, 2012). To this point there has been little on-the-ground impact, however the resurgent interest in collaborative management gives hope that this is likely to improve in the future (FiA & DLF, 2012).

Image 3. Two Irrawaddy dolphins photographed in the trans-boundary pool in 2012. © WWF-Cambodia / Gerard Ryan

4 An isolated population

In the Mekong River today, dolphins are largely restricted to a 190 km linear section of the mainstream between Kratie in Cambodia and the Khone Falls in Laos. Dolphins reside around deep pools in the dry season (Baird & Beasley, 2005; Ryan et al., 2011), but range more widely in the wet season (Beasley, 2007). Mekong dolphins show high site-fidelity around these deep pools, and appear to keep regular home-ranges with little dispersal between core areas (Beasley, 2007; WWF unpublished data). The trans-boundary pool is one of these core areas, however it is separated from the nearest downstream pool by a 60 km complex stretch of river containing a large number of rapids. Although there is limited exchange of individuals among the core areas downstream (WWF, unpublished data), and dolphins are able to traverse rapids (GER pers. obs.), evidence suggests that those dolphins inhabiting the trans-boundary pool are now an isolated sub-population.

Photo-identification surveys have regularly recorded and re-recorded the presence of individual dolphins throughout their range in the Mekong since 2001 (Beasley, 2007; Ryan et al., 2011). During that time, only one individual is known to have left the trans-boundary pool, dispersing far downstream into Cambodia from where it was not recorded to return (Gilbert & Beasley, 2006). There are no records from 2001-2012 of dolphins dispersing upstream into the trans-boundary pool, and no new individuals have been recorded in the pool since 2007 (per Population status below). It is therefore believed that the trans-boundary group is now isolated from the dolphins downstream. Without this dispersal and exchange, the trans-boundary group risks genetic isolation in the long-term, but much more alarmingly, risks simply disappearing with little or no chance of the pool being recolonized in the foreseeable future. Efforts to improve dispersal among groups are likely to greatly increase the chances of persistence of the trans-boundary sub-population (Stacey & Taper, 1992). Increasing dispersal will require a long-term commitment to increase the population size throughout the river.

Image 4. Dolphin in trans-boundary pool. © WWF-Cambodia / Hang Sereyvuth

5 Mortality at the trans-boundary pool

From 1991 to 1997, at least 26 dolphins died in and around the trans-boundary pool (Baird & Mounsouphom, 1994; Baird et al., 1994; Baird & Mounsouphom, 1997; Fig. 2). Six dolphin deaths are also known in the Sekong sub-basin between 1989 and 1997 (Baird & Mounsouphom, 1994; Davies et al., 2006). Gillnets were identified as the main source of mortality, however many cases were also believed to be due to explosive fishing. Several animals were shot or died in fish traps, while the cause of other deaths is unknown.

From 2001 to 2006, eight dolphins either died around the pool, or were recovered downstream of the pool and almost certainty originated there (Gilbert & Beasley, 2006; Beasley, 2007; WWF Unpublished data; Fig 2). These included one juvenile possibly hit by a boat, and a perinate calf, of which the cause of death was not clear. The other deaths were all adults. Gillnets were recorded or implicated in three of the adult deaths, one was reported to have been shot by a Lao policeman, and the cause of death of the other two is unknown. In addition, body parts of

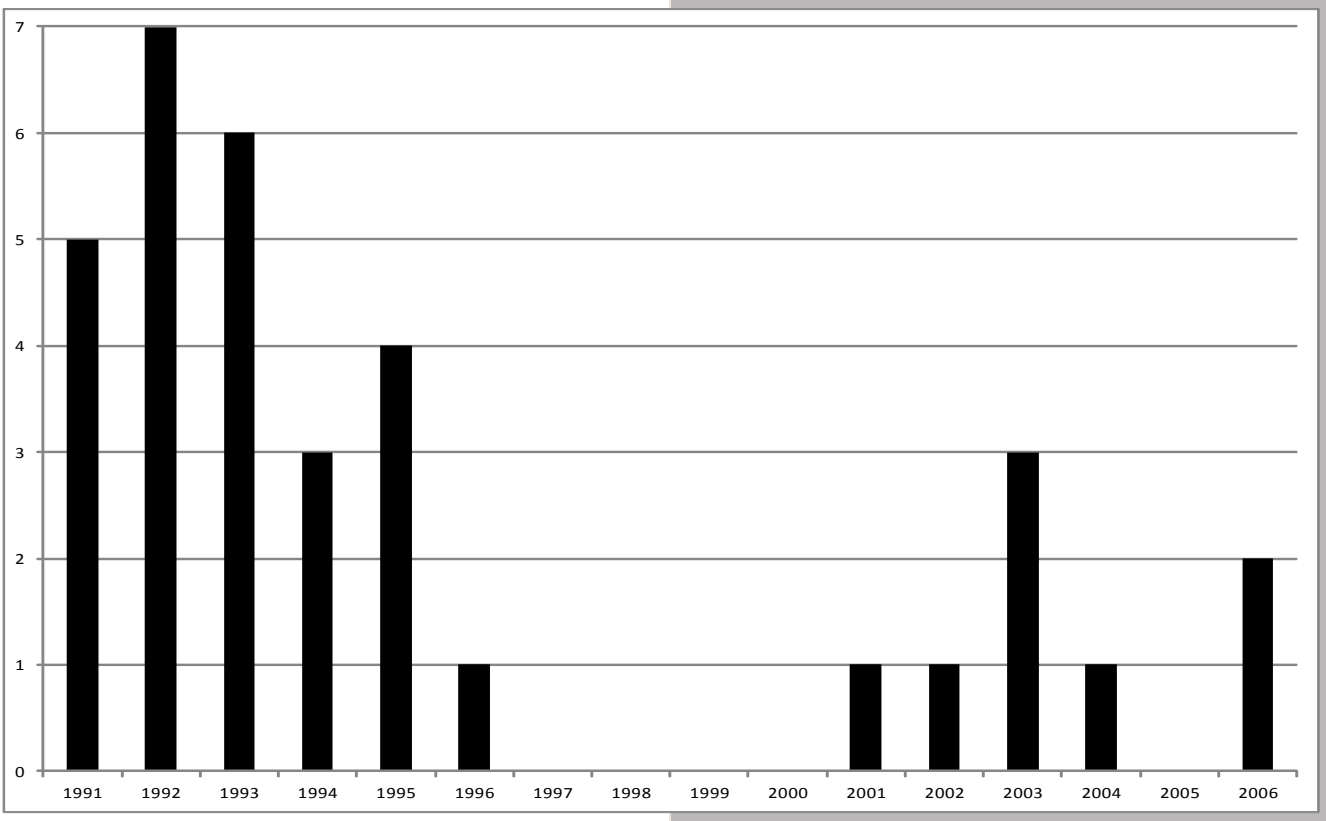

Figure 2. Number of reported deaths around the trans-boundary pool from 1991-2006. 1997-2000 shows a gap in effort to record mortalities, rather than a decrease in mortalities. NB: Baird and Mounsouphom (1994) report six deaths in the 16 months up to April 1992. This figure reports these data as averaged over the 16 months, rounding to five in 1991 and one up to April in 1992 (an additional six were reported for the remainder of 1992, totalling seven for the year).

four dolphins were recovered in 2001; two of which were believed to have died within the preceding year, and two of which were considerably older and may have been from previously recorded mortalities. One additional dolphin may have been shot in the Sekong River in 2006, though this remains unconfirmed (V. Cowling, WWF-Laos, pers. comm. 2012).

Since 2006, no carcasses have been recovered around the pool and there are no reported mortalities. This appears to be good news, but it is not without caveat. With the population so reduced fewer dolphins are expected to die. Strong-handed control on gillnet fishing since 2006 on the Cambodian side very likely also reduced willingness to report dead dolphins for fear of retribution or punishment (especially reporting any dolphins caught in gillnets). Further, evidence from ongoing population studies suggests two animals have died since 2007 (see population status below). The lack of records is certainly not evidence that no animals have died in the area since 2006.

Generally it is an error to interpret the number of carcasses recovered as the exact total number of deaths, as it is unlikely that all dead animals will be found (Williams et al., 2011). The area around the pool is well habited and any carcasses to strand nearby would likely be found, however the area immediately downstream is sparsely populated and highly complex, so carcasses that drift downstream are much less likely to be found. We should therefore interpret recorded deaths as no more than a minimum estimate.

At least 34 dolphins died in the trans-boundary pool area over the past two decades, or nearly two per year that we know of (Fig. 2). In addition to potential difficulty finding some carcasses, there is a recording gap from 1997-2001, so the total number is almost certainly higher.

Image 5. The community pray over a dead dolphin found at the pool in 2006. © WWF-Cambodia / Lor Kimsan

6 Population status and trend

No historic records exist of the size of the dolphin population in the trans-boundary pool, however within living memory as many as 40–50 dolphins may have used area (K. Chantaboualy, Hang Sadam Village, pers. comm., 2012; Phoy V., Anlung Cheuteal Village, pers. comm., 2012). Although the pool appears relatively small to support such a population even for part of the year, the vast migrations of fishes through the falls could easily support such numbers of dolphins in the general area (Daconto, 2001; Poulsen et al., 2002). It is believed that dolphins previously used a larger portion of the surrounding area; moving around channels and closer to waterfalls. Nonetheless, it is impossible to verify the accuracy of these reports today. Since conservation attention began to focus on these trans-boundary dolphins in early 1990's, a minimum of 17 dolphins were reported present in 1993 (Baird et al., 1994; Stacey & Hvengaard, 2002), and local reports suggest that around 25 animals were resident in the area (K. Chantaboualy, pers. comm. 2012); this figure is roughly compatible with the recorded mortalities since then (per above), and backward population modelling (per Appendix B).

Photo-identification (photo-ID) a widely used and well established method to monitor dolphin populations (Hammond et al., 1990), and is much more reliable than simple direct counts. Photo-ID uses photographs to identify unique features of an individual dolphin's fin, and repeated encounters of animals can provide detailed data on the population size and demography and ecology of the group (Ryan et al., 2011). The method was first attempted in Laos in 1993, but met with little success due to poor equipment (Stacey & Hvengaard, 2002). Between 2001-2005, Beasley (2007) identified 11 individual dolphins in the trans-boundary pool, including two calves, one of which is believed to have survived to adulthood. One adult however, left the group and dispersed permanently downstream into another core area in Cambodia in 2003 (Gilbert & Beasley, 2006), suggesting 10 individuals present in 2004 (Fig 3). Given the significant effort that Beasley devoted to photo-ID animals in this area (Beasley, 2007), it is very likely that she captured all animals in the site at that time. In 2006 no photo-identification work was conducted, and simple direct counting at the pool encountered a maximum estimate of seven individuals (CMDCP, 2006).

Image 6. Dolphin in the trans-boundary pool.
© WWF-Cambodia / Gerard Ryan

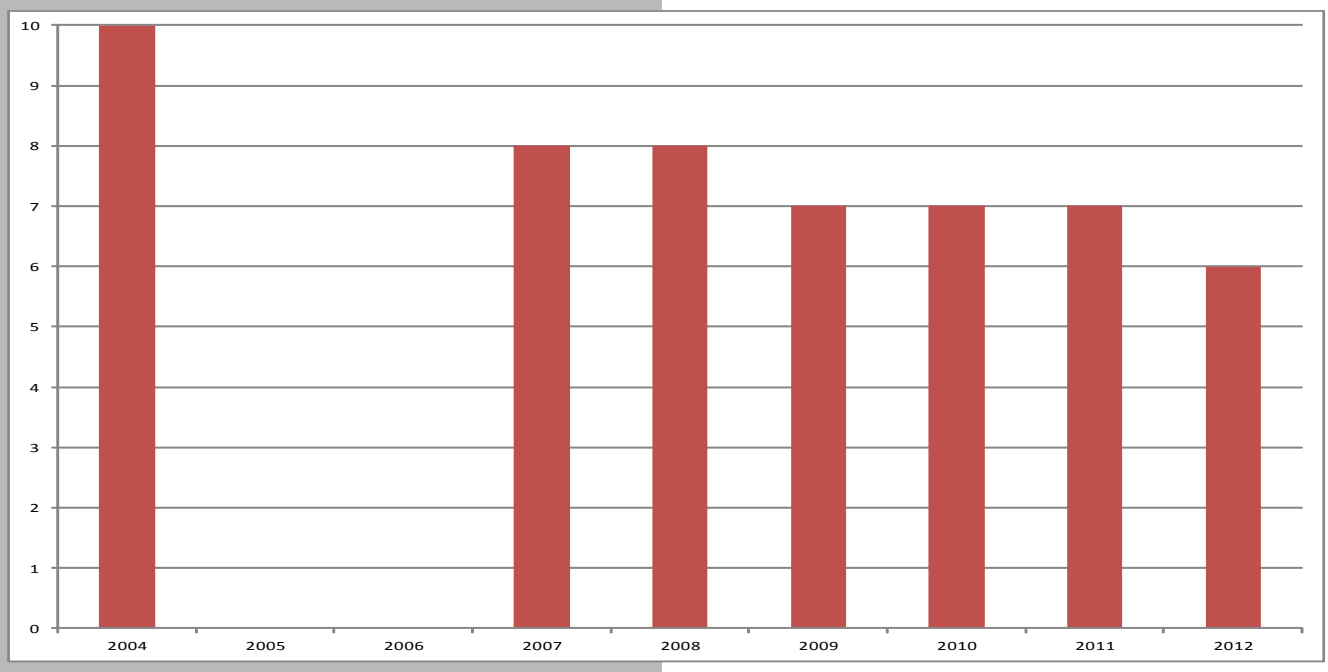

Figure 3. Population of dolphins at the trans-boundary pool from 2004-2012. Data missing in 2005-6.

In 2007, it is believed that just eight animals survived in the trans-boundary pool (Fig. 3). This was comprised of six clearly marked dolphins, as well as two distinct though 'unmarked' individuals believed to be juveniles. In 2008 all individuals known from 2007 were also recorded. In 2009, one of the unmarked animals was no longer recorded (believed dead), however all others were. These animals were all again recorded in 2010 and 2011, totalling a population of seven in those years. In 2012, despite considerable survey effort in the area, one marked individual was not detected and is almost certainly gone from the population. This brings the total number of Irrawaddy dolphins using the trans-boundary pool down to just six individuals (Fig.3). Photographs of these six remaining dolphins are shown in Appendix A.

Since 2007, photo-identification has not recorded any new animals since the first year (Ryan et al., 2011; WWF Unpublished data; Fig. 4). Thirty-four separate days have been spent searching the area under formalized photo-ID protocol between April 2007 and March 2012; dozens of days of less formalized days of observation throughout this time also failed to find new animals. Given the initial rapid accumulation of new individuals, and extended effort, it is extremely unlikely that any individuals have been missed. Although it is typical to pair photographic-identification methods with mark-recapture type analyses, with such a small population, such analysis is not only unnecessary, but would blur an otherwise very clear picture. Considerable effort has been put into surveying the area and only six individuals can now be found – we can be confident that these are the only dolphins remaining in the area.

Image 7. Fin of the Mekong Irrawaddy dolphin in trans-boundary pool captured in 2011. © WWF-Cambodia

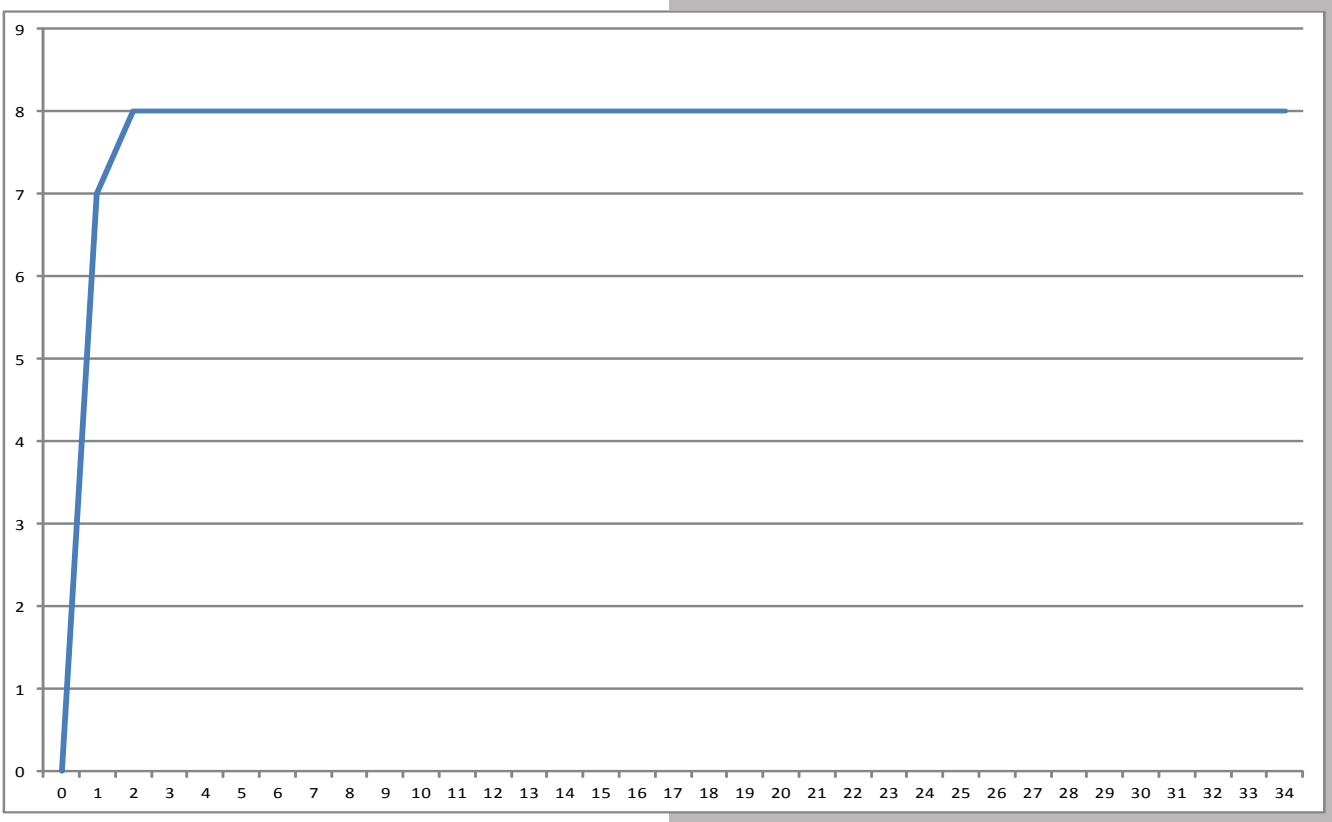

Figure 4. Cumulative total identified dolphins over number of encounter days from 2007–2012.

The persistence of this tiny population will depend highly on chance events, although the trajectory under the current state is certainly downward. Three models of population growth were used to predict persistence of the trans-boundary population—linear, exponential, and 'beta' models. To create the linear and exponential models, linear and exponential regressions were fitted to the data presented in Figure 3. These regressions were then projected forwards to 2050. To acknowledge and account for uncertainty around predictions, the 'beta' model was made. The beta model is based on discrete, stochastic population growth drawn from a Bayesian posterior beta distribution of births and deaths using from the photo-ID data from 2007–2010. The beta model was simulated from 2013-2050. Details of this model are given in Appendix B. Results are displayed in Figure 5. (NB: as the beta model is discrete, i.e. all results must be a whole number, the population model moves stepwise from 6–5–4 etc., rather than a continuous model that may move e.g. 6.25–6.01–5.78–5.33 etc. Fractions of animals are impossible to this adds realism, though looks odd graphically.)

The linear projection suggests the population is gone (population <1) in 2024, while the exponential projection finds it persists until 2043 (Fig. 5). The beta model gives more nuanced interpretation of expected persistence. The 90% credible interval (CI) as bounded by the 5th and 95th percentiles predicts extinction as early as 2024, or persistence beyond 2050. The mean for the beta model was gone in 2038, the median finds a 50% chance of extinction by 2043, while the mode shows that extinction is the most likely outcome from 2037 (Fig. 5). These results represent the predicted time at which there are no more dolphins.

However - a population is effectively extinct once there are no more breeding females and males. The gender of the remaining animals is unknown, so it is not clear based on the individuals remaining when

this point may be reached. Copulation was observed in March 2012, so it is likely that individuals of breeding age of both sexes remain at present. Under current conditions the population will almost certainly be down to four in just a few years, and to three within the decade (Fig. 11). Most optimistically, effective extinction is the point at which the population is <2 individuals. All models agree that effective extinction is likely within ~20 years (Fig. 5), with median time to effective extinction from the beta model in 2032.

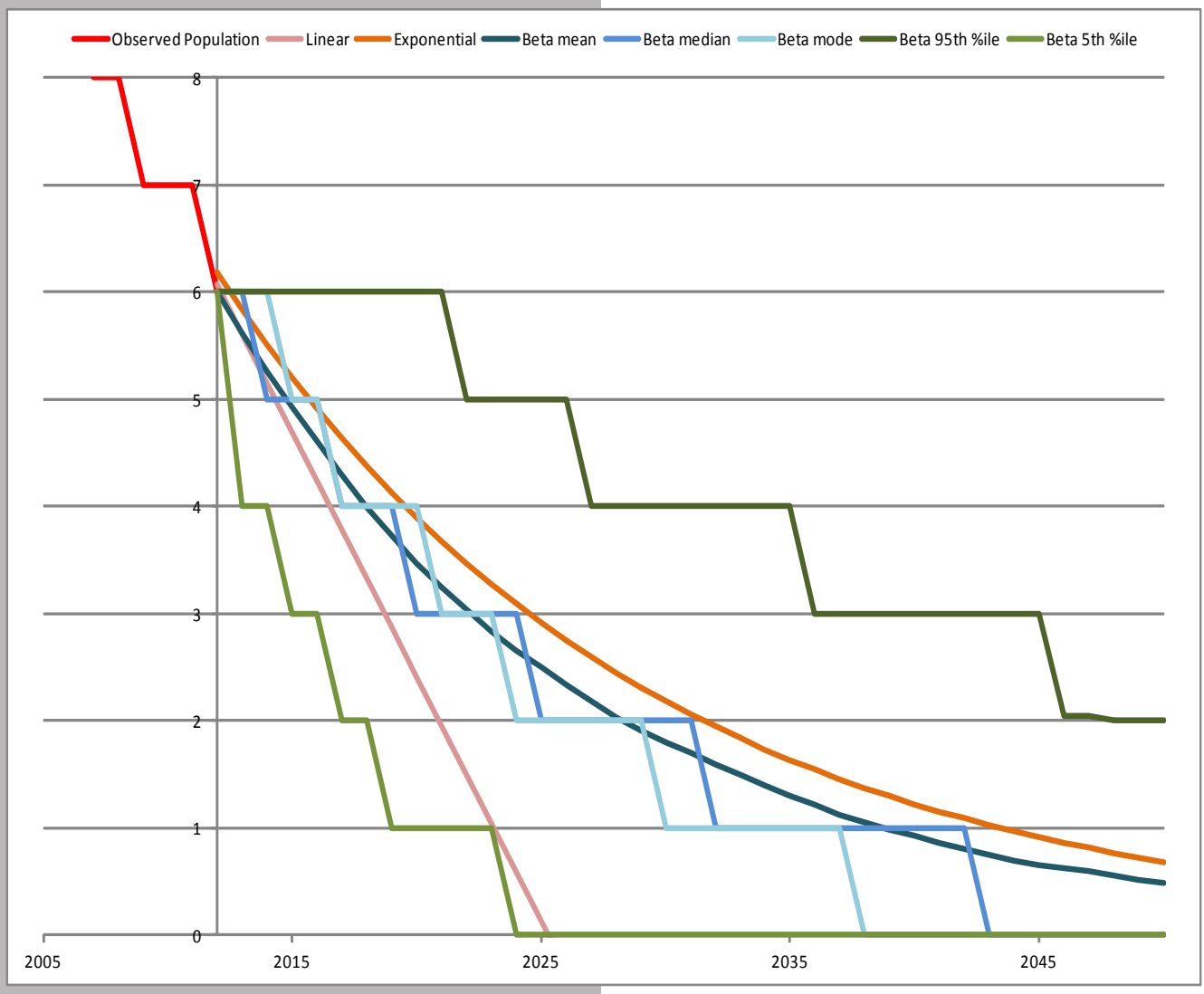

Figure 5. Observed and predicted population from linear, exponential, and beta models in the years to 2050. Vertical axis is at the current time (2012). Data preceding the vertical axis are direct observations since 2007, while following are predictions based on the three models. For the Beta model, the 5th and 95th percentiles bound the 90% CI, and mean, median, and mode are shown.

8 Current threats

Despite the significance of the trans-boundary dolphins for local communities and tourism, they face significant threats at the site—in particular intensive use of gillnets in some parts of the pool, and apparently increasing and illegal use of explosives to fish. Boat traffic is on the increase and is a source of disturbance, especially due to tourism in the dry season. Infrastructure projects in and around the pool could also be highly detrimental.

In repeated visits to the site from January–April 2012, systematic observations regularly counted over 100 separate gillnets in and around the deep pool area and up to 188 on one occasion. The majority of nets were concentrated around the south of Hang Sadam, where dense rows of nets were strung out in shallow water perpendicular to the shore (Fig. 1). Higher densities were also recorded in shallow areas west of the dock at Ban Hang Khone, and in shallow water in front of the village at Anlung Cheuteal (Fig. 1). Gillnets were also observed scattered around other parts of the area on both sides of the border. The presence of gillnets in close proximity to areas very regularly used by the trans-boundary dolphin group is a very grave concern. Gillnets are a well-known threat to small cetaceans worldwide (Reeves et al., 2003). Even if nets are not in the areas most often used by dolphins, it is almost certain that with so many nets animals will occasionally become entangled. With such a small population as this, the

Image 8. Gillnets are the leading identified cause of mortality in the trans-boundary pool. © WWF-Cambodia

risk of entangling dolphins is incompatible with the goal of them surviving in the pool for many years to come.

Destructive fishing with explosives, electrofishing and fish-poisoning are all reported to occur around Au Svay, just downstream of the trans-boundary pool in Cambodia, with the use of explosives is reported to be particularly frequent (Chheng & So, 2011). Observations of unusually large numbers of freshly dead fish floating in the pool itself in early 2012 gives credence to local reports that the use of explosives is also increasing in the surrounding area upstream in Laos. Explosive fishing has already killed dolphins in the Mekong, and electrofishing and poisoning have a high potential to do so. These destructive fishing practices are not only dangerous to the dolphins, unsustainable for fisheries, and extremely damaging to the local ecosystems, but they are a very serious danger to those who practice them—particularly the use of home-made explosives, which can explode in boats. Several fishermen have died in the area this year using explosives. Efforts to control these dangerous practices are not only critical to dolphins, but are a humanitarian necessity requiring better education within local communities of the impacts and risks.

Over the last decade, large numbers of dolphin calves have died in the Mekong from causes that remain unclear (Gilbert & Beasley, 2006; Dove, 2009; Gilbert et al., 2009; Reeves et al., 2009; Seng et al., 2012). Potential contributing factors include water quality and environmental degradation, tourism impacts, disease, or behavioural issues. With so few recorded births in the last decade and fewer calves surviving, greater efforts must be made to identify causes of morality and reduce them to ensure recruitment into the population – as without recruitment the population will certainly disappear. A meeting of international and national experts examined all evidence related to this issue in January 2012, and although the findings were not conclusive, numerous recommendations were made to address the issue (Seng et al., 2012).

Image 9. Fishing activities using gillnet. © WWF-Cambodia / Gerard Ryan

Boat traffic at the site is significant and growing. Boats do not appear to be a major threat to dolphin survival by directly causing mortality (no boat strikes have ever been confirmed in the Mekong and only one is suspected; Beasley 2007; WWF unpublished data). Nonetheless, the 'fast-boats', which travel at high speed between Stung Treng in Cambodia and the border, could foreseeably hit dolphins. Of more concern is the large number of motorized boats regularly traversing the dolphin pool. Motorized boats in the area are typically of the traditional long and narrow, wooden design with long-tail engines, and comprise mainly of fishing vessels, tourist boats, and ferries, moving across the pool on both sides of the border. Large French-colonial boats travelled up to the falls in the late 19th and early 20th century (Osborne, 2000), however in the modern day, motorized vessels are only believed to have been used regularly in the area since 1987 (Stacey & Hvengaard, 2002). Concern arose as early as the 1990's of their effect on dolphins in the area (Baird & Mounsouphom, 1994), and research at the site shows dolphins avoid motorized boats (Stacey & Hvengaard, 2002). In 1993, only around one quarter of the 40 boats on Hang Sadam were motorized. Today, at a conservative estimate at least 70% of the boats using the area would be motorized, and the total number in the area is much higher. Paddle boats are virtually only used for small excursions close to the river bank (such as checking gillnets), and thus the vast majority of boats approaching dolphins are those with motors (GER pers. obs.).

Changing and increasing tourism is also of concern, including a shift from land-based to boat-based dolphin-watching (Beasley et al., 2010). Previously during the dry season, the majority of tourists from Laos were transported to a rock in the centre of the pool to view dolphins. Presently however, larger numbers of tourists remain in boats that often follow dolphin groups around the pool (GER pers. obs.). Kayak tours to the area have also recently began, which afford paddlers the chance to approach dolphins to a very close range, and potentially easily harass them. Although kayaks are relatively slow, and much quieter than motorized boats, if unmanaged, kayaks could be

Image 10. Fishing with a gillnet in the trans-boundary pool. © WWF-Cambodia / Gerard Ryan

a significant additional source of disturbance to the dolphins. With ever-increasing numbers of tourists visiting the dolphin site, increasing boat traffic, and unclear management of vessel movements through the pool, boat traffic is likely to be a significant source of disturbance to this tiny, threatened group.

Significant disturbance due to tourism is unjustified, and more 'dolphin-friendly' options should be promoted. There are several potential options for high-quality land-based viewing experiences on both sides of the border, such as directly from the riverbank at Anlung Cheuteal, and the Cambodian island, or the rocky islets near the centre of the pool in Laos. In the dry season—the peak tourist season—slow water currents do not preclude the use of paddled vessels. These should be encouraged. Simple, yet consistent regulations on the movement and speed of vessels through the centre of the pool—as the key dolphin area—could be very effective in reducing disturbance due to other non-tourist traffic.

Proposed infrastructure projects around the trans-boundary pool also threaten the population. A large concrete pier structure is proposed at Anlung Cheuteal, sited over deep water often used by dolphins. Disturbance during construction, and increased boat traffic directly into a core micro-habitat of the population would be unjustifiably detrimental to the population. The proposed Don Sahong dam site lies just upstream of the trans-boundary pool (ICEM, 2010; Fig 1.). Of particular concern is the excavation of 2.3 million tonnes of rock from the Hou Sahong Channel, directly adjoining the pool (Mega First Corporation Berhad, 2007). If the blasting associated with this excavation does not result directly in deaths or the dispersal of animals away from the area, ongoing noise disturbance from turbine operation almost certainly would. The threat from the Don Sahong dam, as well as other dams is discussed in detail elsewhere (Bezuijen et al., 2007; Ryan & Goichot, 2011).

Image 11. A dolphin dead, entangled in a gillnet. © WWF-Cambodia

9 Status and recommendations

Six dolphins remain isolated in the trans-boundary pool, and therefore only six dolphins exist in all of Laos. Significant threats continue around the site in the form of intensive gillnet use, destructive fishing, and unregulated boat traffic. Infrastructure proposals around the site are significant future threats. These threats are incompatible with the persistence of dolphins in this trans-boundary pool.

The future for dolphins in Laos is bleak, though not hopeless. That most of the threats occur on both sides of the Laos-Cambodia border makes it clear that both nations must respond with parallel actions and trans-boundary cooperation. Dolphins persist in Laos, but without urgent intervention in the trans-boundary pool and surrounding area, they will not persist for long. Actions are urgently needed to reverse the situation. Specifically these actions are:

- **Immediate banning of gillnets** from all parts of the trans-boundary pool throughout the year,
- Concerted effort to **end illegal fishing and the use of explosives** in the area,
- Trans-boundary efforts to **regulate boat traffic** transiting the deep pool,
- **Cancellation of the proposed ramp** and pier at Anlung Cheuteal, and
- **Secure funding** to support conservation efforts at the site, including effective enforcement of the above recommendations.

Image 12. Mekong River Irrawaddy dolphins in the trans-boundary pool. © WWF-Cambodia / Gerard Ryan

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APPENDIX A: The last six dolphins in Laos

Figure A1. Dolphin 035 in 2012. Photo © WWF-Cambodia / Gerry Ryan.

Figure A2. Dolphin 036 in 2012. Photo: © WWF-Cambodia / Gerry Ryan

Figure A3. Dolphin 038 in 2012. Photo: © WWF-Cambodia /Tan Someth Bunwath

Figure A4. Dolphin 039 in 2012. Photo: © WWF-Greater Mekong / Payou Thammavongseng

Figure A5. Dolphin 053 in 2012. Photo: © WWF-Cambodia / Gerry Ryan

Figure A6. Unmarked dolphin in 2012. Photo: © WWF-Cambodia / Gerry Ryan

APPENDIX B: Beta population model

Prediction is an inherently uncertain process. Predictive models should acknowledge this uncertainty, and preferably be able to describe it. The beta model used in this report is done so to acknowledge and describe the uncertainty in predicting the population change and extinction of the trans-boundary dolphins.

Population dynamics can be highly stochastic – the number of births or deaths in a given year can be much higher or lower than the average, based simply on chance. This chance creates uncertainty in predictions, and therefore the model used here is based on these stochastic processes to account for uncertainty.

Populations are also discrete – there cannot be fractions of animals. Modelling processes based on fractions of individuals will introduce additional uncertainty into the model. Using a discrete model, i.e. one that does not allow fractions of animals, reduces uncertainty.

Birth and death are chance events with two alternate outcomes (i.e., birth or not; death or survival). Iterations of these chance events can be called trials, and probabilities of outcomes from such trials are described by beta distributions (Woodworth, 2004). Beta distributions are described by function beta(α, β). The Bayesian posterior distribution of this function (with a non-informative prior) is such that if n is the number of trials, and s is the number of 'successful' outcomes (i.e., a birth or a death), then (Woodworth, 2004):

$\alpha=s+1$ and $\beta=n-s+1$

From photo-ID studies, we can consider each year that an animal is observed as a trial, with an outcome (it dies or not, it gives birth or not). From 2007-2012, 37 separate trials were observed, with two deaths, and no births.

The probability of death is therefore described by the distribution beta(2+1, 37–2+1) = beta(3, 36).

Only females can give birth. We do not know the gender of all individuals, and therefore do not know the true number of trials involving females. Assuming an even gender ratio, the total number of trials is halved to reflect those involving females, such that the probability of giving birth is described by beta(0+1, 37/2-0+1) = beta(1, 19.5).

Although calves may have actually been born in this period, none have been photographed nor recruited into the population. If any were born, they almost certainly died within weeks of birth as is a critical, though common throughout the Mekong (Gilbert & Beasley, 2006; Dove, 2009; Seng et al., 2012). Births in this model therefore can be considered as recruitment into the adult population, sensu Ryan et al. (2011). If calves fail to recruit, they have no impact on the model as used here.

The model

The model was constructed such that the population in a given year was equal to the population in the year before, minus the number of deaths, plus the number of births, with births and deaths chance events based on the beta distributions described above.

As the number of births and deaths in a given year were drawn randomly from the beta distributions, any single iteration of the model would produce a different outcome. Therefore 1,000 iterations of the model were simulated, from which the mean, median, and mode describe the expected or most likely outcomes, and the 5th and 95th percentiles describe the bounds of the 90% credible interval (CI).

All simulations began at the known population size of six in 2012. Each individual had a single chance of death in each iteration, up to a population of 10 (however the population never got above eight in any iteration, Fig. B1). Only one birth could occur per iteration, and births could only occur from a population of two or greater. Once an iteration reached zero it was constrained to remain there (rather than continue to decline into a 'negative' population). Births and deaths were sampled such that a birth or death occurred if a random number was greater than a randomly chosen point on the respective beta distribution. Randomization occurred for each chance of birth or death in each iteration.

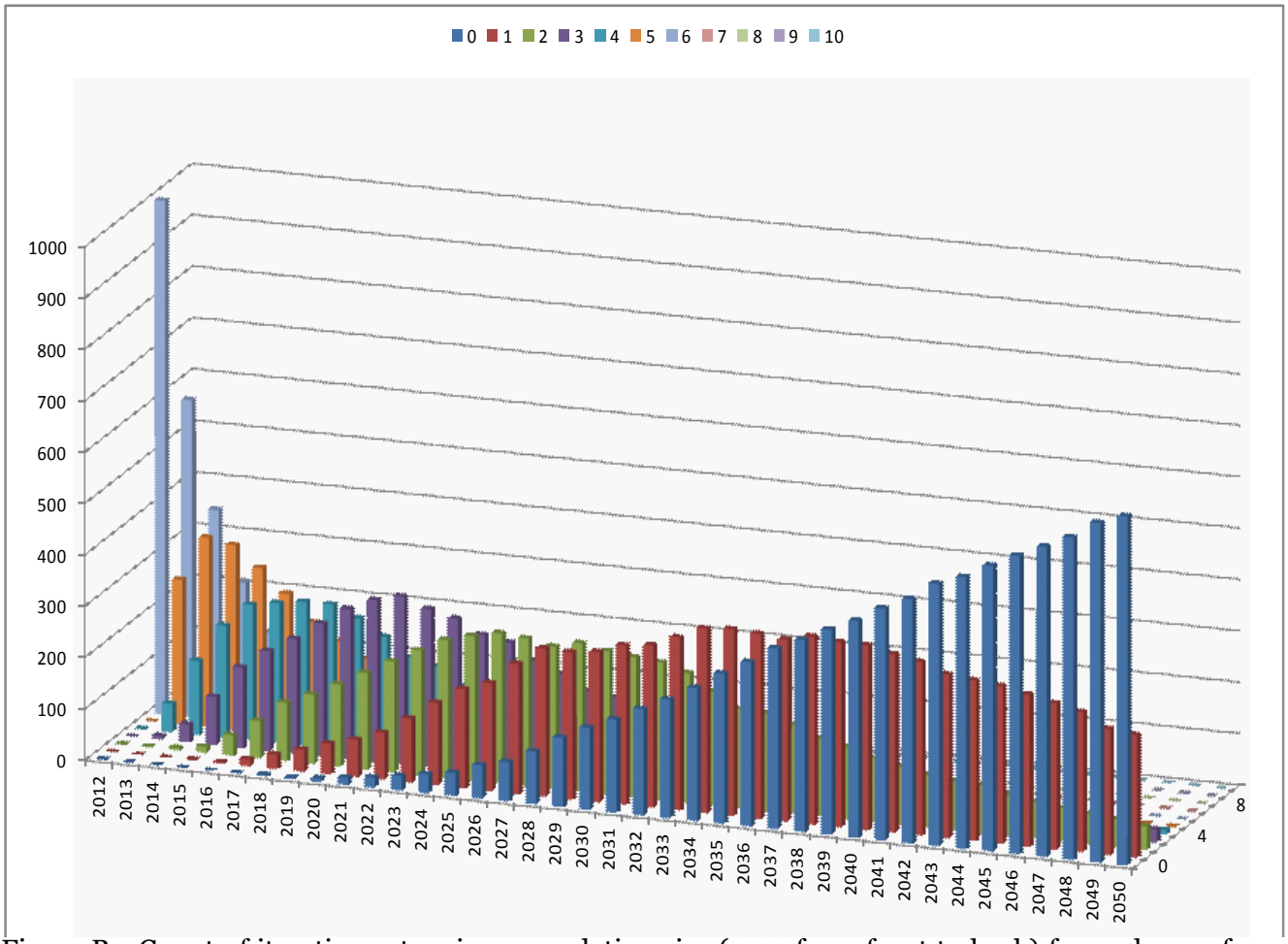

Figure B1. Count of iterations at a given population size (0-10 from front to back) for each year from 2012-2050.

The beta model was constructed in Microsoft Excel 2010, such that the population size in a given year was derived using the formula:

```
=IF(X>0,(X-(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0))
-IF(X>1,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>2,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>3,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>4,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>5,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>6,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>7,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>8,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>9,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)),0)
```

Where X is the population size in the preceding year.

The full simulation was achieved copying this across years from 2013-2050, and repeating it 1,000 times. Each cell was based on 12 random numbers, totalling 456,000 randomizations over the entire model.

The results of this modelling are shown in the main body of this report.

Back-prediction

To assess the reliability of reports of the trans-boundary population size in the 1990s, the beta model was modified to predict the population previously. The model ran such that the population in a given year was equal the population in the following year, plus mortalities, minus births—a simple reversal of the forward prediction. An additional modification was made to this model so that above population size of 10, and each subsequent increase of five animals, an additional chance of birth was allowed, up to a population of 29 (and only ~5 of 22,000 data points reached >29).

This model used MS Excel 2010, such that the population in a given year was derived using the formula:

```
=IF(X>0,(X+(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0))
+IF(X>1,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>2,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>3,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>4,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>5,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>7,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>8,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
+IF(X>9,(IF(RAND()>(BETA.DIST(RAND(),3,36,TRUE)),1,0)),0)
-IF(X>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)
```

-IF(X>9,(IF(C46>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)),0)
-IF(X>14,(IF(C46>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)),0)
-IF(X>19,(IF(C46>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)),0)
-IF(X>24,(IF(C46>1,IF(RAND()>(BETA.DIST(RAND(),1,19.5,TRUE)),1,0),0)),0)),0)

The results of this model suggest a population of around 18 in 1990, (12-26, 90% CI). This is slightly lower than reported values. Although these reports are anecdotal, this may reflect higher mortality rates during the 1990s than more recently. Nonetheless, the predictions of this model roughly match reported values suggesting that there may have only been a small difference in the relative pressures on mortality between 1990 and presently.

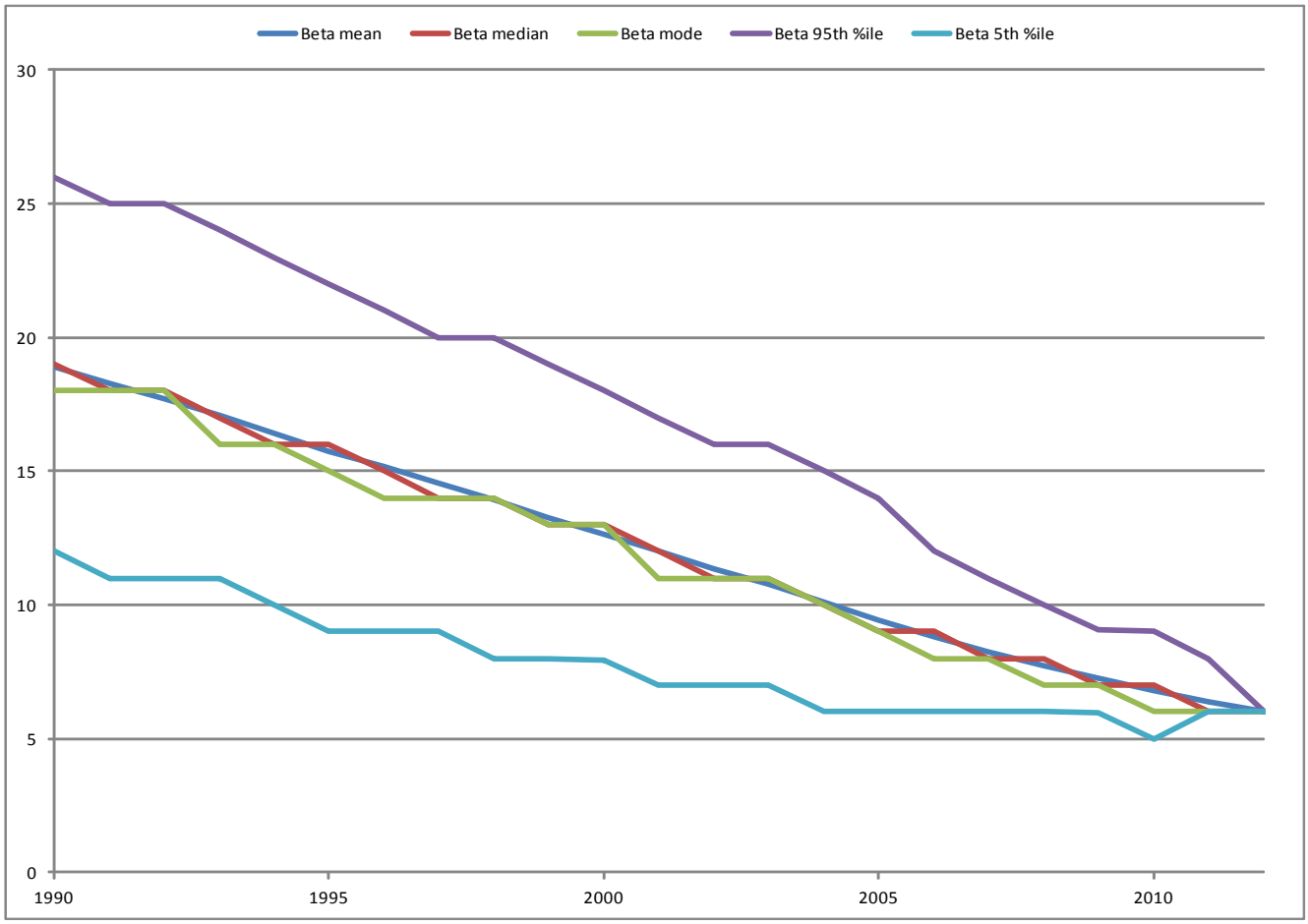

Figure B2. Results of the back-predictive model showing expected population size from 1990-2012.

Greater Mekong in numbers

Today the Greater Mekong region is an integral part of one of the top five most threatened biodiversity hotspots in the world

208
new species discovered in 2010, adding to the 1,345 newly identified since 1997

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300 million
people depend on healthy natural systems such as rivers, forests and wetlands for their food security, livelihoods and customs

850
freshwater fish species live in the Mekong and its tributaries

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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