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in Cambodia's Mekong River

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TECHNICAL REPORT ON THE MONITORING OF THE IRRAWADDY DOLPHIN POPULATION IN THE MEKONG RIVER

THE LONG-TERM POPULATION MONITORING BASED ON MARK-RESIGHT MODELS

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List of Acronyms

BMZ	German Federal Ministry of Cooperation and Development
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMDCP	Cambodia Mekong Dolphin Conservation Project
DFC	Department of Fisheries Conservation
FiA	Fisheries Administration
IUCN	International Union for Conservation of Nature
MAFF	Ministry of Agriculture, Forestry and Fisheries
MFF	Mekong Flooded Forest
SDC	Swiss Agency for Development and Cooperation
SSC	Species Survival Commission of the IUCN
WCS	Wildlife Conservation Society
WWF-BE	World Wide Fund for Nature –Belgium
WWF-CH	World Wide Fund for Nature-Switzerland
WWF-NL	World Wide Fund for Nature-Netherland
WWF-SE	World Wide Fund for Nature-Sweden

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Key findings

The population of the Irrawaddy dolphin in the Mekong River is estimated at 89 individuals in 2020, with a 95% confidence interval of 78-102.

The average annual population growth rate is estimated at 1.02, reflecting a reverse trend of an average annual decline at -2.09% per year from 2007 to 2020. Average annual survival rate is estimated at 0.978 (95% CI 0.944-0.991), or 2.14% mortality rate per year from 2007 to 2020. The seniority is estimated at 0.958 while recruitment rate is estimated at 4.22% per year in 2020.

The population size was estimated by combination of marked and unmarked dolphins whereas, population growth rate, survivorship, recruitment and seniority were estimated based on only marked animals. The unmarked dolphins recorded 16 in 2020 and 18 in 2017.

Overall, these results suggest that the population **has been stable** if compared with the population of the last three years from 2017. The average annual mortality rate at 2.14% is slightly higher than 2.01% in 2017.

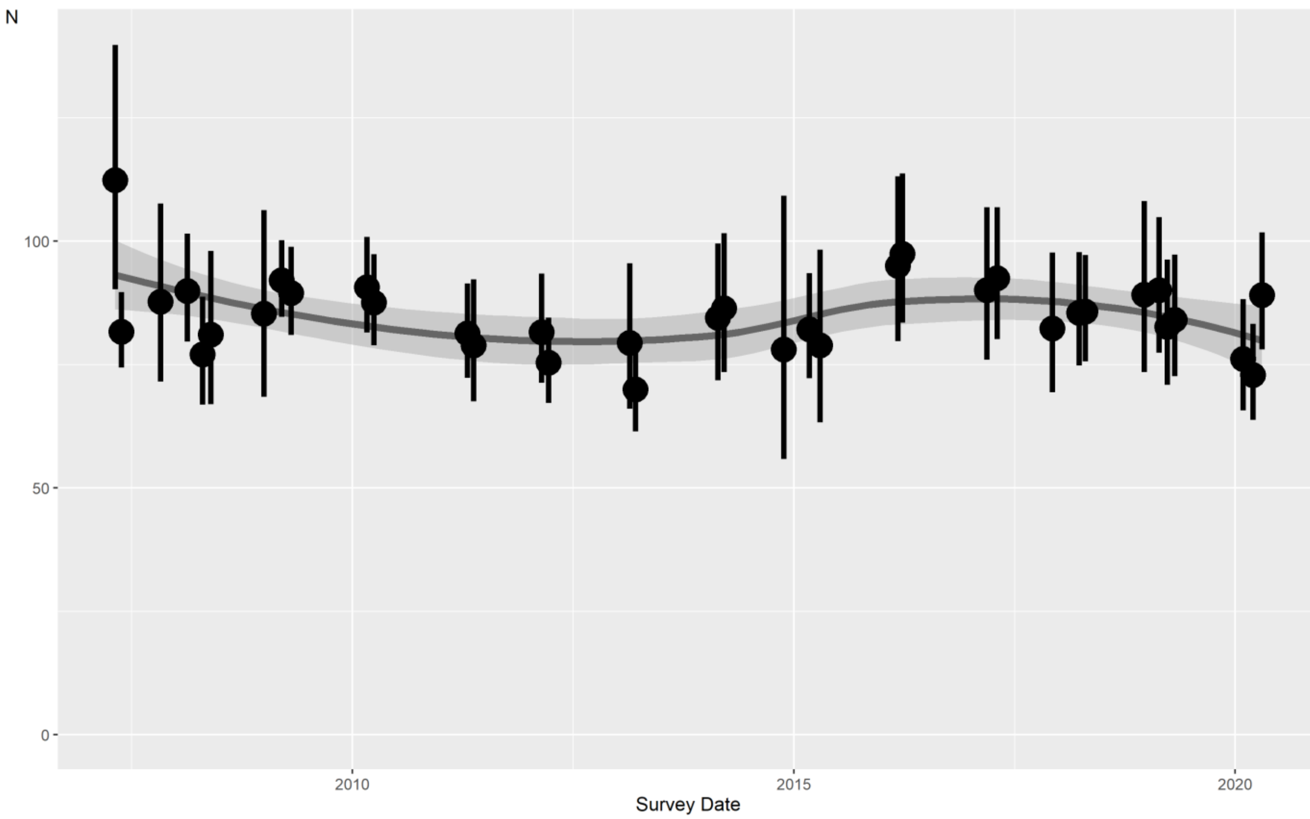

Figure 1: Estimation of the population size of Irrawaddy dolphins in the Mekong River in Cambodia between 2007 and 2020, with 95% confidence interval.

Introduction

The Irrawaddy dolphin inhabits coastal areas of the tropical and sub-tropical Indian and west Pacific oceans, associated with muddy brackish water in river mouths and in freshwater (Beasley, 2011). Freshwater populations of this species can be found in three river systems: the Mahakam in Indonesia, Ayeyarwady in Myanmar and the Mekong River in Cambodia and southern part of the Lao PDR; they are also found in two inland fresh water lakes, Songkla in Thailand and Chilika in India (Beasley, 2011).

In the past, until four or five decades ago, hundreds of Irrawaddy dolphins used to be distributed in the wider range of the *Tonle Sap* (Great Lake), the Mekong Delta and the upper Mekong River and its three main tributaries Sekong, Sesan and Srepok; however, this population is now inhabiting only a small stretch of the Mekong River from Kratie provincial town north to the Khone waterfall at the Cambodian and Lao border, about 180 km. The population gradually declined to approximately 200 individuals in 1997 (Baird & Beasley, 2005), 127 in 2005 (Beasley *et al*., 2009), 93 in 2007 (Beasley *et al*., 2012), 85 in 2010 (Ryan *et al.*, 2011) and 80 individuals in 2015 (Phan *et al*., 2015).

The Irrawaddy dolphin in the Mekong River was classified as 'Critically Endangered' on the Red List of the IUCN (International Union for Conservation of Nature) in 2004 (Smith & Beasley, 2004) and classified as one of the 58 threatened species under the Cambodian Government's sub-decree on "*Determination of Types of Fisheries and Endangered Fisheries Product*" in 2009. In addition, it is listed by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) as an Appendix I species.

The major threats facing the current protection and management of this species include gillnet entanglement, illegal fishing practices including electrofishing, and poisoned bait, overfishing due to human population growth (Thomas *et al.*, 2019), the current impacts of Covid-19 disease, and changes of water flow due to a combination of construction of upstream dams and climate change. Based on a simulation model, Lauri *et al*. (2012) predicted a change in downstream flows at Kratie of 25-160% higher in the low-water season and 5-24% lower in the high-water season from a baseline recorded in 1982-1992. There was a lot more uncertainty about the impacts of climate change but changes due to dam construction were predicted to be much greater than the effects of climate change. The Covid 19 makes majority of workers loss employment and return back home along the Mekong dolphins' range to do fishing; this has put a tremendous pressure on the Mekong River.

The first survey in the Mekong River and its three tributaries by Baird estimated not more than 200 individuals in 1997 (Baird & Beasley, 2005). The first photo-identification was conducted between 2001 and 2005 and estimated the population at 127 individuals with a 95% confidence interval of 108-146, based on a closed capture and recapture model (Beasley *et al.*, 2005; Beasley *et al.*, 2009). Using the same population models on data obtained from a second series of surveys, conducted between 2004 and 2007, the population was estimated at 93 individuals with a confidence interval of 86-101 and a decline of approximate 7% per year. The separate photo-identification mark-resight study between 2007 and 2010 estimated the population at 85 individuals with a 95% confidence interval of 78-91, a population growth rate at 0.98 and no observed recruitment (Ryan *et al.*, 2011). From surveys conducted between 2010 and 2015, the population was estimated at 80 individuals with a 95% confidence interval of 64-100 and population growth rate at 0.98 (Phan *et al*. 2015). Data derived from surveys conducted between 2015 and 2017 estimated a population size of 92 individuals with a 95% confidence interval of 80-106 and the average annual population growth at 0.98 (Phan *et al*. 2017). These data indicate that the population size has increased since 2015 and average annual population growth has increased from 0.93 to 0.98 and the mortality rate has been reduced (Table 1).

Table 1: Summary of Population Estimates for Irrawaddy Dolphins in the Mekong River, Cambodia

Survey Years	Population Estimate (methodology)	95% Confidence Interval	Population Growth	Decline Rate	Reference
1997	<200 Direct count	NA	NA	NA	Baird and Beasley, 2005
2001-2005	127 (Photo-ID Mark and Recapture)	108-146	NA	6.4%*	Beasley *et al*.2009
2004-2007	93 (Photo-ID Mark and Recapture	86-101	0.93	7%	Beasley *et al*. 2012
2007-2010	85 (Photo-ID Mark-resight)	78-91	0.978	2.2%	Ryan *et al*. 2011
2010-2015	80 (Photo-ID Mark-resight)	64-100	0.984	1.6%	Phan *et al*. 2015
2015-2017	92 (Photo-ID Mark-resight)	80-106	0.979	2.01%	Phan *et al*. 2018

*This estimated population decline from January 2004 to April 2005

In 2012, the decline observed in the dolphin population initiated a comprehensive conservation strategy that comprises the establishment of "the Mekong River Dolphin Management and Protection Zones" and effective law enforcement by a team of river guards and supports the monthly monitoring of the dolphin population. This strategy is strongly supported by the government of Cambodia and the participation of local communities residing along the range of the Irrawaddy dolphins' in the Mekong River. This conservation strategy has been successful in reducing the incidence of illegal gill nets in key areas of the dolphin's habitat and has subsequently reduced the mortality of dolphins in nets. The continuation of the photo-identification programme provides a constant means of monitoring every dolphin within the Mekong River population and also provides a means to assess the success of the conservation action plan, in addition to providing insights to long term population trends.

The photo-identification database for the Mekong River dolphin population now spans around two decades and to better manage this huge resource, all survey and imagery data is currently being compiled in "Finbase[1]", a purpose built photo-identification software. The team at the Sarasota Dolphin Research Programme, the Chicago Marine Mammal Society, has worked with the team in Cambodia to develop a Finbase interface suitable for the unique nature of the Mekong River dolphin database and to accommodate the Khmer language. It is hoped that this management system will allow the Cambodian team to easily manage and analyze the extensive dataset that exists and, for the first time, will consolidate all data into one platform. The effective management of the river dolphin dataset will improve population estimation and other life history parameter calculations in the future.

This report provides an update on the Mekong River dolphin conservation strategy and its significant contribution to the protection and management of the riverine system and the dolphin population. A review of the dolphin monitoring programme conducted between 2007 and 2020 is also provided.

Research Methodology

Methods follow previous work described in Phan and colleagues (2015, 2018), Ryan and colleagues (2011), and Dove and colleagues (2008).

[1] https://www.fisheries.noaa.gov/national/marine-mammal-protection/finbase-photo-identification-database-system

Study Area

The study area covers the 180-km stretch of the Mekong River from Kratie provincial town (UTM 48p: 610295, 1380961) to the Khone water fall (UTM 48P: 603017, 1540158) at the international border between Stung Treng province in Cambodia and Champassak province in the Lao PDR, which also covers the 37-km stretch of the Ramsar Site in Stung Treng province. This stretch of the Mekong River has numerous riverine habitats including a diverse and rich mosaic of seasonally flooded riverine vegetation, sandbars, deep pools, rocky rapids, a big number of flooded islands, and river bank flooded forest. Such habitats are not only important to fish to shelter, breed and grow, but they are also indispensable for a range of globally threatened taxa of large mammals, amphibians, reptiles and water birds, including the Irrawaddy dolphin. The entire 180 km river stretch was designated as *the Mekong Dolphin Protection and Management Zone* under the Sub-Decree of the Cambodian government in 2012. Part of this Mekong stretch is also defined as both *the Mekong Fisheries Biodiversity Management and Conservation Zone* under the Proclamation of the MAFF in 2013 and the Stung Treng Ramsar site registered in the list of the Ramsar Convention in 1999. This site is currently under the consistent and increasing threat of degradation by a variety of unsustainable activities including clearance of the riparian and river channel vegetation, urban and agricultural developments, electro and explosive-fishing and over-fishing due to population growth. The survey route covered the current range of Irrawaddy dolphins that includes the nine deep pools (indicated in black color on the map), where majority of dolphins concentrate to inhabit during the dry season, and Stung Treng Ramsar site (see Fig 2). Preak Brosap and Sambor Wildlife Sanctuaries located on both sides of the Mekong dolphins' range, were recently designated by the Government, and those have significantly reduced pressure caused by anthropogenic activities on the Mekong River, especially on dolphins.

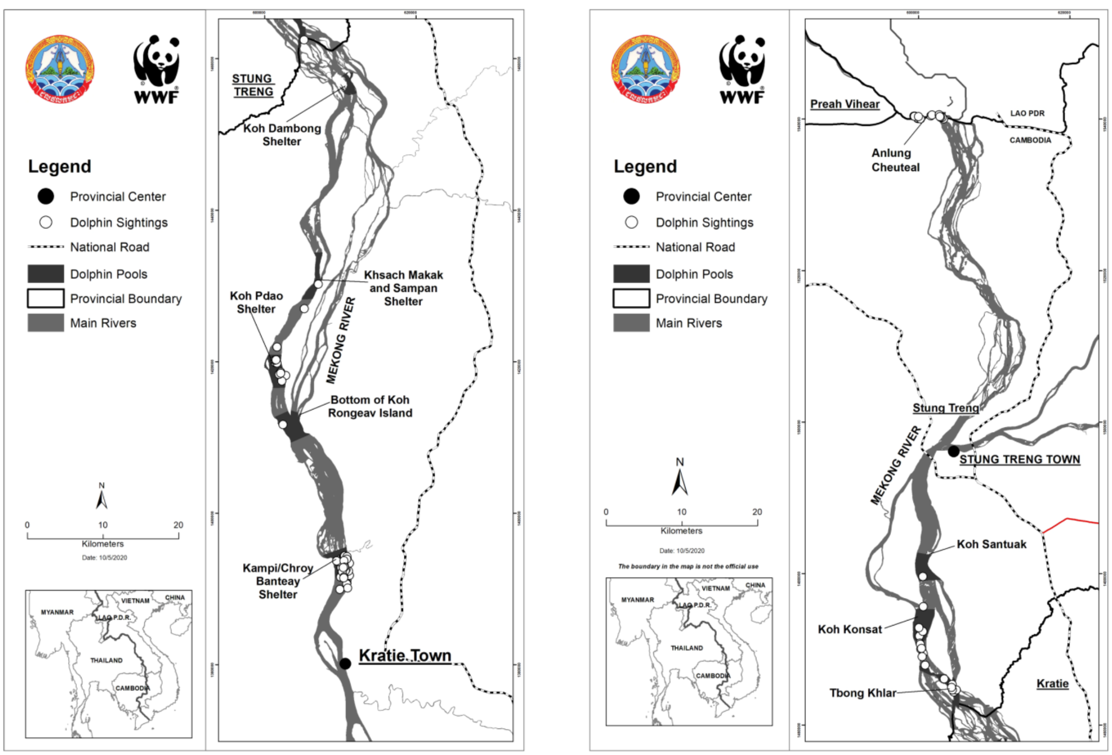

Figure 2: The study route and sightings showing Irrawaddy dolphin distribution along the Mekong River between December 2017 and April 2020, over a 180 km distance from Kratie Township to the border between Cambodia and Lao PDR

Field Survey

Dolphin data have been consistently collected using protocols developed in 2005 (Ryan *et al*., 2011; Phan *et al.*, 2015; Phan *et al.*, 2018). Between 2007 and 2020, thirty-six complete and river-wide surveys were conducted, (Table 2). Overall, the surveys were conducted during the dry season between February and April, when the water level was low, which increased the possibility of detecting dolphins as there was less water area to search. Each survey lasted between nine and eleven days and consisted of one upriver and one downriver survey. The survey area covered the entirety of the dolphin's known range and spanned from Kratie to the Khone Falls and back again, starting at 8am and finishing at 4pm (Figure 2). The research team members used a boat and survey speed was ~5 – 10 km/hour. Where the river width was more than 500m in breadth, a zigzag search pattern was conducted, from river bank to river bank, to improve coverage of the entire survey area. The team comprised seven observers, two on the bow looking forward, plus two observing port and starboard sides plus two looking behind. At least one experienced boat driver was present on every trip and each observer station was rotated to reduce fatigue.

When dolphins were sighted, the boat travelled to ~100m upstream of the sighting and floated, with the engine stopped, back in the direction of the dolphin sighting, in order to minimize disturbance. A paddle was used to cautiously approach the dolphins. Attempts were made to photograph the dorsal fins of all dolphins within the group, using various camera models including Nikon D200/Nikkor 70-400 mm, Canon EOS 350D/Sigma 170-500 mm, Canon EOS 350D/Canon 100-400 mm, Canon 450D/Sigma 170-500 mm, Canon EOS 450D/Canon 100-400 mm, Canon EOS 50D/Canon 100-400 mm, Canon EOS 7D/Canon 100-400, and Canon EOS 7D2/Canon 100-400 mm. Photographs were obtained over a period of 30-120 min as it was generally considered that this time was sufficient to capture images of all of the dolphins within the group while minimizing disturbance.

Table 2: A Summary of Survey Information and Data of Irrawaddy Dolphins in the Mekong River, April 2007 - April 2020

Survey dates	Survey Length (days)	Estimated Individuals sighted	Cumulative marked animals	Average number of unmarked animals	Survey sighting rate
17-25 Apr 2007	9	61	61	10	1.52
21-29 May 2007	9	61	75	5	2.02
29 Oct-08 Nov 2007	11	42	77	9	1.31
18-27 Feb 2008	10	60	79	7	1.53
21 Apr - 01 May 2008	11	48	80	5	1.63
25 May- 03 Jun 2008	10	41	81	7	1.41
30 Nov -09 Dec 2008	10	38	84	2	1.24
13 - 22 Mar2009	10	70	86	8	1.89
21-30 Apr 2009	10	64	87	9	1.86
02-10 Mar 2010	9	63	88	11	1.79
31 Mar- 09 Apr 2010	10	62	88	10	1.79
21-29 Apr 2011	9	56	91	7	1.68
17-25 May 2011	9	47	91	9	1.51
21-29 Feb 2012	9	53	92	8	1.49
21- 29 Mar 2012	9	53	92	9	1.79
21 Feb- 01 Mar 2013	9	42	93	17	1.57
16-24 Mar 2013	9	47	93	8	1.79
20-28 Feb 2014	9	49	94	11	1.41
17-25 Mar 2014	9	50	95	11	1.40
19-27 Nov 2014	9	23	95	16	1.26
05-13 Mar 2015	9	54	95	10	1.61
18-26 Apr 2015	9	37	95	14	1.38
05-13 Mar 2016	9	51	100	18	1.43
25 Mar-02 Apr 2016	9	55	103	21	1.60
09-18 Mar 2017	10	48	105	20	1.65
20-29 Apr 2017	10	55	106	18	1.71
04-12 Dec 2017	9	46	108	12	1.57
26 Mar-03 Apr 2018	9	54	109	17	1.83
20-28 Apr 2018	9	56	111	15	1.82
19- 27 Dec 2018	9	44	111	19	1.45
20-28 Feb 2019	9	52	111	19	1.65
26 Mar-03 2019	9	49	111	16	1.67
25 Apr- 03 May 2019	9	51	111	17	1.67
04-12 Feb 2020	9	48	111	12	1.60
13- 21 Mar 2020	9	49	114	10	1.76
21- 29 Apr 2020	9	57	120	16	1.74

Photo Identification

Images of the dolphin's dorsal fins were reviewed and only clear focused, and fins taken at an aspect of close to a 90-degree angle to the camera (perpendicular) were used for identification analyses. All adult dolphins were able to be individually identified by using dorsal fin shape, deformities, pigmentation, scars and lesions. Dolphins that did not have clear marks were either juveniles or sub-adults. It was possible to distinguish these individuals within groups, based on dorsal fin shape and other features; however, these individuals were not added to the photo-identification catalogue and were treated differently in some analyses. Dolphin calves (<1year) were recorded but were not included in population parameter analyses. The population models were run in R (R 3.6.1; Development Core Team 2019), and the scripts are available within the library of R packages in the Comprehensive R Archive Network (CRANhttps://cran.r-project.org).

Analytical Methods

To estimate the Mekong dolphin population size, using Mark-resight models, a robust design (zero-truncated) Poisson-log normal estimator (ZPNE) was used, which was developed under program Mark (White and Burnham, 1999; McClintock *et al.,* 2009; and McClintock and White, 2012). The surveys conducted between 2007 and 2020, provided a total number of marked and unmarked dolphins of each survey (see table 2). Based on this dataset, estimates were made of the number of unmarked individuals for each primary survey ($\cup_t$), mean resighting probability for each survey period (α_t) on the log-scale, the variance in resighting due to individual heterogeneity (σ_t^2) on the log-scale, apparent survival within the super survey periods (φ_t), the probability transitioning from an observable (e.g., within the study area) to unobservable state (e.g., out of the study area) between survey periods given whether an individual was observed (γ_t''), and the probability of remaining unobservable (e.g., outside the study area) between primary surveys given an individual was unobservable (γ_t'). The derived parameters included the population size of each survey (N_t) and the mean resighting rate for each survey. Using these parameters, we modeled the following based on Ryan *et al*., (2011); unmarked dolphins ($\cup$) were modeled as a function of survey i.e., assuming the capture of a number of unmarked individuals varies by each survey. Resighting probability was modeled as a constant across the surveys ($\alpha_.$) and as a function of the surveys (α_t). Heterogeneous individuals were modeled as constant ($\sigma_.^2$), equal to zero ($\sigma^2 = 0$), as well as a function throughout the surveys (σ_t^2). Survival was modeled as constant ($\varphi_.$) and as a function of the survey (φ_t). Probability transitioning was modeled as constant ($\gamma_.'' \; and \; \gamma_.'$), either separate or equal to each other (i.e., $\gamma'' = \gamma'$). Using the model with the lowest Akaike's Information Criterion (AIC) and implementing a correction for small sample size (AICc), models were ranked and compared (Burnham and Anderson, 2002). The survivorship of adult animals is the number of animals that survived from time t to t+1 (denote as φ), obtained from the most accurate model. Population growth rate, seniority and recruitment were used as a reverse-time approach (Pradel, 1996; Nichols *et al.,* 2000). Population growth rate (λ_t) was estimated as a function of surviving animals (φ) from the population at time t and seniority (ρ) at t+1 (Equation 1). The convention of referring to a population growth rate as an inference of population size decrease [λ_t<1], stasis [λ_t =1], and increase [λ_t >1] was used (Nichols *et al.,* 2000). Seniority (ρ) is the probability that an individual present at time t was present at t-1. The new recruitments ($ʃ_t$) are animals not in the population at time t, but instead result from reproduction, entering the population between time t and t+1 (Ryan *et al.,* 2011), (Equation 2).

Equation 1: Growth rate as a function of relative contribution survival and seniority

$$\lambda_t = \frac{\varphi_t}{\rho_{t+1}}$$

Equation 2: Recruitment as a function of survival and seniority

$$f_t = \varphi_t \left(\frac{1 - \rho_{t+1}}{\rho_{t+1}} \right)$$

Results

Our best model selection indicated that the mean resighting probability varied per survey (α_t), individual heterogeneity ($\sigma_.^2$) was constant, survival ($\varphi_.$) was constant, the number of unmarks varied by time surveys ($\cup_t$) and transition probabilities were constant ($\gamma_.^{''}$ and $\gamma_.'$), (see appendix). The next best model was differed only in its assumption that there was no additional variance in resighting due to individual heterogeneity ($\sigma^2 = 0$).

From the best model (AICc =7251.88), population size was estimated at 89 individuals in 2020, with 95% confidence intervals of 78 – 102, (Fig 3). The population growth rate was estimated at λ_t=1.02, reflecting the reverse trend of the average annual decline rate at -2.09% over the time period from 2018 to 2020. For survival, the probability of adult dolphin survival from time t to t+1, was estimated at 0.978 (0.944-0.991, 95% CI), with an estimation of mortality rate of 2.14% per year. For the seniority, the probability of adult dolphins observed at time t, being present as well at time t-1, was 0.958. The new recruitment, the new marked dolphins that weren't present at time t, but were found at time t+1, was 4.22% per year. The probability of transitioning from an observable to unobservable states, given by an individual ($\gamma_t^{''}$), was estimated at 0.037 (0.005 SE) and the probability of remaining in unobservable states between primary surveys, for a given individual (γ_t') was 0.928 (0.022 SE).

Table 3: Summary of Population Estimates for the Irrawaddy Dolphin of the Mekong River in 2020, Cambodia

Survey Years	**Population Estimate**	**95% CI**	**Population Growth Rate**	**Decline Rate**	**Reference**
2018-2020	89	78-102	1.02	-2.09%	Eam *et al*. 2020)

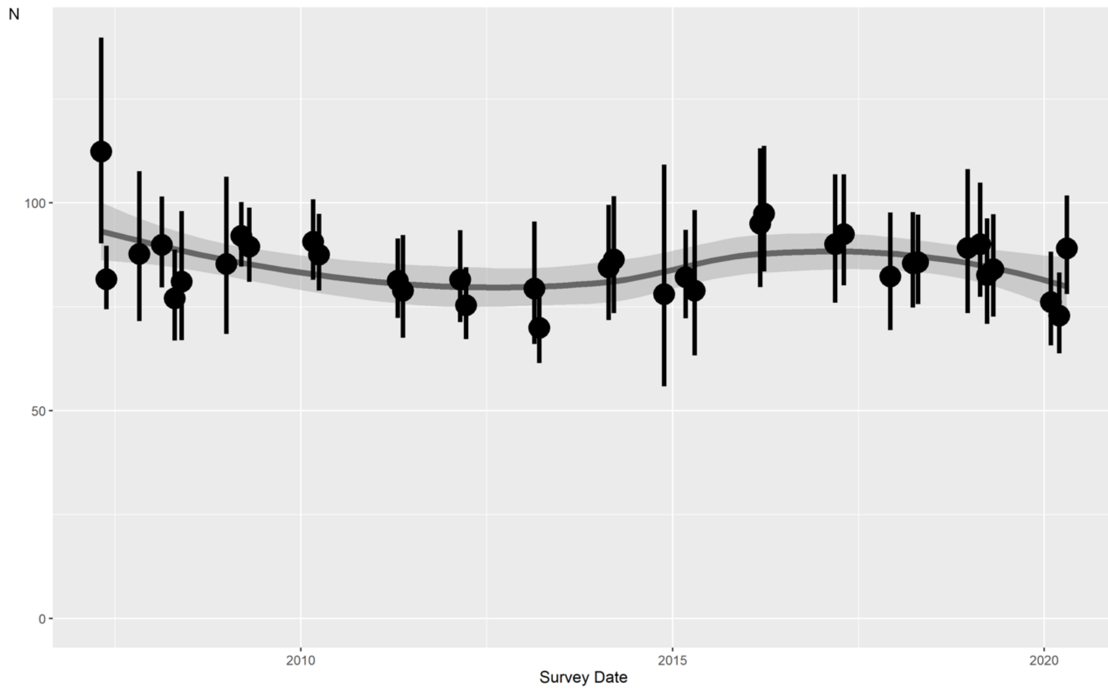

Figure 3: Estimation of the population size (N) of Irrawaddy dolphins in the Mekong River of Cambodia between 2007 and 2020, with 95% confidence interval

120 uniquely marked dolphins were identified and entered into the database for the period 2007-2020. The average number of unmarked dolphins recorded was 14 in 2015, 18 in 2017 and 16 in 2020 (Fig 4), resulted from surviving calves to juveniles. Average group size was 8 (range 1-28) amongst the primary surveys during the period from 2017 to 2020.

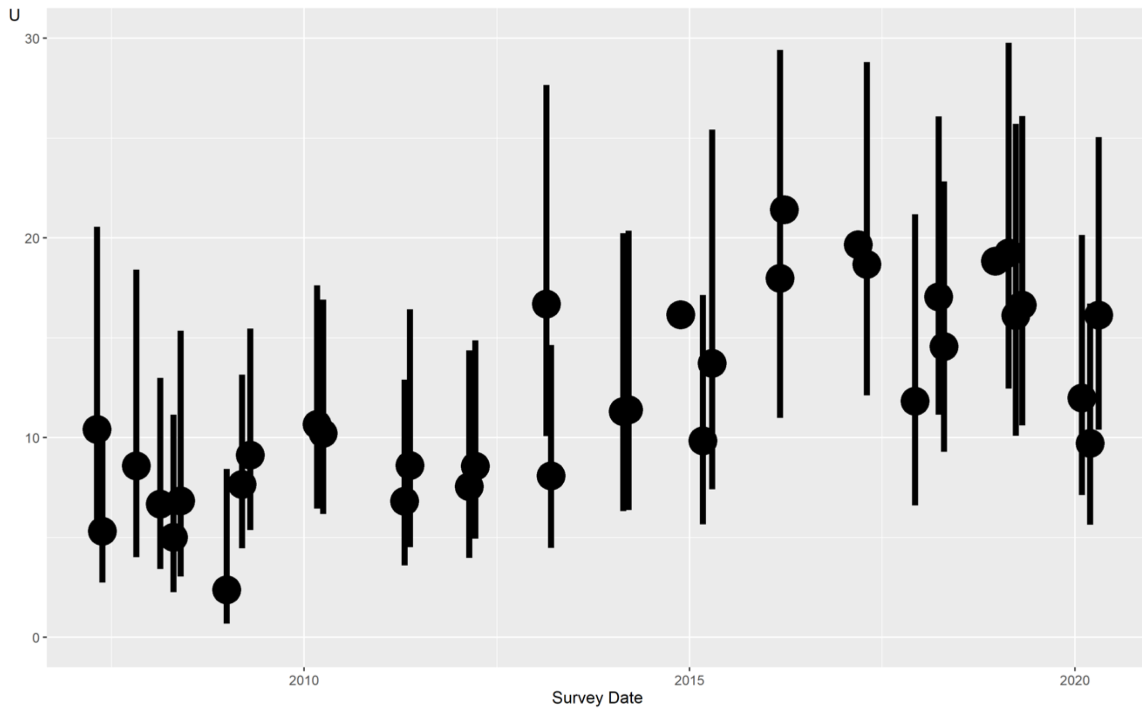

Figure 4: Estimation of the number of unmarked dolphins (U) for each primary survey between 2007 and 2020, with 95% confidence interval

The top model ranked in Table 2, illustrates the resighting probability variation across the surveys. The average number of times of an individual was resighted is 1.24 with a variation across the surveys (Fig 5).

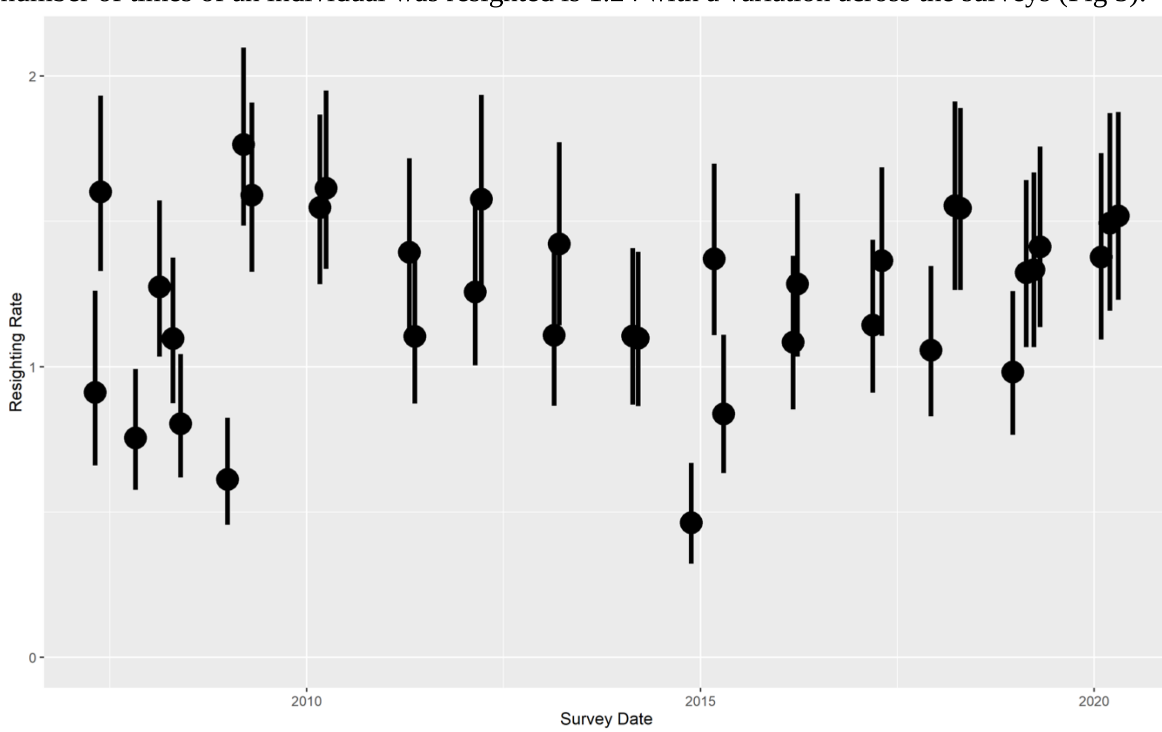

Figure 5: Resighting rate of Irrawaddy dolphins in the Mekong River between Kratie and Stung Treng provinces across the surveys, 2007 and 2020

Discussion and Conclusion

A long-term monitoring programme for Irrawaddy dolphin in the Mekong River has been conducted over a period of 14 years, using a systematic approach to data collection and analyses. Our current estimate for 2020 estimates the population size to be 89 (78-102, 95% CI), including both marked and unmarked individuals. This is similar to previous estimates 92 individuals (80-106, 95% CI) in 2017 (Phan *et al.*, 2018), 80 individuals (64-100, 95% CI) in 2015 (Phan *et al.*, 2015), 85 individuals (78-91, 95% CI) in 2010 (Ryan *et al.*, 2011), and 93 individuals (86-101, 95% CI) in 2007 (Beasley 2007).

The average annual decline had been noticeably reduced from 7% from 2004 to 2007, 2.2% from 2007 to 2010, 1.6% from 2007 to 2015 and was slightly increased to 2.01% for the period from 2007 to 2017. The findings in 2020 calculate a population growth rate of 1.02 [λ_t = 1.02] indicating the potential stabilization of the population. The annual survival rate of 0.978 (0.944-0.991, 95% CI) indicates a good probability of adult dolphins surviving to the next survey period. Thus, this study shows a similar survival rate published in previous studies: 0.979 (0.922- 0.995 95% CI) in 2017 (Phan *et al*., 2018); 0.976 (0.901-0.995, 95% CI) in 2015 (Phan *et al.*, 2015). The average annual mortality rate of 2.14% is slightly higher than 2.01%, as published from 2017 (Phan *et al.*, 2018); however, it is still lower than the 2.4% rate calculated for 2015 (Phan *et al.*, 2015). In addition, a seniority rate of 0.958 [ρ = 0.958] was calculated, which suggests that adult dolphins in the study population present at time t were also there at time t-1. This is lower than that published previously ρ =0.99 (Phan *et al*., 2017; Phan *et al.*, 2015; Ryan *et al.*, 2011). This can be interpreted as the sensitivity of population growth to adult survival (Equation 1). This study also indicates a potential increase in recruitment (4% per year), whereas previous models calculated a much lower rate (near 0 in 2017; 0.8% in 2015; 0.1% in 2010).

Due to the government's strict ban on logging and loss of employment due to Covid-19 virus, fishing pressure, including the use of gillnets, long lines with many hooks and other destructive gears, has increased.

Despite these challenges, the current estimated population of 89 in 2020 appears stable, is comparable with the population models derived in 2017. The confidence intervals of two population estimates also overlap each other. Interestingly, during the 2020 dry season 2 -3 dolphins were reported in front of the Royal Palace in Phnom Penh and in the Srepork River which is one of the three tributaries of the Mekong. These sightings were not accounted for in the 2020 survey and indicate that there is still potential for dolphins to move outside of the currently known range.

The river guards' effective enforcement of the law on fisheries and relevant legislations has contributed significantly to safe guarding the dolphins and, as such, this important initiative has been improved by increasing the number of patrolling days from 15 days/month in 2016 to 22 days/month from 2017 onwards. Between 2017 and the first six months of 2020, this has resulted the removal of 320.72km of gillnet, ~131km of long-line with many hooks and the arrest and prosecution of 14 illegal fishers who were using electric fishing gear.

In conclusion, studies to date indicate that if pressure caused by anthropogenic activities can be reduced, and if gillnets can be eliminated, we expect that the Mekong River dolphin population will continue to increase as evidenced by the 4.22% recruitment rate compared with 0% in 2017 and 0.8% in 2015; survival rate is 0.978, and population growth of 1.02. The population size is still small; however, and new threats may present new risks. It is also possible that dolphins may move from the currently known core areas and, as such, conservation programmes should be flexible and incorporate any changes to the dolphin population range when necessary. In addition, further focused studies, to better understand the dolphin's biology, habitat preferences and prey status would provide additional data that can better inform conservation management plans. The insights from this and previous publications provide a basis to highlight and reiterate previous recommendations and to provide new recommendations moving forward.

Recommendations

In order to understand the state of the population of the Mekong River dolphins, it is strongly recommended that:

1. The consistent monitoring of the Mekong River dolphin population be continued. This is the longest-running freshwater monitoring program for river dolphins and provides critical data for conservation management and support additional studies that allow will provide more detailed information on dolphin biology and habitat preferences;

2. Law enforcement be improved in response to the increase of anthropogenic activities that are currently putting additional pressure on Mekong River resources and which are negatively impacting both fish biodiversity and the dolphins;

3. The Mekong River in Cambodia remains a free-flowing river. Any large-scale infrastructure development projects such as dams are not compatible with the survival of dolphins and other migratory aquatic species including the Mekong Giant Catfish;

4. Alternative medium and large-scale livelihoods be provided to local people so that pressure can be reduced on the Mekong River while they are facing the impacts of Covid 19;

5. The coordination and collaboration with Lao PDR officials be improved to better protect the trans-boundary pool dolphin group and fisheries biodiversity and thereby also connectivity between Stung Treng Ramsar site in Cambodia and Siphandone Ramsar Site in Laos;

6. The management of the Stung Treng Ramsar site be improved to increase natural fish stock enhancement for both dolphin prey and sustainable consumption by local community members;

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Appendix

Model selection results for the Irrawaddy dolphins Mark-resight analysis

Model	Npar	AICc	DeltaAICc	weight	Deviance
$\alpha_t \sigma_.^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	76	7251.88	0	1.00E+00	7093.36
$\alpha_t \sigma_{=0}^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	75	7272.27	20.39	3.74E-05	7115.92
$\alpha_t \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	112	7296.48	44.60	2.07E-10	7058.09
$\alpha_. \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	41	7358.01	106.13	0.00E+00	7274.13
$\alpha_. \sigma_t^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	76	7417.97	166.09	0.00E+00	7259.45
$\alpha_t \sigma_.^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	75	7545.79	293.91	0.00E+00	7389.44
$\alpha_t \sigma_.^2 \cup_t \varphi_t \gamma_.^{''} = \gamma_.'$	112	7559.42	307.54	0.00E+00	7321.03
$\alpha_t \sigma_{=0}^2 \cup_t \varphi_t \gamma_.^{''} = \gamma_.'$	111	7572.04	320.16	0.00E+00	7335.91
$\alpha_t \sigma_t^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	110	7621.97	370.09	0.00E+00	7388.11
$\alpha_{t.} \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	40	7671.79	419.91	0.00E+00	7590.00
$\alpha_. \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	39	7680.24	428.36	0.00E+00	7600.54
$\alpha_. \sigma_.^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	40	7682.33	430.45	0.00E+00	7600.54
$\alpha_t \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	76	7700.04	448.16	0.00E+00	7541.52
$\alpha_. \sigma_{=0}^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	77	7702.20	450.32	0.00E+00	7541.51
$\alpha_. \sigma_{=0}^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	74	8954.38	1702.50	0.00E+00	8800.20
$\alpha_. \sigma_t^2 \cup_t \varphi_t \gamma_.^{''} = \gamma_.'$	112	187370.88	180119.00	0.00E+00	187132.49
$\alpha_. \sigma_t^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	113	190249.53	182997.65	0.00E+00	190008.87
$\alpha_t \sigma_t^2 \cup_t \varphi_t \gamma_.^{''} = \gamma_.'$	147	214254.96	207003.08	0.00E+00	213935.72
$\alpha_t \sigma_t^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	148	214257.32	207005.44	0.00E+00	213935.72
$\alpha_. \sigma_t^2 \cup_t \varphi_. \gamma_.^{''} = \gamma_.'$	75	221176.03	213924.15	0.00E+00	221019.68
$\alpha_. \sigma_.^2 \cup_t \varphi_t \gamma_.^{''} = \gamma_.'$	77	221180.38	213928.50	0.00E+00	221019.68
$\alpha_. \sigma_.^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	78	221182.55	213930.67	0.00E+00	221019.68
$\alpha_t \sigma_t^2 \cup_t \varphi_. \gamma_.^{''} \gamma_.'$	111	221255.81	214003.93	0.00E+00	221019.68
$\alpha_t \sigma_.^2 \cup_t \varphi_t \gamma_.^{''} \gamma_.'$	113	221260.34	214008.46	0.00E+00	221019.68

Note: ($\cup_t$) the number of unmarked individuals for each super survey, the mean resighting probability across the surveys (α), heterogeneous individuals(σ^2), survival (φ), and probability transitioning to an unobservable state between primary survey periods ($\gamma^{''}$) given an individual was observable, and the probability of remaining unobservable given an individual was unobservable (γ'). These parameters were estimated as a constant (.), for each survey period (t) or set equal to zero (=0). The minimum AICc was 7251.88.