



## Fishing for the facts: river dolphin bycatch in a small-scale freshwater fishery in Bangladesh

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1 **Fishing for the facts: river dolphin bycatch in a small-scale freshwater**  
2 **fishery in Bangladesh**

3

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18

19 **Abstract**

20

21 Fisheries bycatch is a primary driver of cetacean declines, especially for threatened  
22 freshwater cetaceans. However, information on the factors influencing cetacean susceptibility  
23 to bycatch in small-scale fisheries is limited, impeding development of evidence-based  
24 conservation strategies. We conducted 663 interviews with fishers from southern Bangladesh  
25 to investigate the influence of net and set characteristics on seasonal bycatch rates of Ganges  
26 River dolphins *Platanista gangetica gangetica* and assess the sustainability of annual  
27 mortality levels. Between October 2010-October 2011, 170 bycatch events (and a minimum  
28 of 14 mortalities) were reported, 89% of which occurred in gillnets. The probability of  
29 bycatch increased as water depth declined, and as net mesh size increased. While the number  
30 of recorded bycatch incidents was higher in gillnets, risk of mortality was greater in set  
31 bagnets. Our mortality estimate indicates that fisheries-related bycatch currently exceeds the  
32 sustainable limit recommended by the International Whaling Commission by 3.5 times.  
33 Numerous regulations have been developed to improve the productivity of commercially  
34 important fisheries, if regulations were effectively enforced these may also reduce river  
35 dolphin bycatch.

36

37 **Keywords:** bycatch; gillnet; Ganges River dolphin; local informant data; *Platanista*  
38 *gangetica gangetica*, small-scale fisheries

39

## 40 **1. Introduction**

41

42 Incidental capture of non-target species in fisheries, known as bycatch, is a primary driver of  
43 declines in many animal groups including cetaceans (Lewison et al., 2004). The majority of  
44 global aquatic mammal bycatch is thought to occur in gillnets, curtain-like nets set vertically  
45 in the water column to trap fish by their gills (Read et al., 2006). Among cetaceans, bycatch-  
46 related mortality is considered the principal cause of the decline in vaquita *Phocoena sinus*,  
47 the world's most threatened cetacean, and to have contributed significantly to the extinction  
48 of the Yangtze River dolphin *Lipotes vexillifer* (D'Agrosa et al., 2000; Turvey et al., 2007).  
49 Concerns about the impact of bycatch on the status of aquatic species has prompted research  
50 into factors affecting bycatch rates. A range of factors have been identified and can be  
51 divided into: gear (e.g. mesh size, hook type; Kraus et al., 1997; Forney et al., 2011),  
52 operational (e.g. location, season; Vinther, 1999; Yeh et al., 2013), and species-specific (e.g.  
53 species behaviour, body size; Wallace et al., 2008; Yeh et al., 2013).

54

55 Independent-observer programmes are the ideal source of data on factors affecting bycatch,  
56 however, this is logistically unfeasible in many small-scale fisheries. Given the ubiquity of  
57 gillnets within small-scale fisheries (Moore et al., 2010), low-cost solutions for studying  
58 bycatch are urgently needed.

59

60 Interviews with local informants using the same environment as target species are an  
61 increasingly popular method for obtaining data on key conservation parameters rapidly, at  
62 low-cost, over wide geographic areas, and can also provide a perspective on past and present  
63 status and trends where data are otherwise absent (Moore et al., 2010; Turvey et al., 2013).

64 Interviews constitute an important alternative source of data for conservation and have been  
65 used to study harvesting intensity (Jones et al., 2008), population trends (Lozano-Montes et  
66 al., 2008) and bycatch (Moore et al., 2010; Liu et al., 2017) across many taxa. However,  
67 studies have demonstrated a range of biases affecting the accuracy of informant data,  
68 including: 1) under-reporting of illegal behaviours to avoid negative personal consequences  
69 (Tourangeau and Yan, 2007), 2) declining recall accuracy over longer time periods (Bradburn  
70 et al., 1987), 3) misremembering facts where the event is deemed ‘unimportant’ or occurs  
71 regularly (Daw et al., 2011), and 4) misidentification of species (Moore et al., 2010). For these  
72 reasons, standardised interview-based surveys have rarely been used to generate baselines on  
73 patterns and levels of bycatch for freshwater cetaceans.

74

75 Freshwater cetaceans are amongst the most threatened mammals (Reeves, Smith, Kasuya,  
76 2000), partly due to small-scale fishery interactions and small population size which makes  
77 them vulnerable to even low levels of mortality (e.g. Krützen et al., 2018). Minimum  
78 estimates of bycatch indicate that fishing gear entanglement represents a significant source of  
79 mortality: e.g. 87% of Irrawaddy dolphin *Orcaella brevirostris* mortalities in the Mekong  
80 River are attributed to gillnet entanglement, making it the most significant threat to this  
81 population (Beasley et al., 2007; Beasley et al., 2013). However, the nature of these  
82 interactions and levels of mortality are poorly understood and impede the development of  
83 robust conservation solutions (Reeves et al., 2013).

84

85 The Ganges River dolphin *Platanista gangetica gangetica* occurs in Nepal, India, Bangladesh  
86 and possibly Bhutan, and is considered Endangered by IUCN (Smith, Braulik and Sinha,  
87 2012). Given its conservation status, killing and trade of dolphins is prohibited under the  
88 Indian Wildlife Protection Act (1972), the Bangladesh Wildlife Preservation Act (2012), the

89 Nepal National Parks and Wildlife Conservation Act 2029 (1973), the Convention on  
90 International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the  
91 Convention on Migratory Species (CMS). While efforts are ongoing to address knowledge  
92 gaps on abundance (Richman et al., 2014), habitat preferences (Smith et al., 2009) and  
93 population trends (Smith et al., 2001; Richman, 2015), there is a lack of resources for  
94 addressing knowledge gaps regarding patterns and sustainability of bycatch (Mansur et al.,  
95 2008).

96

97 Focusing on an isolated population of Ganges River dolphins in southern Bangladesh, we  
98 conducted an interview survey with fishers to identify the drivers of gillnet bycatch and to  
99 quantify annual mortality. We demonstrate that despite the biases associated with this  
100 approach, interviews are a powerful tool for addressing some of the knowledge gaps on  
101 freshwater cetacean bycatch in small-scale fisheries. We use these data to make informed  
102 recommendations for conservation management.

103

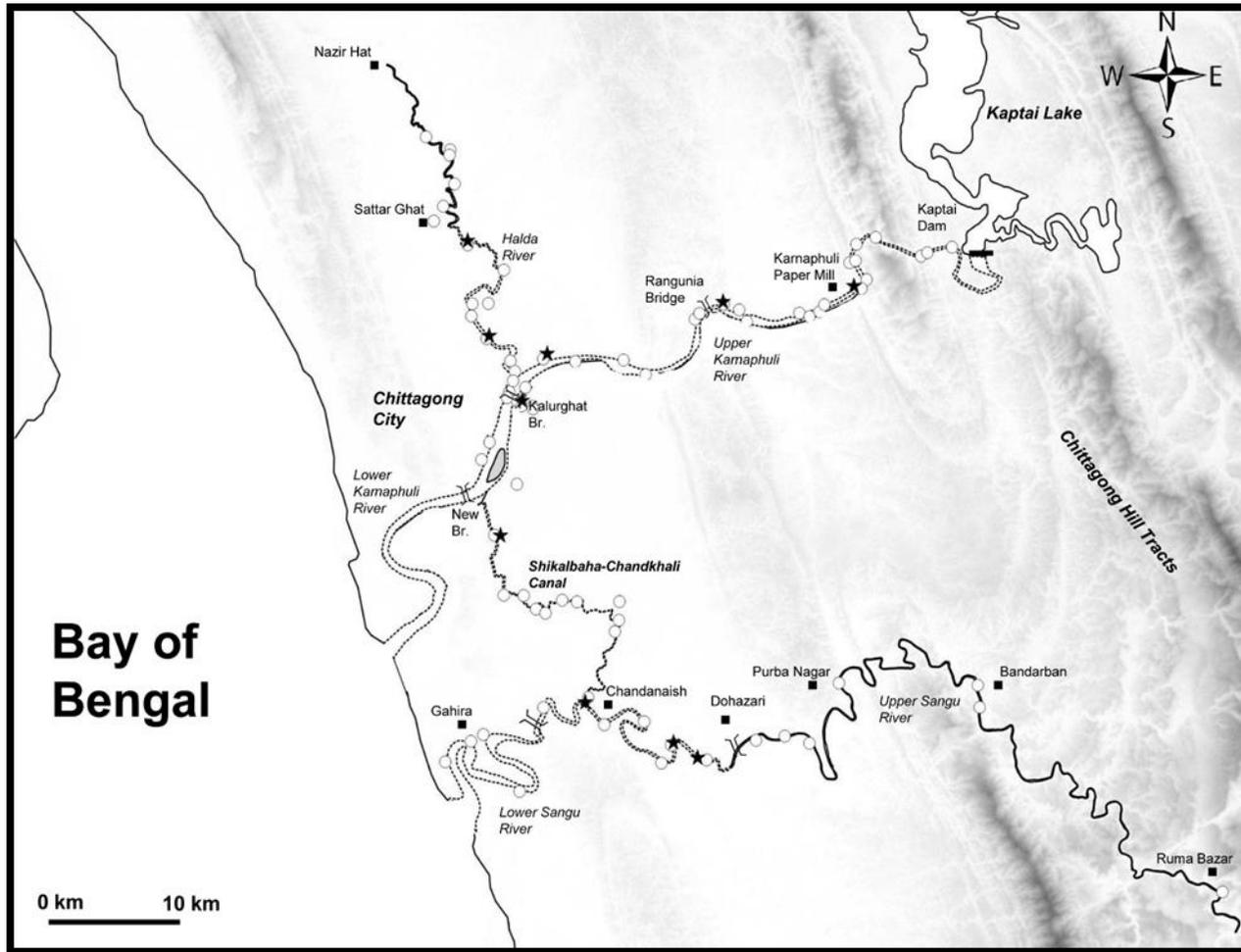
## 104 **2. Methods**

105

### 106 *2.1. Data collection*

107

108 Fisher interviews were carried out from October 2011-February 2012 in settlements  
109 bordering the Halda, Karnaphuli and Sangu rivers and the Shikalbaha-Chandkhali Canal,  
110 collectively known as the Karnaphuli-Sangu river complex (Figure 1). Interview teams  
111 visited every settlement within the study area. Because of the lack of a robust sampling frame  
112 of the target population (active fishers), random sampling was not possible. Informants were  
113 interviewed based on suitability and availability, and asked to suggest other potential



117 informants (Newing, 2011). Fishers fish in groups of two to ten individuals: to ensure no  
118 duplicate recording of bycatch events, members of each group were identified and only one  
119 individual from each group was interviewed. The aim of the interviews was to document: 1)  
120 information on the characteristics of bycatch events between October 2010-October 2011; 2)  
121 anecdotal information about older bycatch events, 3) knowledge and attitudes on fishery  
122 regulations. Interviews were carried out by three teams consisting of a translator (a zoology  
123 student from the University of Chittagong and living in the local fishing community) who  
124 was responsible for conducting the interview, and a note-taker (native English speakers) who  
125 recorded responses in English. Translators were told to ask questions in exactly the way they  
126 were detailed in the questionnaire, and to translate responses as provided. Translators were  
127 asked to inform the note-taker if they did not understand the informant's response. Interview  
128 teams were encouraged to maintain neutral expressions and neutral responses throughout the  
129 interviews so as not to bias informant responses (Bernard, 2006). A standardised  
130 questionnaire (Supplementary Table 1, ~~and~~ 2) was used and designed to a maximum of 30  
131 minutes to reduce potential non-responses or inaccurate responses from informant fatigue.  
132 Questionnaire design was based on recommendations in Bernard (2006) and comprised  
133 closed and open-ended questions. Closed questions incorporated a 'don't know' option to  
134 minimise pressure to provide responses, and an 'other' option to accommodate unforeseen  
135 responses. The questionnaire was developed in English and translated into Bangla by the  
136 three translators. The questionnaire was then translated back into English to ensure no loss of  
137 meaning. Discrepancies were discussed, and the translation process was iterated until  
138 satisfactory translation was achieved. Questionnaire and sampling design were trialled in a  
139 pilot study comprising 46 interviews in 10 settlements across all waterways (Figure 1).  
140 Informant consent was obtained prior to interviews; informants were assured of  
141 confidentiality and that they could end interviews at any time and were briefed on the

142 objectives of the research. The project design was approved by the Zoological Society of  
143 London Ethics Committee.

144

145 Levels of relevant knowledge were assessed at the start of interviews by asking informants to  
146 identify the Ganges River dolphin and two local, common fish species (phasa *Setipinna*  
147 *phasa*; ilish *Tenualosa ilisha*) from photographs and describe where they occur (sea/river). If  
148 informants struggled to identify the dolphin, they were prompted with clues about behaviour  
149 and size. Informants were assigned to one of three reliability categories: high (identified all  
150 species); medium (identified dolphin and one other species); and low (recognised only one  
151 species, identified only the fish or unable to identify any species). Informants who received a  
152 low reliability score were not interviewed. Informants were asked where they fish, how long  
153 they have lived in the study area and whether they were retired to ensure information was  
154 specific to the area of interest and for the time-frame of interest (i.e. October 2010–October  
155 2011). Informants were questioned about the types and characteristics of gear they use (e.g.  
156 mesh size, length, net depth, number of hooks); fishing effort (average days/week, months);  
157 and fishing location(s); and were assigned a median river depth based on their reported  
158 fishing location (see Supplementary Material for details regarding the estimation and  
159 validation of net measurements, and estimation of median river depth). A subset of  
160 informants (n=114), who were willing to participate in a longer interview, were asked  
161 questions about regulations governing local fisheries and the dolphin. To quantify levels of  
162 bycatch/year, informants were asked to describe all bycatch events from the approximate  
163 previous 12-month period of October 2010–October 2011 (e.g. gear involved, location).  
164 Informants were only asked to recall bycatch events from the last 12-months as the detail for  
165 events prior to this period became increasingly vague. If the last recalled bycatch event dated  
166 >1 year earlier, they were asked to describe this event only.

167

168 To validate numbers of informant-reported mortalities, an independent mortality monitoring  
169 network was established in October 2011. Informants were issued with a phone number to  
170 call if they saw/heard of dead dolphins or bycatch events. Rewards were not offered for  
171 reporting mortalities or bycatch to discourage intentional killings.

172

## 173 2.2. *Data analysis*

174

### 175 2.2.1. *Informant reports of gear use, and comparison with observed gear use*

176

177 For the interview data, numbers of gear types and people using each gear was calculated.  
178 Reported gears were assigned to one of six locations ((1) Halda River; 2) Shikalbaha-  
179 Chandkhali Canal; Sangu River, divided into 3) Lower and 4) Upper Sangu at Dohazari  
180 Bridge; Karnaphuli River, divided into 5) Lower and 6) Upper Karnaphuli at Kalurghat  
181 Bridge) to investigate variation in bycatch across the study area. The Sangu and Karnaphuli  
182 were split into lower and upper reaches based on the availability of suitable dolphin habitat,  
183 and presence of dolphins respectively. Seasonality in gear use was investigated by calculating  
184 the number of nets in use between monsoon months (June-October) and non-monsoon  
185 months (November-May) for gillnets, long-shore nets (a rectangular net set on poles running  
186 adjacent to the river bank), set bagnets (a funnel-shaped net fixed to the river bed) and seine  
187 nets (rectangular net where one end is held on shore, and the other is driven by boat in a large  
188 arc across the river and brought back to shore; both ends are simultaneously pulled to shore).  
189 We excluded dragnets, hand nets, long-lines and rod and lines from the analysis as fishers use  
190 these gear casually and see them as relatively unimportant, so we consider it likely that their  
191 use was under-reported. Reported numbers of active gear were validated by comparing

192 numbers of reported gears in February, against numbers observed during boat-based surveys  
193 (see Supplementary Material for further details): the comparison was restricted to February as  
194 observational data was only available for this period.

195

### 196 2.2.2. *Factors influencing bycatch in gillnets*

197

198 A logistic generalised linear model with binomial error structure was used to investigate the  
199 effect of net and set characteristics (Table 1) on the ~~likelihood~~ probability of dolphin bycatch  
200 per gillnet per season. The analysis was restricted to gillnet bycatch as there were too few  
201 bycatch incidents in other gear types. We used all bycatch data dating back to 1986, though  
202 most (96%) reported bycatch events occurred in the last two years. The response was  
203 modelled per season (monsoon or non-monsoon) and was modelled as binary rather than a  
204 count due to little variation in bycatch events per season, or days fished per week in each  
205 season (mean number of days fished=5; SD=1.16). We excluded data from the Halda River  
206 and Shikalbaha-Chandkhali Canal, and the Upper Sangu River due to insufficient fishing  
207 effort and lack of dolphin sightings respectively (Richman et al., 2014). Midpoint values were  
208 used where measurements were reported as ranges. Data from informants who fish multiple  
209 locations, were retired, or of questionable capacity to recall facts accurately (i.e. drunk or  
210 nervous) were excluded, leaving a dataset of 2,149 observations (i.e. individual net set per  
211 season) from 580 informants.

212

213 The relationship between response and predictor variables was inspected for non-linearity  
214 using generalised additive model plots fitted with cubic smoothing splines using the ‘mgcv’  
215 package in R version 3.~~60.0~~ (R Development Core Team, 2013), with continuous variables  
216 plotted in linear, log and quadratic forms. Variance inflation factors (VIF) were used to

217 **Table 1.** Net and set variables considered for use in models investigating factors influencing probability of bycatch.

Variable	Definition	Unit
<b>Net characteristics</b>		
Mesh size (continuous)	Inside stretched distance between two knots on opposite sides of same mesh	Centimetres
Net length (continuous)	Length along longest edge of net	Metres
Net depth (continuous)	Length along shortest edge of net	Metres
Net type (categorical)		Drifting Fixed
<b>Set characteristics</b>		
Location (categorical)		Upper Karnaphuli River Lower Karnaphuli River Halda River Lower Sangu River Shikalbaha-Chandkhali Canal
Season (categorical)		Monsoon (mid-Jun to mid-Oct) Non-Monsoon (mid-Oct to mid-Jun)
Median river depth (continuous)		Metres

219 identify collinear variables using the ‘corvif’ function in the R package ‘AED’; VIF scores >3  
220 were considered evidence of collinearity (Zuur et al., 2009), and the variable that explained a  
221 greater proportion of model variance was retained.

222

223 A global model containing all possible remaining predictor variables (Table 1) and three two-  
224 way interactions that described potentially meaningful relationships between variables (net  
225 length and mesh size, season and location, season and mesh size) was fitted in R. Backward  
226 stepwise selection was used to identify the best model according to Akaike’s information  
227 criterion (AIC). Models were ranked according to AIC, and model selection was based on  $\Delta i$   
228 (the difference in AIC between model  $i$  and the minimum AIC for the model set). Models  
229 with  $\Delta i < 2$  were considered to have equivalent support. Coefficient estimates from the best  
230 model were used to predict bycatch probability per gillnet per season across a range of mesh  
231 size (1-11cm) and river depth (1-12m) values taken from the the interviews in the Lower and  
232 Upper Karnaphuli, and Lower Sangu.

233

### 234 2.2.3. *Annual mortality and validation with observational data*

235

236 A minimum count of annual fisheries-related dolphin mortality was calculated by summing  
237 numbers of dolphins that were discovered alive but subsequently killed, found alive but died  
238 and found dead in all net types during October 2010-October 2011. To validate informant  
239 data, we compared the number of mortalities reported during interviews for October 2011  
240 against the number of mortalities reported through the mortality monitoring network.

241 Reported and observed mortalities were considered the same incident if they occurred at the  
242 same location and in the same month. Where possible we tried to verify the cause of death  
243 with post-mortem analysis.

244

245 *2.2.4. Outcome of gillnet and set bagnet entanglements*

246

247 Chi-squared tests were used to test for differences in mortality frequencies between gillnets  
248 and set bagnets (gears with greatest numbers of bycatch events), with bycatch events assigned  
249 to one of two outcomes (alive/dead). Dolphins discovered alive in nets but killed during  
250 release were also classed as ‘dead’. Data on bycatch events across all time periods were used  
251 to maximise sample size.

252

253 *2.2.5. Sustainability of fishing-related mortality*

254

255 The International Whaling Commission sub-committee on small cetaceans agreed that “*it*  
256 *would be a matter of concern if bycatches/ and/or directed takes exceeded half the maximum*  
257 *growth rate of a population*” (International Whaling Commission, 1996). The population  
258 growth rate of Ganges River dolphins is unknown, so we adopted a conservative value of 4%  
259 as recommended by Wade (1998) for cetaceans where growth rate is unknown. A population  
260 estimate of 196 (95% CI: 187-273) was used based on a survey from 2012 (Richman, 2015).  
261 It is assumed the population is closed as it is isolated from the Ganges River system by a  
262 stretch of the Bay of Bengal (Smith et al., 2001).

263

264 *2.2.6. Fishery regulations: knowledge, attitudes and compliance*

265

266 We calculated the proportion of informants who: 1) could describe local fishing regulations,  
267 including the regulation prohibiting the killing and trade of the Ganges River dolphin; 2)  
268 comply/ don’t comply with fishery regulations 3) are satisfied with the compensation scheme

269 during the Ilish fishing bans. Informant data on regulation details were validated by the  
270 fisheries department. We extracted key statements from the interviews describing the  
271 perceived causes for the differences in levels of knowledge about fishing regulations and  
272 reasons for non-compliance.

273

### 274 **3. Results**

275

#### 276 *3.1 Informant reports of gear use, and comparison with observed gear use*

277

278 A total of 663 interviews were carried out in 74 settlements; we assume this sample  
279 represents a substantial proportion of the region's fisher population for these reasons: 1)  
280 interview teams visited every settlement within the study area and continued looking for new  
281 fishers until further enquiry resulted in no new informants to interview); 2) the comparison of  
282 reported and observed gear types were similar (Supplementary Material Figure 2). Gillnets  
283 were the dominant gear type recorded during our interviews (n=1027) followed by set  
284 bagnets (n=196), seine nets (n=137) and long-shore nets (n=64). We detected seasonality in  
285 net use with numbers of active gear during monsoon months almost double that of the non-  
286 monsoon months.

287

#### 288 *3.2 Factors influencing bycatch in gillnets*

289

290 Informants recalled 304 unique bycatch incidents from 1986 onwards, with 248 having  
291 sufficient detail on associated net characteristics. Of the 304 reported bycatch incidents, a  
292 total of 170 were recorded from October 2010-October 2011; the majority occurred in

293 gillnets (89%, n=151) and set bagnets (10%, n=17), with two further bycatch incidents in  
294 long-lines (Table 2).

295

296 Net depth was excluded from the analysis due to collinearity with mesh size. Model selection  
297 favoured a single model retaining mesh size, location, season and median river depth (Table

298 3). We note that stepwise model selection may exclude some aspects of the model that are  
299 useful in understanding the mechanisms of bycatch. For example, there are five candidate  
300 models within 10  $\Delta$ AICc of our selected model. These models included net-length, net-type  
301 and some interactive effects of mesh-size. These effects have negligible impacts on our  
302 predictions but may be useful to consider in future studies. Probability of bycatch during

303 October 2010-October 2011 declined with decreasing mesh size and increasing median river  
304 depth and showed a similar pattern of decrease across all locations and both seasons (Figure  
305 2). There were spatio-temporal differences in the overall bycatch probability: there was  
306 higher probability in the Lower Sangu relative to the Lower and Upper Karnaphuli for all  
307 mesh sizes and depths, and a higher probability during the monsoon relative to non-monsoon  
308 for all locations (Figure 2).

309

### 310 *3.3 Annual mortality and validation with observational data*

311

312 Of the 170 bycatch events from October 2010-October 2011, 14 dolphins were reported dead:  
313 eight in gillnets, five in set bagnets, one in a long-line with the remainder released alive  
314 (Table 2). Of the 14 mortalities, 11 were dead upon discovery, one died during release and  
315 two were killed to assist with their removal from fishing gear (Table 2). Of the nine reports of  
316 intentional killings from 1986-2011, six were to assist with removal from fishing gear, two as  
317 punishment for damaging gear, and one for its oil.

318 **Table 2:** Total number of bycatch events (Total [released alive, killed, alive but died during release, released dead]) between October 2010 and October 2011, and between  
 319 October 2011 to 1986.

320

Gear type	No. bycatch events between Oct 2010 – Oct 2011 (Total [alive, killed, alive but died, dead])	Total no. bycatch events between 1986 - Oct 2011 (Total [alive, killed, alive but died, dead])*
Gill nets	151 [143, 2, 1, 5]	213 [189, 4, 4, 16]
Hand nets	0 [0, 0, 0, 0]	2 [1, 0, 0, 1]
Long line	2 [1, 0, 0, 1]	10 [6, 0, 0, 4]
Seine net	0 [0, 0, 0, 0]	8 [4, 3, 0, 1]
Set bag nets	17 [12, 0, 0, 5]	71 [42, 2, 1, 26]
Total	170 [156, 2, 1, 11]	304 [242, 9, 5, 48]

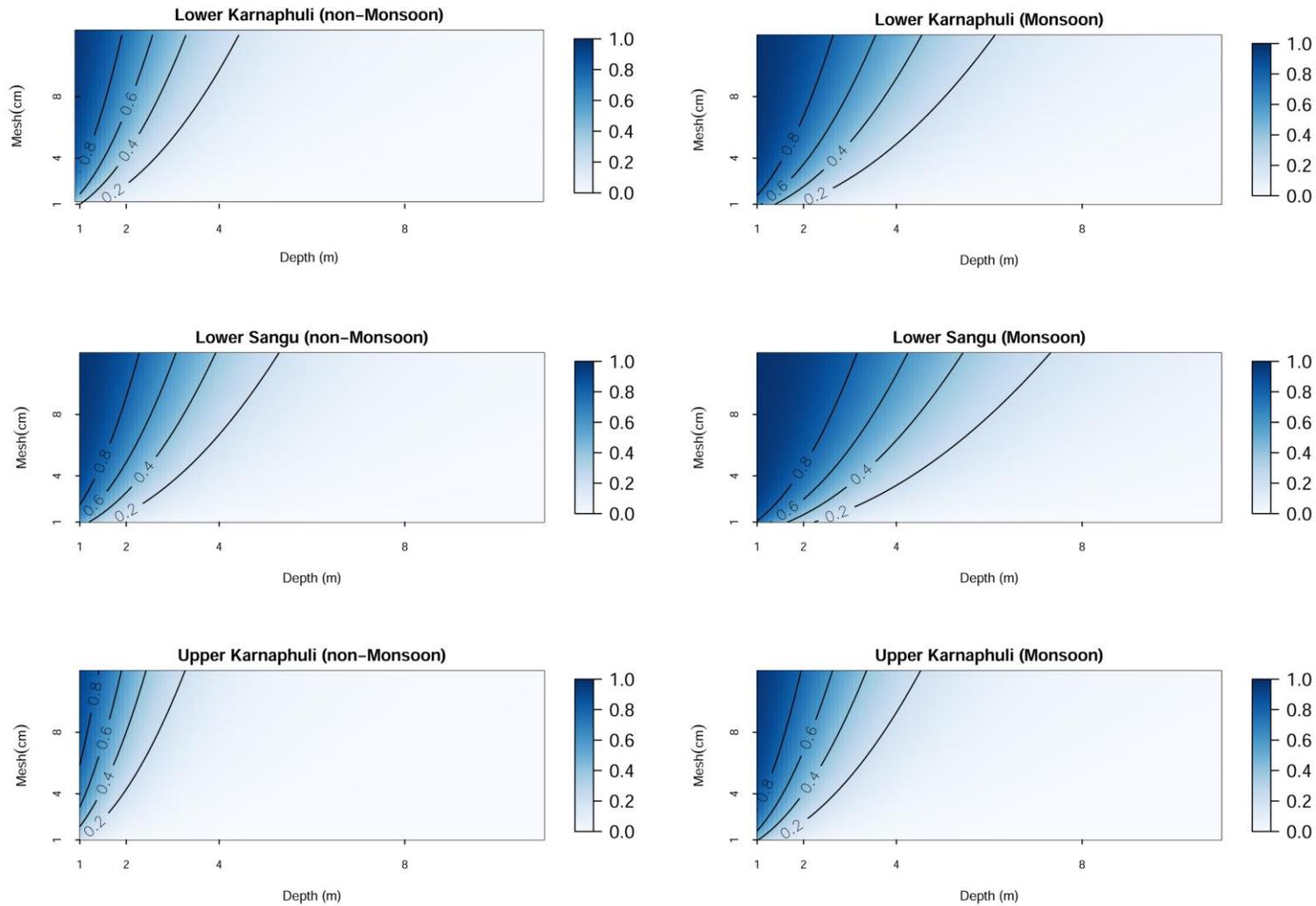
321 \* Note that for bycatch events further back than October 2010 informants were not asked to recall every bycatch event each year, simply the last one they could remember.

322

323 **Table 3:** Model results summary of factors affecting dolphin bycatch.

Model	K	AICc	ΔAICc	Weight
Mesh size, River depth, Season, Location	6	789.36	0	0.59
Mesh size, River depth, Season, Location, Net length	7	791.37	2.01	0.22
Mesh size, River depth, Season, Location, Net length, Net length*Mesh size	8	792.57	3.21	0.12
Mesh size, River depth, Season, Location, Net length, Net length*Mesh size, Season*Mesh size	9	794.29	4.93	0.05
Mesh size, River depth, Season, Location, Net length, Net type, Net length*Mesh size, Season*Mesh size	11	796.01	6.65	0.02
Mesh size, River depth, Season, Location, Net length, Net type, Net length*Mesh size, Season*Mesh size, Season*Location	12	799.87	10.52	0.00

324



325

326 **Figure 2:** Probability of bycatch per gillnet per season (non-monsoon and monsoon) in the Lower Karnaphuli, Lower Sangu and Upper Karnaphuli rivers. Contour lines and

327 shading represent probability of bycatch. See Supplementary Figures 3-5 for confidence limits.

328 The mortality estimate represents a minimum only as interview data were obtained non-  
329 randomly and so data was not extrapolated to the entire population, and fishers may have  
330 under-reported bycatch events. Independent data from the mortality monitoring network  
331 confirmed two of the dolphin mortalities reported during our interviews (October 2011), and  
332 confirmed a further two mortalities outside of our study period (November and December  
333 2011). The October mortalities were not observed by the survey team but were verified by  
334 photographs that appeared in the local newspaper. The November and December mortalities  
335 were observed by the survey team.

336

### 337 *3.4 Outcome of gillnet and set bagnet entanglements*

338

339 The outcome of bycatch in gillnets and set bagnets differed significantly ( $\chi^2=171.6$ ,  $df=2$ ,  
340  $p<0.0001$ ), with 41% ( $n=29/79$ ) of set bagnet entanglements resulting in mortality relative to  
341 11% ( $n=24/213$ ) of gillnet entanglements (Table 2).

342

### 343 *3.5 Sustainability of fishing-related mortality*

344

345 The estimate of annual mortality ( $n=14$ ) represents a mortality rate of 7% of the population  
346 (196 individuals) and therefore exceeds the sustainable limit (half the maximum growth rate  
347 = 2%) recommended by the International Whaling Commission.

348

### 349 *3.6 Fishery regulations: knowledge, attitudes and compliance*

350

351 Fishers described seven regulations in the form of gear bans, mesh-size restrictions, species-  
352 size restrictions and seasonal bans (Table 4). Only two of 580 informants knew it was illegal

353 **Table 4:** Details of fishery regulations in place in study area. Data were obtained from local informants and verified by the local fisheries department.

354

Type of regulation	Regulation details	Timing	Proportion who knew of the regulation	Proportion of informants who comply with the law
<b>Gear ban</b>	Monofilament, synthetic nylon gill nets ( <i>current jaal</i> )	All year	37%	70%
	Explosives, weapons and poison for harvesting fish	All year	49%	99%
	Mosquito-mesh nets	All year	41%	12%
<b>Mesh size restriction</b>	Gill nets with stretched mesh size <10 cm in the Ilish fishery	All year	65%	51%
<b>Species size restriction</b>	Ban on harvesting young Ilish < 23 cm	November to May	68%	32%
<b>Seasonal closure</b>	Ban on all fishing activity in the Halda River, except fishers employed by government to harvest carp eggs	February to July	82%	45%
	Ten-day ban on all fishing activity every year to protect Ilish brood stock	15 days in September/ October	87%	35%

355 to kill the dolphin. Fewer than 50 percent of informants knew about the gear bans (Table 4).  
356 Knowledge was higher for the regulations affecting the Ilish fishery and the Halda fishing  
357 ban (>60 percent; Table 4). Levels of compliance with regulations were low (Table 4), other  
358 than for the laws banning explosives and *current jaal*. Informants provided the following  
359 reasons for the differing compliance levels: a) compliance with the *current jaal* regulation is  
360 high because fines are high (n=1); b) compliance with the mosquito-mesh net regulation is  
361 low because fines are low and nets are not confiscated by officials (n=2); c) compliance with  
362 the poison-fishing regulation is high as it's difficult to fish conspicuously and other fishers  
363 will punish offenders (n=1); d) compliance with the Ilish (n=4) and Halda (n=5) regulations  
364 is low because they're economically valuable fisheries so there's a lot to be gained from  
365 breaking the laws. Four fishers described that most fishers are in debt to informal money  
366 lenders (*Mohajan*) and the threat of failing to repay loans (i.e. physical threats to self and  
367 familymembers) is greater than the threat of sanction from fishery enforcement officers (i.e.  
368 fines, seizure of fishing gear).

369

370 Interviews revealed that the government compensates fishers for loss of earnings during the  
371 ilish ban with a 10kg sack of rice/household; however, 65 percent (n=74/114) receive it  
372 infrequently and 28 percent (n=32/114) had never received compensation. Ninety two percent  
373 of informants (n=103/114) said they were unsatisfied with rice as a form of compensation,  
374 and 86 percent (n=89/103) reported it doesn't allow them to repay debts.

375

#### 376 **4. Discussion**

377

378 Fisheries-related mortality represents one of the most significant threats to freshwater  
379 cetaceans (Smith et al., 2001; Choudhary et al., 2006) but limited resources prevent

380 quantification of levels and drivers of mortality in these conservation-priority taxa. We  
381 demonstrate that interviews provide much-needed insight into the drivers and levels of  
382 mortality of Ganges River dolphin bycatch in gillnets. Given the ubiquitous presence of these  
383 gear across the geographic range of Ganges River dolphins, these results are likely mirrored  
384 elsewhere. The scale of fisheries-related mortality we describe here is of major conservation  
385 significance for this endangered mammal and should be a catalyst for developing pragmatic  
386 solutions to bycatch.

387

#### 388 *4.1 Drivers of dolphin bycatch*

389

390 Growing human demands for fishery resources will likely exacerbate aquatic mammal  
391 bycatch by intensifying competition for the same resource (Read, 2005). Previous studies  
392 have described a spatial overlap between Ganges River dolphins and small-bodied fish in  
393 shallow-water areas (Bashir et al., 2010; Kelkar et al., 2010). These feeding preferences  
394 might explain the elevated bycatch rates we detected in shallow-water areas. Worryingly,  
395 competition between fishers and dolphins is likely to increase as declines in large-bodied fish  
396 have been reported across India and Bangladesh (Kelkar et al., 2010), forcing fishers to  
397 switch to fishing smaller size-classes. Bycatch rates in shallow-water are further exacerbated  
398 by the ‘barrier’ effect created by gillnets set in these areas. Where the water depth is  
399 particularly shallow, mean gillnet length does not differ greatly from the width of the river  
400 (approximately 300m; Richman, 2015). Informal discussions with fishers revealed intentional  
401 setting of nets across the river to create a barrier to migrating fish, a pattern that has been  
402 observed elsewhere (e.g. Kelkar et al., 2010).

403

404 We'd assume a preference for small-bodied prey would increase dolphin vulnerability to  
405 bycatch in smaller-mesh gillnets, however, this contrasts with our findings. While dolphins  
406 exhibit less preference for large-bodied fish, previous research (Kelkar et al., 2010) describes  
407 the aggregation of dolphins around spawning ilish, catla and ruhi which are targeted using  
408 large-mesh nets. The presence of these feeding aggregations might also explain elevated  
409 bycatch rates during the monsoon, which coincides with a peak in spawning activity (Rahman  
410 et al., 2017).

411

412 We detected spatio-temporal patterns in the probability of bycatch that may serve to support  
413 more targeted efforts at reducing bycatch. Bycatch probability is higher in the Lower  
414 Karnaphuli and Lower Sangu than the Upper Karnaphuli, and increases markedly during the  
415 monsoon. The spatial differences in bycatch probability likely reflect the abundance of  
416 dolphins in these rivers (abundance is highest in the Lower Sangu and lowest in the Upper  
417 Karnaphuli (Richman, 2015). The relationship between bycatch probability and season may  
418 reflect changes in fishing effort that we were unable to capture using our question design.  
419 While we were unable to detect a difference in the mean number of days fished per season,  
420 data from other studies (Rahman et al., 2017) suggests there is a significant increase in  
421 monsoon fishing effort. Other studies using fisher interview data have effectively captured  
422 changes in harvesting and fishing effort (Jones et al., 2008; Daw et al., 2011), and so  
423 modified question design could provide further insights into the relationship between bycatch  
424 and season.

425

426 To date, the majority of bycatch mitigation effort for this species has focused on addressing  
427 gillnet bycatch. While gillnet fisheries undoubtedly pose a significant threat to the Ganges  
428 River dolphin our data indicate that set bagnetts constitute a significant source of mortality.

429 This gear is rarely considered in bycatch studies, possibly reflecting low levels of mortality in  
430 other regions or differences in the detectability of bycatch cases. Given the prevalence of this  
431 net throughout river dolphin habitat in Bangladesh, studies are needed to assess the  
432 significance of this gear to overall bycatch.

433

#### 434 *4.2 Reliability of informant data*

435

436 Interviews with local informants can yield accurate information on species status and  
437 constitute a low-cost tool for monitoring where standard monitoring methods may be  
438 prohibitively expensive (Turvey et al., 2013). Our findings regarding the distribution of  
439 bycatch in gear type, and the characteristics of these bycatch events agree with interview data  
440 from the Sundarbans and Brahmaputra (Mahabub et al., 2012; M. Datta pers. comm. 2014)  
441 leading us to conclude that interviews have proven an important tool for characterising  
442 dolphin bycatch in southern Bangladesh. Where possible we took a number of steps to  
443 control for cognitive biases (e.g. we limited the analysis to bycatch events recalled within the  
444 last year, validated reported net measurements), however, the accuracy of recall may have  
445 been improved by the fact bycatch events are regarded as memorable because of the damage  
446 they cause to nets resulting in subsequent loss of earnings.

447

448 Concern regarding the accuracy of the informant data largely relates to the quantifying of  
449 mortality: we believe this figure was underestimated, and so also the degree by which  
450 mortality is unsustainable. We incorporated numerous procedures to improve the accuracy of  
451 informant responses, however, two major sources of bias could not be accounted for: 1)  
452 interviewed fishers were a sample from the wider population, though the data suggests the  
453 sample incorporated the majority of active winter fishers, and; 2) fishers may have

454 intentionally under-reported bycatch and intentional killings. Under-reporting of harvesting/  
455 poaching is common in situations where the species is protected (Turvey et al., 2013). While  
456 the interviews revealed almost no awareness of the laws protecting dolphins, unintentional  
457 killing of animals is forbidden by religious laws and may have created an unwillingness to  
458 discuss these events. The low proportion of bycatch events that resulted in death may be seen  
459 as further indication of informant under-reporting. However, in the absence of data to assess  
460 survival rates from gillnet entanglement it is not possible to determine whether the gap  
461 between bycatch and mortality arises from under-reporting or high bycatch survivability.

462

#### 463 *4.3 Sustainability of dolphin bycatch*

464

465 The extinction of the Yangtze River dolphin has been a wake-up call to the dire status of  
466 freshwater cetaceans. The area occupied by many species has declined dramatically, for the  
467 Indus River dolphin by as much as 80% since the 1870s (Braulik et al., 2014), and most  
468 species are listed as threatened on the IUCN Red List of Threatened Species. While there is  
469 historical evidence to suggest that the Ganges River dolphin has undergone a range decline  
470 following the construction of the Karnaphuli River dam in 1962 (Smith et al., 2001), little is  
471 known about trends in population size of the Karnaphuli-Sangu rivers population. In 2012,  
472 the population was estimated at 196 (95% CI: 186-208) individuals (Richman, 2015).

473 Assuming our estimate of annual mortality is representative of previous years, it is difficult to  
474 reconcile with population persistence. Historically, it was thought the population was isolated  
475 from the Ganges river system by 75kms of marine water, (i.e. the Bay of Bengal; Smith et al.,  
476 2001). However, recent sightings of dolphins in full salinity seawater (Richman, 2015) leave  
477 us questioning whether this is in fact an open population. Given the implication of ongoing

478 mortality at the level reported here, urgent efforts are needed to determine whether the  
479 population is closed and whether the mortality estimate is consistent over time.

480

#### 481 *4.4 Opportunities for mitigating bycatch*

482

483 Intentional killing of river dolphins due to persecution, and for their products that are used for  
484 food, oil and most importantly medicine, is widely documented (Choudhary et al., 2006;  
485 Beasley, 2007; Richman, 2015). We found evidence of intentional killing for both purposes,  
486 though the market for dolphin products appears to be small and dying out due to its low  
487 economic value driven by a greater desire for conventional medicine (Richman, 2015). Our  
488 data suggest that intentional killing of bycaught dolphins is to ease with their removal from  
489 fishing gear, and as punishment for damaging nets are greater threats. Worryingly, there is a  
490 near absence of knowledge regarding the regulations that prohibit the killing of river dolphins  
491 in Bangladesh despite Ahmed (2004) recommending an awareness-raising programme. In  
492 2013, the Bangladesh Cetacean Diversity Project (BCDP) established the *Shushuk Mela*  
493 project, a boat-based exhibition that engages local communities in freshwater cetacean  
494 conservation efforts. Part of their educational programme involves: 1) teaching fishers how to  
495 effectively release dolphins alive from fishing gear with minimal damage to the gear, and 2)  
496 the government regulations protecting dolphins. The exhibition has had a positive impact on  
497 attitudes towards freshwater cetaceans and changed local fishing practices (Mansur, Akhtar  
498 and Smith, 2014). The expansion of this scheme into the Karnaphuli-Sangu rivers complex  
499 could be an effective tool for overcoming the intentional killing of dolphins in this area.

500

501 Our data highlight numerous existing fishery regulations that, if enforced effectively, may  
502 reduce dolphin bycatch levels. Less-well adhered-to fishery regulations include the ilish

503 fishing ban in the late monsoon (September to October), and the ban on the use of gillnets  
504 with a mesh size of less than 10cm in the ilish fishery. Effective enforcement of these  
505 measures would reduce dolphin bycatch by: a) limiting monsoon fishing effort, and b)  
506 limiting the use of nets with a mesh size that are associated with dolphin bycatch.  
507 Furthermore, bans on small-mesh nets, particularly non-selective gear such as mosquito-mesh  
508 nets, would reduce the exploitation and depletion of dolphin prey. However, both this and  
509 another recent study exploring concerns around ilish fishery management in Bangladesh  
510 (Dewhurst Richman et al., 2016) highlight many social and economic challenges (i.e. unfair  
511 distribution of compensation/benefits; a poor understanding of beneficiary preferences in  
512 terms of types of compensation; unintended consequences such as forcing fishers to use  
513 illegal fishing methods) that need to be addressed before these measures can be properly  
514 enforced.

515

516 A willingness to comply with regulations that govern the management of natural resources is  
517 largely determined by the probability that a contravention will be detected, and to a lesser  
518 degree, the severity of the punishment (Keane et al., 2008). Most studies of enforcement have  
519 focused on ensuring the gain from rule compliance is greater than non-compliance, such as  
520 increasing the severity of penalties (Keane et al., 2008). Increasing the severity of penalties  
521 on the Karnaphuli-Sangu fishers, in the absence of other efforts, will only exacerbate levels  
522 of debt and reliance on informal money lenders. Formal microcredit institutions with grace  
523 periods during fishing bans, adequate forms of compensation and financing of alternative  
524 income generating activities have been proposed (Dewhurst Richman et al., 2016) as  
525 potential mechanisms by which to overcome the compliance issues described here.

526

527 **5. Conclusion**

528

529 This study highlights the tremendous value of interviews for quantifying and characterising  
530 the harvest of a poorly-known species, while simultaneously exploring issues associated with  
531 governance and compliance. Given the ubiquitous use of gillnets across the range of the  
532 Ganges River dolphin our results are likely to be mirrored elsewhere highlighting the dire  
533 conservation status of this species. However, the many existing fishery regulations that are  
534 already in place for economically-important fish species could, if compliance were increased,  
535 contribute to simultaneously conserving river dolphins. River dolphin conservation need not  
536 hinder fishery production but instead could be yet another catalyst for addressing the social  
537 and economic barriers that impede sustainable fisheries management.

538

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540

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