

**The riparian tree species composition and diversity of the midstream of
Halda River in Chittagong, Bangladesh**

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Abstract

Riparian vegetation has been depleting in the many river basins of Bangladesh. Consequently, this study assessed the tree species composition, structure and diversity of the midstream area of the Halda River in Bangladesh. Twenty two quadrats (20 × 20m in size) were sampled. A total of 414 individual tree stems of ≥10 cm DBH of 36 tree species belonging to 31 genera and 15 families were enumerated. Density, Basal area and volume of the tree species were measured. Different diversity indices, i.e. Shannon-Wienners Diversity Index, Simpson's Dominance Index, Pielou's Species Evenness Index, Margalef's and Menhinick's richness index were calculated. Fabaceae was the most represented family with nine species, followed by Moraceae, Meliaceae and Anacardiaceae. Density, basal area and volume of the trees were 470.45 stem/ha, 19.09m²/ha and 139.42m³/ha, respectively. *Samanea saman* was found to be dominant, showing a maximum IVI, followed by *Swietenia mahagoni*, *Mangifera indica*, *Eucalyptus camaldulensis* and *Artocarpus heterophyllus*. The findings of the study will be helpful for the posterior researchers in their research work and their future tree based planning programs and conservation. So it is recommended that greater emphasis should be taken to proper management and conservation against over extraction and illegal felling for the maintenance of existing tree species composition and density.

Keywords: Bangladesh, Diversity, Halda River, Riparian tree species, Species composition

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34 **1. Introduction**

35 Rivers are the prominent and important feature of the landscape, playing crucial roles in the
36 development of any country. Any country's economy and development are greatly dependent
37 on the ecosystem services that rivers provide such as fresh water supply, fish production,
38 transportation, waste assimilation etc., along with the provision of a wide array of recreation
39 and tourism options(1). As a nationally important river the Halda River in Chittagong,
40 Bangladesh need to be conserved. This river hosts the breeding ground of major Indian carps
41 from where the fertilized eggs are collected directly. Besides, Halda River is the main source
42 of the drinking water for city of dwellers of Chittagong Metropolitan Area (CMA). However,
43 this river is vulnerable due to many natural and anthropogenic factors. Different man made
44 activities such as industrial discharge, tobacco farming discharge, rubber dam construction,
45 brick-field construction, illegal quarrying for of sands etc. continue to threaten its
46 existence(2). Besides, the riverbank erosion, an increase of salinity in the river threatens the
47 livelihood of several thousand fishermen and fish egg collectors. Some of these threatening
48 and destructive factors can be maintained by a proper management of the riverbank tree
49 species(3,4).

50 The riparian tree species play an important role in the reduction of river bank erosion which
51 contributes to the maintenance of the river depth(Van et al. 2004). The tree cover and more
52 tree species density is an important factor for an increasing rainfall which is important for
53 dilution of the salinity and pollutants(5,6).

54 As Halda is one of the most resourceful rivers, many researches were conducted in the recent
55 past. Studies were done to assess the surface water quality of Halda River from September
56 2015 to March 2016(7),and the pollutants discharged into the Halda River through major
57 canals (8). The river flow of Halda and its impact on Halda ecosystem was also estimated (10).
58 The conservation of Halda river in cooperation with river-dependent community was o
59 investigated by Kabir et al.(2015). Studies were also done on the spawning of major Indian

60 carp(12), while the biodiversity status of carps in the river assessed via their distribution and
61 most important zones of spawning (13). Bhuyan and Bakar(2017) looked at the sediment and
62 the heavy metal contamination in the water of the HaldaRiver. Zaman (2014) focused a
63 research project on awakening local people who are dependent on this river.

64 Despite of all these studies above mentioned, the tree vegetation on the two banks of this
65 river which is the most important component of HaldaRiver ecosystem is still
66 unexplored. Therefore, this investigation assessed the tree species composition and diversity of
67 the midstream area of the river bank.

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69 **2. Materials and Methods**

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71 **2.1 Description of the study area**

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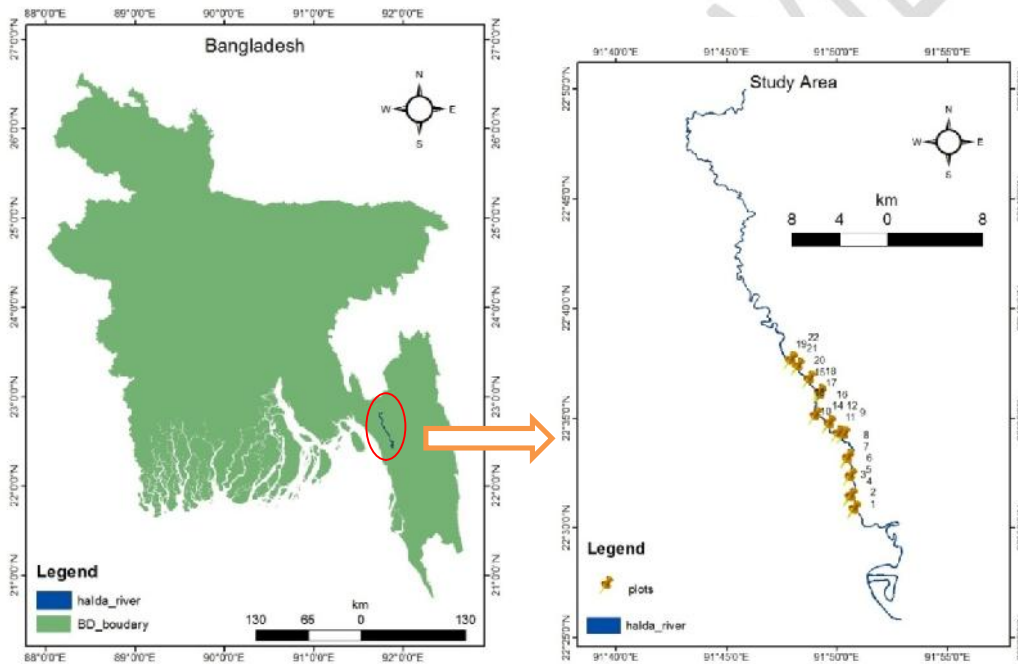
73 The Halda River is one of the major rivers in the South-East region of Bangladesh. Halda
74 (22°28'56.09"N & 91°54'07.62"E), the third main river of Chittagong after the Karnaphuli
75 and the Sangu, is such a resourceful river of Bangladesh (Kabir et al. 2013) which originates
76 from the Batnatali Hill Ranges of RamgarhUpazila under Khagrachari District, Bangladesh.
77 It flows through Fatikchhari, Hathazari and RaozanUpazilas and Chandgaon Thana of
78 Chittagong before ending into the Karnaphuli River. It is the only natural spawning ground of
79 Indian major carp species (Kabir et al., 2015). The air temperature of the river was recorded
80 23 to 33 throughout the year and monthly total rainfall ranged from 0.03 inches
81 (December) to 31.75 inches (June) with 0' rainfall in January and February(14). The research
82 was carried out in the midstream of Halda river(from Nazirhat, Fatikchhari to Sattarghat,
83 Raojan)which lies between 22°30'49.608" to 22°37'40.152' north latitude & 91°50'43.224" to
84 91°47'51.936" east longitudes(**Figure 1**). The total length of the midstream area of this river
85 from Nazirhat to Shattarghat is about 19.6km and about 8800 m² of the riparian midstream
86 were sampled. The midstream area was covered with rural settlement, homestead forests, crop
87 lands, fallow lands, water bodies, natural and plantation forests with exposed soil(15). But in
88 the riparian area homestead and plantation this two land class was mainly found.

89

90

91 **2.2 Sampling methods**

92 Systematic sampling method was followed during inventory of tree species. The whole
93 sampling and primary data collection was done by a small boat (cockleboat). The plots were
94 taken with an approximate interval of 2km by using GPS and after each of that 2 km
95 (approx.) interval two sampling plots of 20 ×20 m in size were taken on the both sides of the
96 river. Total 22 quadrants of 400 m² were taken on each sides of the river which covered about
97 8800 m² sampling area (**Figure 1**). The plots were taken from the starting point of the tree
98 species on each bank. Tree species having more than 10cm diameter at breast height (DBH)
99 were counted and DBH of them were measured by diameter tape, then the total height and
100 merchantable height were also measured by Relascope.
101



102
103 **Figure 1** Map of the study area of Halda river
104

105
106 **2.3 Data analysis**
107

108 After collection of field data, to calculate the diversity index, quantitative characteristics data
109 were compiled and processed. Basal area of the tree species was calculated by the following
110 equation(16):

111 Basal area = $\pi D^2/4$; where, D = Diameter at breast height, $\pi = 3.1416$

112 For each species relative density, relative frequency, relative abundance and Importance
113 Value Index (IVI) were calculated following the methods developed by (17). Identified plants
114 were arranged taxonomically and categorized according to their habit form.

115 **I. Frequency and relative frequency (%):**

116 Frequency of a species = $\frac{\text{Totalno.ofquadratesinwhichthespeciesoccurs}}{\text{Totalnumberofquadratesstudied}}$

117 Relative Frequency (RF%) = $\frac{\text{Frequencyofonespecies}}{\text{sumofallfrequencies}} \times 100$

118 **II. Density and relative density(%):**

119 Density of a species = $\frac{\text{Totalno.ofindividualsofaspeciesinallquadrats}}{\text{Totalno.ofsampleplotsofallspecies}}$

120

121 Relative density of a species = $\frac{\text{Totalno.ofindividualsofthespecies}}{\text{Totalno.ofindividualsofallspecies}} \times 100$

122 **III. Abundance and relative abundance (%)**

123 Abundance of a species = $\frac{\text{Totalno.ofindividualsofaspeciesinallthequadrats}}{\text{Totalno.ofquadratsinwhichthespeciesoccured}}$

124 Relative Abundance (RA%) = $\frac{\text{Abundanceofonespecies}}{\text{Totalabundanceofallthespecies}} \times 100$

125 **IV. Relative Dominance (%)**

126 Relative Dominance (RDo) = $\frac{\text{Basalareaofspeciesinallquadrats}}{\text{Totalbasalareaofallspeciesinallquadrats}} \times 100$

127 **V. Important Value Index (IVI)**

128 Importance Value Index (IVI) = Relative Frequency (RF) + Relative Density (RD) + Relative
129 Dominance (RDo) ; according to Curtis,1959(18).

130

131 **2.4 Functional Diversity**

132

133 Functional diversity is defined as the variety of interactions with ecological process and can
134 be quantified by determining the nature and extent to which functional groups are represented
135 in an ecological system (19). Functional diversity, evenness and richness were measured
136 using different methods.

137 Generally, species diversity is determined not only by the number of species within a
138 biological community i.e., species richness, but also by the relative abundance of individuals
139 in that community. Species abundance is the number of individuals per species, and relative
140 abundance refers to the evenness of distribution of individuals among species in a
141 community. Two communities may be equally rich in species but differ in relative
142 abundance(20).

143 Four diversity indices, i.e. Shannon-Wiener Diversity Index (H), Margalef 's richness index
144 (R), Simpon's Diversity Index (D), Pielou's Species Evenness Index (E) and Menhinick's
145 richness index(DI) were analyzed as following (Margalef 1958; Pielou 1984; Shannon &
146 Weiner 1963a; Simpson 1949a) respectively to get a picture of tree species diversity in Halda
147 river.

148 **I. Shannon-Weinner Diversity Index**

149 The Shannon-Weinner's biodiversity Index is commonly used to characterize
150 species diversity in a tree species community. As like as Simpson's index, Shannon's
151 index accounts for both abundance and evenness of the species present. Equitability assumes
152 a value between 0 and 1 with 1 being complete evenness. Shannon-Wiener's diversity index
153 value is Maximum when the number of individuals of all species is equal; value is zero if
154 there is only one species (Shannon & Weiner 1963).

155 **Shanon-Weinners equation:**

$$156 \quad H = - \sum_{i=1}^S P_i \ln P_i$$

157 Where,

158 H = The Shannon diversity index

159 P_i = Fraction of the entire population madeup of species i

160 S = Numbers of species encountered

161 = Sum from species 1 to species S

162 **II. Simpson's Diversity Index**

163 A community dominated by one or two species is considered to be less diverse than one in
164 which several different species have a similar abundance. It is a measurement of diversity
165 which takes into account the number of species present as well as the relative abundance of
166 each species. As species richness and evenness increase, so diversity increases.

167 Simpson's Index, $D = \frac{\sum n(n-1)}{N(N-1)}$

n = Total number of organisms of a particular species

N = Total number of organisms of all species

D = Simpson's Diversity Index

168 With this index, 0 represents infinite diversity and 1 indicates no diversity. That is meant that
169 the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to
170 get over this problem, D is often subtracted from 1 (22)

171 So, Simpson's Index of Diversity = $1 - D$

172 The value of this index also ranges between 0 and 1, but now, the greater the value, the
173 greater the sample diversity.

174

175 **III. Margalef's Richness index**

176 It is measured by: $R = S - 1 / \ln N$

177 Where, R = Margalef's Richness index

178 S = Total no. of species

179 N = Total no. of individual of all species

180 Margalef's richness index (R) is high in communities that include a greater number of species
181 and in which the number of individuals of each species decreases relatively slowly on passing
182 from the more abundant to the less abundant ones (21).

183 **IV. Pielou's Species Evenness Index**

184 It is measured by the following equation:

185
$$E = \frac{H}{\ln(S)}$$

186 Where, E = Species Evenness

187 H = The Shanon-Weinner's biodiversity Index

188 S= Total number of species

189 V. Menhinick's richness index

190 Menhinick's richness index was calculated by using the formulae given by Menhinick (1964)
191 as:

192
$$DI = \frac{S}{\sqrt{N}}$$

193 Where, DI= Menhinick's richness index

194 S=No. of species

195 N=No. of total species

196 2.5 Structural Composition

197 A total of 448 tree stems per ha were considered for height class distribution. The tree
198 individuals were categorized into 4 height classes and a total of 414 individuals having (DBH)
199 10cm were categorized into 7 diameter classes to determine the structural composition of the
200 tree species.

201 3. RESULTS

202 3.1 Tree species composition

203 A complete list of trees having Diameter at Breast Height (DBH) 10cm were recorded from
204 the total 22 quadrates of Halda riparian areas. A total of 36 tree species belonging to 31
205 genera and 15 families were recorded from the quadrates. The most common tree species
206 were *Swietenia mahagoni*, *Samanea saman*, *Mangifera indica*, *Areca catechu*,
207 *Artocarpus heterophyllus*, *Albizia lebeck*, *Acacia auriculiformis* etc. (**Tables 1 and 2**).
208 Fabaceae family shows the highest number of tree species (9) followed by Moraceae and
209 Meliaceae (4) and Anacardiaceae, Arecaceae and Myrtaceae each with 3 tree species. Stem
210 density per hectare was found to be 470.45 stem/ha in total, where *Swietenia mahagoni*
211 possessed the highest followed by *Samanea saman* and *Eucalyptus camaldulensis* (**Table 2**).

212 Total Basal area and volume of all the recorded tree species were calculated as 19.09m²/ha
 213 and 139.42m³/ha respectively. *Swietenia mahagoni* was noticed as highly dominant plant
 214 species. People also planted *Samanea saman*, *Eucalyptus camaldulensis*, *Mangifera indica*,
 215 *Artocarpus heterophyllus*, *Areca catechu*, *Albizia lebbbeck*, *Acacia auriculiformis*, *Acacia*
 216 *mangium*, *Bombax ceiba* for meeting fruit, fuel, timber needs.

217

218 **Table 1 List of tree species recorded from Halda riparian**

Sl. No.	Family	Sl. No.	Binomial name	Local name	No. of individual
1	Anacardiaceae	1	<i>Mangifera indica</i>	Aam	33
		2	<i>Spondias mombin</i>	Amra	1
		3	<i>Lannea coromandelica</i>	JiolBadi	8
2	Apocynaceae	1	<i>Alstonia scholaris</i>	Chatim	1
3	Arecaceae	1	<i>Areca catechu</i>	Supari	21
		2	<i>Cocos nucifera</i>	Narikel	9
		3	<i>Borassus flabellifer</i>	Tal	1
4	Bombacaceae	1	<i>Bombax ceiba</i>	Shimul	13
5	Dipterocarpaceae	1	<i>Dipterocarpus turbinatus</i>	Teliya Garjan	1
6	Elaeocarpaceae.	1	<i>Elaeocarpus serratus</i>	Jalpai	1
7	Euphorbiaceae	1	<i>Trewia nudiflora</i>	pitali	9
8	Fabaceae	1	<i>Samanea saman</i>	Raintree	66
		2	<i>Acacia auriculiformis</i>	Akashmoni	15
		3	<i>Acacia mangium</i>	Mangium	14
		4	<i>Erythrina variegata</i>	Mandar	6
		5	<i>Albizia lebbbeck</i>	Kalokoroi	16
		6	<i>Albizia procera</i>	Sadakoroi	6
		7	<i>Senna siamea</i>	Minjiri	1
		8	<i>Albizia odoratissima</i>	Tetuakoroi	2
		9	<i>Cassia fistula</i>	Sonalu	1
9	Lythraceae	1	<i>Lagerstroemia speciosa</i>	Jarul	10

10	Meliaceae	1	<i>Swieteniamahagoni</i>	Mahagoni	74
		2	<i>Aphanamixispolystachya</i>	Pitraj	1
		3	<i>Khayaanthotheca</i>	Lombu	7
Sl. No.	Family	Sl. No.	Binomial name	Local name	No. of individual
10	Meliaceae	4	<i>Chukrasiatubularis</i>	Chikrashi	4
11	Moraceae	1	<i>Artocarpusheterophyllus</i>	Kanthal	20
		2	<i>Ficusbenghalensis</i>	Bot	2
		3	<i>Streblusasper</i>	Sheora	4
		4	<i>Artocarpuslacucha</i>	Borta	4
12	Myrtaceae	1	<i>Eucalyptus camaldulensis</i>	Eucalyptus	42
		2	<i>Syzygiumgrandae</i>	Dhakijam	1
		3	<i>Syzygiumfruticosum</i>	Puti jam	5
13	Rhamnaceae	1	<i>Ziziphusjuzuba</i>	Boroi	1
14	Rubiaceae	1	<i>Neolamarckiacadamba</i>	Kadam	7
15	Verbenaceae	1	<i>Gmelinaarborea</i>	Gamar	5
		2	<i>Tectonagrandis</i>	Shegun	2

219

220

221 **Table 2 List of tree species with stem density per hectare recorded from Halda riparian**
 222 **area**

Serial number	Local name	Binomial name	No. of individual	Stem/ha
1	Akashmoni	<i>Acacia auriculiformis</i>	15	17.05
2	Mangium	<i>Acacia mangium</i>	14	15.91
3	Kalokoroi	<i>Albizialebeck</i>	16	18.18
4	Tetuakoroi	<i>Albiziaodoratissima</i>	2	2.27

5	Sadakoroi	<i>Albizia procera</i>	6	6.82
6	Chatim	<i>Alstonia scholaris</i>	1	1.14
7	Pitraj	<i>Aphanamixis polystachya</i>	1	1.14
8	Supari	<i>Areca catechu</i>	21	23.86
9	Kanthal	<i>Artocarpus heterophyllus</i>	20	22.73
10	Borta	<i>Artocarpus lacucha</i>	4	4.55
11	Shimul	<i>Bombax ceiba</i>	13	14.77
12	Tal	<i>Borassus flabellifer</i>	1	1.14
13	Sonalu	<i>Cassia fistula</i>	1	1.14
14	Chikrashi	<i>Chukrasia tabularis</i>	4	4.55
15	Narikel	<i>Cocos nucifera</i>	9	10.23
16	Teliyagarjan	<i>Dipterocarpus turbinatus</i>	1	1.14
17	Jalpai	<i>Elaeocarpus serratus</i>	1	1.14
18	Mandar	<i>Erythrina vari egata</i>	6	6.82
Serial number	Local name	Binomial name	No. of individual	Stem/ha
19	Eucalyptus	<i>Eucalyptus camaldulensis</i>	42	47.73
20	Bot	<i>Ficus benghalensis</i>	2	2.27
21	Gamar	<i>Gmelina borea</i>	5	5.68
22	Lombu	<i>Khaya anthotheca</i>	7	7.95
23	Jarul	<i>Lagerstroemia speciosa</i>	10	11.36
24	Jiolbadi	<i>Lannea coromandelica</i>	8	9.09
25	Aam	<i>Mangifera indica</i>	33	37.50

26	Kadam	<i>Neolamarckia cadamba</i>	7	7.95
27	Raintree	<i>Samanea saman</i>	66	75.00
28	Minjiri	<i>Sennasiamea</i>	1	1.14
29	Amra	<i>Spondiasmombin</i>	1	1.14
30	Sheora	<i>Streblusasper</i>	4	4.55
31	Mahagoni	<i>Swieteniamahagoni</i>	74	84.09
32	Puti jam	<i>Syzygiumfruticosum</i>	5	5.68
33	Dhakijam	<i>Syzygiumgrandae</i>	1	1.14
34	Shegun	<i>Tectonagrandis</i>	2	2.27
35	Pitali	<i>Trewianudiflora</i>	9	10.23
36	Boroi	<i>Ziziphusjuba</i>	1	1.14

223

224

225 3.2 Diversity Indices

226 Among the diversity indices, 2.86 was found for Shannon-Wienners Diversity Index where
 227 Simpson's Dominance Index was 0.91. Moreover, Margalef's Richness Index was calculated
 228 as 5.81, Pielou's Species Evenness Index was 0.80 and Menhinick's richness index was
 229 1.77(Table 3).

230

231 **Table 3 Diversity indices of the tree species in Halda riparian area**

Diversity indices	Diversity index value
Shannon-Wiener Diversity Index	2.86
Simpon's Diversity Index	0.91
Margalef's Richness Index	5.81
Pielou's Species Evenness Index	0.80

Menhinick's richness index	1.77
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234 3.3 Importance Value Index (IVI) of Riparian Halda tree species

235 Importance Value Index (IVI) of the tree species was assessed along with basal area (BA),
 236 Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo) of each species.
 237 *Samaneasaman* possessed the highest IVI (59.28%) followed by 40.92% of
 238 *Swieteniamahagoni*, 24.12% by *Mangifera indica*, 18.12% by *Eucalyptus camaldulensis* and
 239 17.69% by *Artocarpus heterophyllus* shown in (Table 4 and Figure 2).

240

241 Table 4 Phytosociological attributes of the recorded tree species from the 22 quadrats

242 in riparian Halda [Here, RD = Relative density, RF = Relative Frequency, RA = Relative

243 Abundance, RDo = Relative Dominance, IVI = Importance Value Index]

Sl. No.	Binomial name	Local name	BA (m)	RD (%)	RF (%)	RA (%)	RDo (%)	IVI
1	<i>Acacia auriculiformis</i>	Akashmoni	0.39	3.62	4.08	3.03	2.06	9.77
2	<i>Acacia mangium</i>	Mangium	0.50	3.38	3.40	3.40	2.60	9.38
3	<i>Albizia lebbek</i>	Kalokoroi	0.94	3.86	2.04	6.47	4.90	10.81
4	<i>Albizia odoratissima</i>	Tetuakoroi	0.09	0.48	0.68	2.43	0.46	1.63
5	<i>Albizia procera</i>	Sadakoroi	0.28	1.45	2.04	2.43	1.47	4.96
6	<i>Alstonia scholaris</i>	Chatim	0.05	0.24	0.68	1.21	0.28	1.20
7	<i>Aphanamixis polystachya</i>	Pitraj	0.02	0.24	0.68	1.21	0.08	1.00
8	<i>Areca catechu</i>	Supari	0.23	5.07	2.72	6.37	1.20	9.00
9	<i>Artocarpus heterophyllus</i>	Kanthal	1.03	4.83	7.48	2.21	5.38	17.69
10	<i>Artocarpus lacucha</i>	Borta	0.17	0.97	2.72	1.21	0.90	4.59

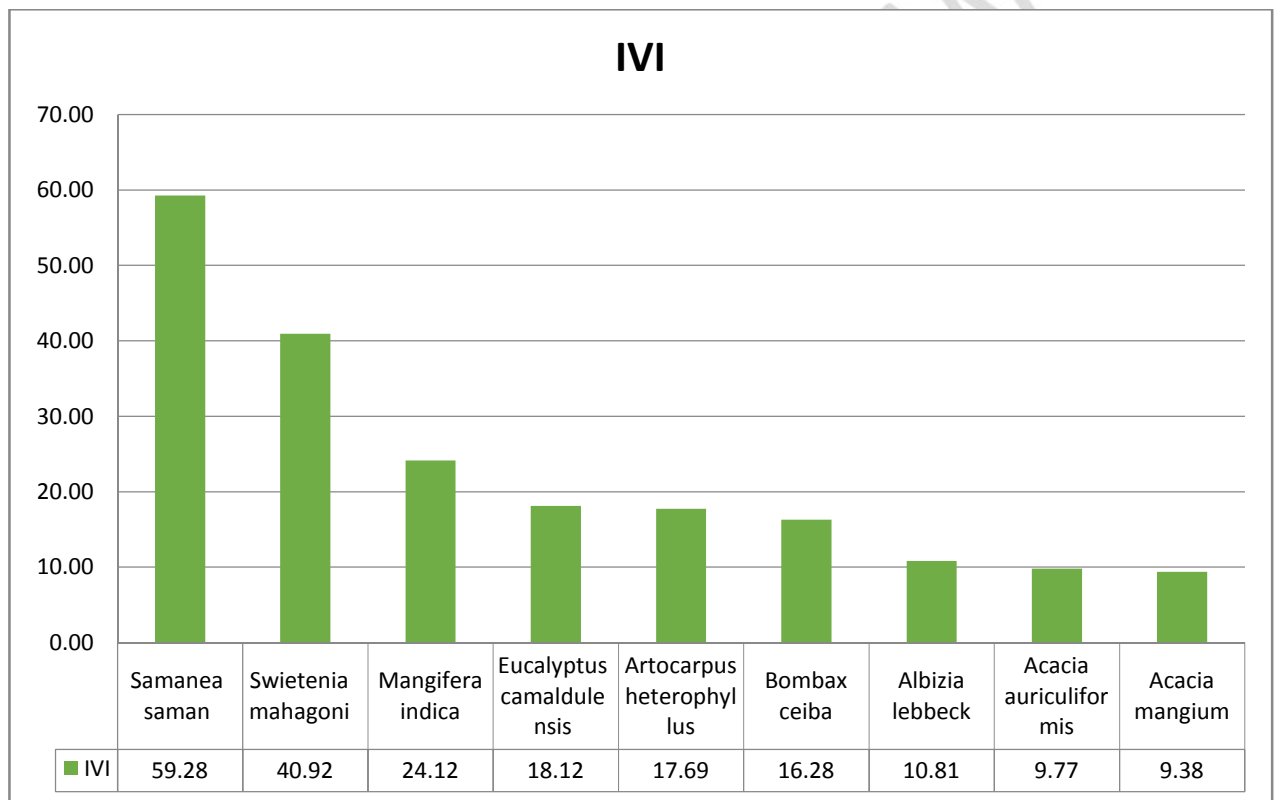
11	<i>Bombaxceiba</i>	Shimul	1.34	3.14	6.12	1.75	7.01	16.28
12	<i>Borassusflabellifer</i>	Tal	0.05	0.24	0.68	1.21	0.25	1.17
13	<i>Cassia fistula</i>	Sonalu	0.03	0.24	0.68	1.21	0.13	1.06
14	<i>Chukrasiatabularis</i>	Chikrashi	0.16	0.97	2.04	1.62	0.83	3.83
15	<i>Cocosnucifera</i>	Narikel	0.42	2.17	2.72	2.73	2.18	7.07
16	<i>Dipterocarpusturbinatus</i>	Teliyagarjan	0.05	0.24	0.68	1.21	0.25	1.17
17	<i>Elaeocarpusserratus</i>	Jalpai	0.02	0.24	0.68	1.21	0.12	1.04
18	<i>Erythrinavariegata</i>	Mandar	0.09	1.45	2.04	2.43	0.50	3.99
19	<i>Eucalyptus camaldulensis</i>	Eucalyptus	0.87	10.14	3.40	10.19	4.58	18.12
20	<i>Ficusbenghalensis</i>	Bot	0.12	0.48	1.36	1.21	0.61	2.46
Sl. No.	Binomial name	Local name	BA (m)	RD (%)	RF (%)	RA (%)	RDo (%)	IVI
21	<i>Gmelinaarborea</i>	Gamar	0.29	1.21	2.04	2.02	1.54	4.79
22	<i>Khayaanthoheca</i>	Lombu	0.13	1.69	0.68	8.50	0.66	3.03
23	<i>Lagerstroemia speciosa</i>	Jarul	0.39	2.42	3.40	2.43	2.03	7.84
24	<i>Lanneacoromandeliaca</i>	Jiolbadi	0.19	1.93	3.40	1.94	0.99	6.33
25	<i>Mangiferaindica</i>	Aam	1.91	7.97	6.12	4.45	10.03	24.12
26	<i>Neolamarckiacadamba</i>	Kadam	0.38	1.69	2.72	2.12	1.98	6.39
27	<i>Samaneasaman</i>	Raintree	5.80	15.94	12.93	4.22	30.41	59.28
28	<i>Sennasiamea</i>	Minjiri	0.06	0.24	0.68	1.21	0.29	1.21
29	<i>Spondiasmombin</i>	Amra	0.01	0.24	0.68	1.21	0.06	0.99
30	<i>Streblusasper</i>	Sheora	0.11	0.97	2.04	1.62	0.58	3.59
31	<i>Swieteniamahagoni</i>	Mahagoni	2.06	17.87	12.24	4.99	10.81	40.92
32	<i>Syzygiumfruticosum</i>	Puti jam	0.13	1.21	2.04	2.02	0.70	3.95

33	<i>Syzygium grandae</i>	Dhakijam	0.10	0.24	0.68	1.21	0.53	1.46
34	<i>Tectonagrandis</i>	Shegun	0.10	0.48	0.68	2.43	0.52	1.68
35	<i>Trewianudiflora</i>	Pitali	0.58	2.17	2.04	3.64	3.02	7.24
36	<i>Ziziphusjube</i>	Boroi	0.01	0.24	0.68	1.21	0.06	0.99

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247

248 **Figure 2** Important Value Index (IVI), distribution of the riparian tree species of Halda
 249 midstream.

250

251 3.4 Structural composition based on height (m) classes

252 The structural composition of tree species of Riparian Halda tree species was assumed by
 253 determining 4 height classes, such as; 2- <7 m, 7- <12 m, 12- <17 m, and 17- <22 m (**Table**
 254 **5**). The highest percentage of tree individuals (47.34%) belong to the 12- <17 m height class

255 followed by 7- <12 m (34.54%) and 17- <22 m height class (9.90%). The lowest percent
 256 (8.21%) of trees occurred in highest height class 2- <7 m range. Number of tree species, % of
 257 the tree individuals and number of tree individuals showed that maximum species occurred in
 258 height class of 12- <17 m.

259

260 **Table 5 Percentage distribution of tree species in different height (m) classes**

Binomial name	% distribution of tree species into different height(m) classes				Total
	2- <7 m	7- <12 m	12- <17 m	17- <22 m	
<i>Acacia auriculiformis</i>	0.00	1.45	2.17	0.00	3.62
<i>Acacia mangium</i>	0.48	1.21	1.69	0.00	3.38
<i>Albizialebeck</i>	0.00	0.24	0.97	2.66	3.86
<i>Albiziaodoratissima</i>	0.00	0.48	0.00	0.00	0.48
<i>Albiziaprocera</i>	0.00	0.24	1.21	0.00	1.45
<i>Alstoniascholaris</i>	0.00	0.24	0.00	0.00	0.24
<i>Aphanamixispolystachya</i>	0.00	0.24	0.00	0.00	0.24
<i>Areca catechu</i>	0.00	0.48	4.59	0.00	5.07
<i>Artocarpusheterophyllus</i>	0.97	3.14	0.72	0.00	4.83
<i>Artocarpuslacucha</i>	0.00	0.24	0.72	0.00	0.97
<i>Bombaxceiba</i>	0.00	0.97	1.45	0.72	3.14
<i>Borassusflabellifer</i>	0.00	0.24	0.00	0.00	0.24
<i>Cassia fistula</i>	0.00	0.24	0.00	0.00	0.24

<i>Chukrasiatubularis</i>	0.00	0.00	0.97	0.00	0.97
<i>Cocosnucifera</i>	0.24	1.21	0.00	0.72	2.17
Binomial name	% distribution of tree species into different height(m) classes				Total
	2- <7 m	7- <12 m	12- <17 m	17- <22 m	
<i>Dipterocarpusturbinatus</i>	0.00	0.24	0.00	0.00	0.24
<i>Elaeocarpusserratus</i>	0.00	0.00	0.24	0.00	0.24
<i>Erythrinavariegata</i>	1.21	0.24	0.00	0.00	1.45
<i>Eucalyptus camaldulensis</i>	0.24	0.00	5.56	4.35	10.14
<i>Ficusbenghalensis</i>	0.24	0.24	0.00	0.00	0.48
<i>Gmelinaarborea</i>	0.00	0.00	0.97	0.24	1.21
<i>Khayaanthotheca</i>	0.00	1.21	0.48	0.00	1.69
<i>Lagerstroemia speciosa</i>	0.00	1.69	0.72	0.00	2.42
<i>Lanneacoromandelica</i>	1.93	0.00	0.00	0.00	1.93
<i>Mangiferaindica</i>	1.69	1.45	4.83	0.00	7.97
<i>Neolamarckiacadamba</i>	0.00	0.00	1.69	0.00	1.69
<i>Samaneasaman</i>	0.72	3.86	11.35	0.00	15.94
<i>Sennasiamea</i>	0.00	0.00	0.24	0.00	0.24
<i>Spondiasmombin</i>	0.24	0.00	0.00	0.00	0.24
<i>Streblusasper</i>	0.00	0.97	0.00	0.00	0.97

<i>Swieteniamahagoni</i>	0.00	12.56	5.31	0.00	17.87
Binomial name	% distribution of tree species into different height(m) classes				Total
	2- <7 m	7- <12 m	12- <17 m	17- <22 m	
<i>Syzygiumfruticosum</i>	0.00	1.21	0.00	0.00	1.21
<i>Syzygiumgrandae</i>	0.00	0.00	0.24	0.00	0.24
<i>Tectonagrandis</i>	0.00	0.00	0.00	0.48	0.48
<i>Trewianudiflora</i>	0.00	0.24	1.21	0.72	2.17
<i>Ziziphusjube</i>	0.24	0.00	0.00	0.00	0.24
Total	8.21	34.54	47.34	9.90	100

261

262

263 3.5 Structural composition of tree species based on diameter class distribution

264 7 diameter classes (cm) were determined to assume the structural composition. These were
 265 10- <20 cm, 20 -<30 cm, 30- <40 cm, 40- <50 cm, 50- <60 cm, 60- <70 cm and 70- <80 cm.
 266 Among them, 48.79% of all the tree individuals (202 tree stems of 414 stems) belonging to
 267 26 tree species were in the diameter range of 10- <20 cm (**Table 6**). Only *Samanea saman*
 268 belongs to the highest dbh class 70- <80 cm.

269

270 **Table 6 Percentage distribution of each tree species into different diameter (cm) classes**

Binomial name	% distribution of tree individuals into different diameter(cm) classes							Total
	10- <20	20- <30	30- <40	40- <50	50- <60	60- <70	70- <80	
<i>Acacia</i>	2.66	0.97	0.00	0.00	0.00	0.00	0.00	3.62

<i>auriculiformis</i>								
<i>Acacia mangium</i>	1.69	1.69	0.00	0.00	0.00	0.00	0.00	3.38
<i>Albizialebeck</i>	0.24	2.66	0.97	0.00	0.00	0.00	0.00	3.86
<i>Albiziaodoratissima</i>	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
<i>Albiziaprocera</i>	0.00	1.45	0.00	0.00	0.00	0.00	0.00	1.45
<i>Alstoniascholaris</i>	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
<i>Aphanamixispolystachya</i>	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
<i>Areca catechu</i>	5.07	0.00	0.00	0.00	0.00	0.00	0.00	5.07
<i>Artocarpusheterophyllus</i>	1.69	1.93	1.21	0.00	0.00	0.00	0.00	4.83
<i>Artocarpuslacucha</i>	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97
<i>Bombaxceiba</i>	0.72	0.97	0.48	0.48	0.24	0.24	0.00	3.14
<i>Borassusflabellifer</i>	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
<i>Cassia fistula</i>	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
<i>Chukrasia tabularis</i>	0.24	0.72	0.00	0.00	0.00	0.00	0.00	0.97
<i>Cocos nucifera</i>	0.72	1.45	0.00	0.00	0.00	0.00	0.00	2.17
<i>Dipterocarpusturbinatus</i>	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
<i>Elaeocarpus serratus</i>	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
<i>Erythrina variegata</i>	1.45	0.00	0.00	0.00	0.00	0.00	0.00	1.45
<i>Eucalyptus camaldulensis</i>	7.97	2.17	0.00	0.00	0.00	0.00	0.00	10.14
<i>Ficus benghalensis</i>	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.48
<i>Gmelina arborea</i>	0.00	0.24	0.97	0.00	0.00	0.00	0.00	1.21
Binomial name	% distribution of tree individuals into different diameter(cm) classes							Total
	10- <20	20- <30	30- <40	40- <50	50- <60	60- <70	70- <80	
<i>Khayaanthothea</i>	1.69	0.00	0.00	0.00	0.00	0.00	0.00	1.69
<i>Lagerstroemia speciosa</i>	0.72	1.45	0.24	0.00	0.00	0.00	0.00	2.42
<i>Lanneacoromandelic</i>	1.69	0.24	0.00	0.00	0.00	0.00	0.00	1.93

<i>a</i>								
<i>Mangifera indica</i>	3.14	2.42	1.69	0.72	0.00	0.00	0.00	7.97
<i>Neolamarckia cadamba</i>	0.00	1.69	0.00	0.00	0.00	0.00	0.00	1.69
<i>Samanea saman</i>	3.14	6.04	4.35	1.21	0.24	0.24	0.72	15.94
<i>Sennasiamea</i>	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.24
<i>Spondias mombin</i>	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
<i>Streblus asper</i>	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.97
<i>Swietenia mahagoni</i>	12.32	4.83	0.72	0.00	0.00	0.00	0.00	17.87
<i>Syzygium fruticosum</i>	0.97	0.24	0.00	0.00	0.00	0.00	0.00	1.21
<i>Syzygium grandae</i>	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.24
<i>Tectona grandis</i>	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.48
<i>Trewia nudiflora</i>	0.24	1.45	0.24	0.24	0.00	0.00	0.00	2.17
<i>Ziziphus jujuba</i>	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Total	48.79	35.51	11.35	2.66	0.48	0.48	0.72	100

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274 **4. Discussion**

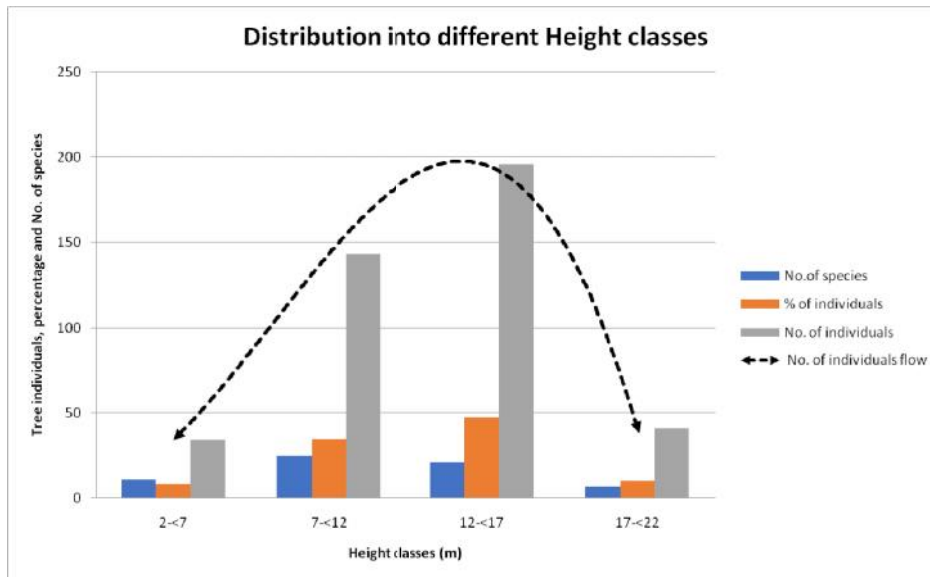
275 The composition and diversity status are the important factors for the judgement of a forest
 276 status. In the riparian midstream area of Halda River, a total of 36 tree species belonging to
 277 15 families were recorded in which 53.33% of the families are represented by one species,
 278 20% of the families by three species, 13.33% of the families by four species and only 6.66%
 279 of the families represented by two and the rest of 6.66% by nine tree species. The findings
 280 showed a moderate species composition compared to a study conducted by Wittmann and his
 281 team where 46 species belonging to 26 families were identified in Riparian forest area (26).

282 The higher IVI possessing species *Samanea saman*, *Swietenia mahagoni*, *Mangifera indica*,
 283 *Eucalyptus camaldulensis* and *Artocarpus heterophyllus* indicating the most abundant species

284 and *Ziziphus jujube*, *Spondias mombin*, *Aphanamixis polystachya*, *Elaeocarpus serratus* and
285 *Cassia fistula* as the rarest species of the midstream of Halda River.

286 The distribution of tree individuals among different height classes showed a reverse U-shaped
287 curve. That means, as the height class increases, the number of individuals and species are
288 reducing and indicates that old, mature trees are very scarce in the study area (**Figure 3**).

289



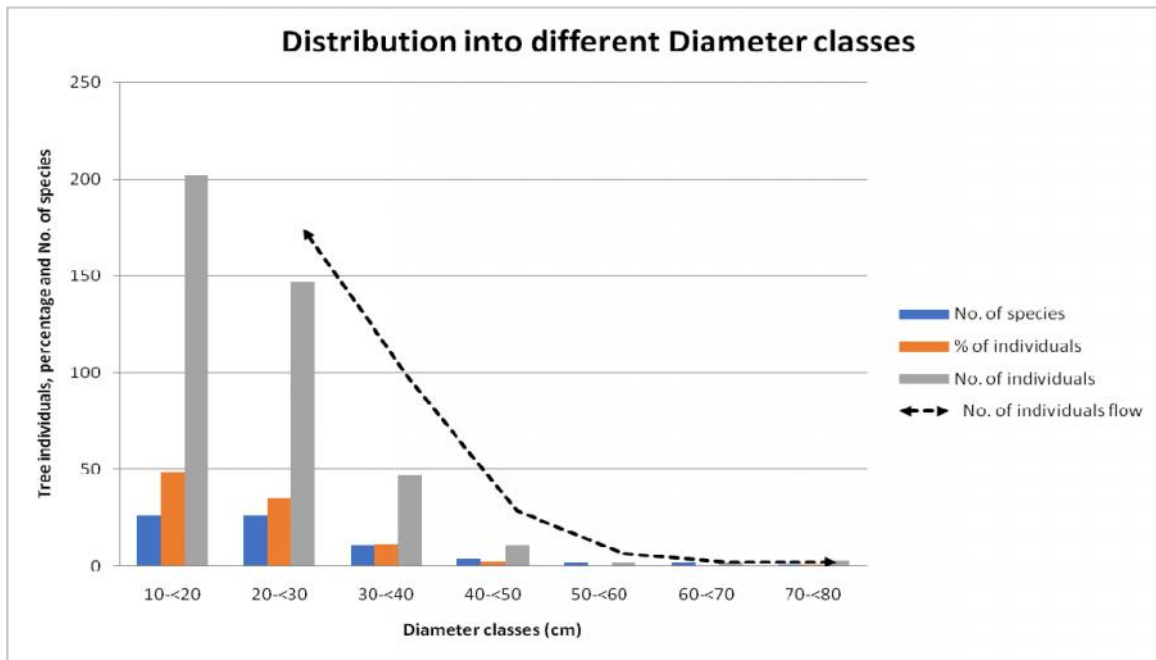
290

291 **Figure 3** Vertical distribution of tree species and individuals into different height classes

292

293 Again, the height distribution of tree species revealed an almost reverse J-shaped curve
294 (**Figure 4**). The number of species and percentage of tree individuals were maximum in the
295 lower DBH ranges and the number of tree individuals is progressively decreasing with the
296 increase of dbh. These indicate that most of the tree stems are young and old growth stems
297 already disappeared from the riparian area.

298



299

300 **Figure 4** Distribution of tree species, number and percentage of tree individuals into
 301 different diameter classes

302

303 As the species diversity is determined not only by the number of species within a biological
 304 community but also by the relative abundance of individuals in that community, so from the
 305 general observation of the diversity indices the following discussions could be given.

306 The value of Shannon-Wieners Diversity Index 2.86 which generally indicates a relatively
 307 diversity rich area as the value of this index range between 1.5 to 3.5 (Shannon & Weiner
 308 1963c) but as Shannon-Wieners Diversity Index is used while comparing the diversity of
 309 two different land areas, the value was found richer comparing to theriparian forest of the
 310 lower Miranda River which value was found between 0.75 and 2.17(mean: 1.43 ± 0.39)(26).

311 Then, Simpson's diversity index was found 0.91 which indicates a high diversity of riparian
 312 tree species of Halda as its value is closer to 1 and it also shows that if two individual species
 313 would be given randomly from the quadrants there would be 91% possibility to find them of
 314 different species (Simpson 1949b).

315 The Margalef's Richness Index (5.81) and Menhinick's richness index (1.77) which indicates
 316 the number of species or richness of species along with Pielou's Species Evenness Index

317 (0.80) which ranges from (0-1) and which shows the relative abundance indicating the
318 riparian Halda midstream as a high diversity area.

319

320 **5. Conclusions**

321 Halda River is one the most resourceful river in Bangladesh not only for the hosting of major
322 Indian carps but also for a number of hydrology related ecosystem services. In this study, the
323 riparian tree vegetation was investigated through direct measurement of tree species. In the
324 study area, tree species such as fruit species, woody and timber species were found which
325 indicates that the riparian area plays important role from both ecological and economic point
326 of view providing food, fuel-wood, timber, and edible fruits for the surrounding local people.
327 It was also revealed that tree species with diameter at breast height of 10<20 cm was the most
328 dominant. Besides, dominant tree species was with a height of 12-<17 m. It is important to
329 mention here that this research has some limitations. The present study was conducted only in
330 the middle stream of the Halda river basin. As Halda is a 98 km long river, the future research
331 should focus on the whole river basin including both the upstream and lower stream of the
332 Halda river system. Particularly future research should investigate how the tree species
333 diversity has been changing over the changing time and environmental conditions. Despite of
334 limitations, this composition and quantitative information of the tree species will be helpful to
335 the policy makers, conservationists and river managers in formulating and implementing
336 future forest resources conservation programs of Halda riparian vegetation. Therefore, a
337 proper strategy for the conservation and management in the study area is required to the best
338 utilization of riparian tree species by the local villagers. It is expected that the information
339 generated through this research will be interesting to study more representatives of riparian
340 plant communities from other type of forest that exist in Bangladesh to know more about
341 these plant communities.

342

343 **References (not in accordance to journal guidelines!)**

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UNDER PEER REVIEW