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Lists of Species

Revised checklist and distribution maps of *Anopheles* (Insecta: Diptera: Culicidae: Anophelinae) mosquitoes of Bangladesh

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Abstract: It has been 25 years since the publication of the first checklist of mosquito in Bangladesh and several significant taxonomic changes have occurred. Therefore, considering these changes, we prepare an updated list of *Anopheles* species in Bangladesh along with their distribution maps. A total of 36 Anopheles species have been listed from Bangladesh and these species belong to either the sub-genus *Anopheles* or *Cellia* but we captured 30 species in our study. Eleven species were distributed all over Bangladesh but Anopheles nivipes and *An. turkhudi* were found only in Bandarban and Cox's Bazar areas respectively. *Anopheles sundaicus* were found limited number in the costal belt of Bangladesh. Nearly all *Anopheles* species were found in Southeastern hilly parts of Bangladesh. However, *An. vagus*, *An. philippinensis*, *An. barbirostris* distribute all over the Bangladesh with high density.

Introduction

On a global scale, *Anopheles* mosquitoes are well known as annoying biting pests and vectors of human and animal pathogens with malaria being the most important infection in terms of human morbidity and mortality. Some species of *Anopheles* can also transmit canine heartworm *Dirofilaria immitis*, filariasis-causing species such as *Wuchereria bancrofti* and *Brugiamalayi*, and viruses (Lehrer 2010). In Bangladesh, malaria is the most important human pathogen transmitted by *Anopheles* mosquitoes and there are seven known vector species.

Anopheles mosquitoes have been reported from different parts of British India (including the area that would eventually become Bangladesh) before the partition in 1947 (James and Liston 1911; Covel 1927; Covel 1931; Barraud 1933; Christophers 1933; Puri 1936; Puri 1948). After the partition of India, Quraishi andTalibi (1956) accumulated the records of mosquitoes collected by different researchers and reported 31 species of *Anopheles* from the then East Pakistan (which is now an independent Bangladesh). Plan of Operation of Malaria Eradication Program, MEP (1960) of Bangladesh reported 25 species of Anopheline mosquitoes. After the independence of Bangladesh in 1971, several researchers actively surveyed the mosquito species present in the country (Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Rosenberg 1983). Ahmed (1987) summarized Mosquito fauna of Bangladesh for the first time and this list included 32 species and 2 varieties of *Anopheles* mosquitoes. A number of other reports (Ahmed *et al*. 2004; Bashar 2006; Jannat and Ahmed 2006; Ahmed *et al*. 2009; Alam*et al*. 2010; Jannat and Ahmed 2010; Chowdhury *et al.* 2011; Alam *et al*. 2012; Bashar *et al*. 2012a,b;) on mosquitoes from across Bangladesh are available since this first report. Despite this work, it has been 25 years since the publication of the first checklist of mosquito in Bangladesh and several significant taxonomic changes have occurred (e.g., species name changes, a variety changed to a species, and one species divided into many varieties). In addition, several new species distribution records for a number of different species have been recorded. Considering these changes, it seems appropriate to prepare an updated list of *Anopheles* species in Bangladesh along with their up-to-date distribution maps.

Materials and Methods

We collected mosquitoes from different regions of the People's Republic of Bangladesh. It is a sovereign state located in southern Asia. The landmass of Bangladesh covers an area of about 147,570 sq km and the human populations is estimated at about 170 million. Bangladesh extends from 20°34" N to 26°38" N latitude and from 88°01" E to 92°41" E longitudes. The Indian States of West Bengal, Assam, Meghalaya and Tripura border Bangladesh in the west, north and east, respectively. Myanmar (Burma) forms the southern part of the eastern frontier, while the country is encompassed in the south by the Bay of Bengal. Bangladesh belongs to tropical monsoon climate. The rainy season of the southwest monsoon typically occurs from June to September, and rainfall is frequent and heavy ranges between 1500- 2500 mm of rain over this period. The winter season starts from November and ends in February and the dry season is typically spread over from March until the early June. Almost all over the year, humidity is generally very high (i.e., close to 90%) (BBS 2012).

From 2005 to 2011, we collected samples from Dhaka, Dinajpur, Bandarban, Khagrachari, Rangamati, Cox's bazaar, Thakurgaon, Khulna, Kushtia, Maymensing,

Netrokona, Moulvibazar and Manikgonj districts (Figure 1). Adult mosquitoes were collected using light traps (LTs), pyrethrum spray (PS), and human bait (HB) following the World Health Organization procedures (WHO1975). LTs were hanged 1.5 meter above the ground level in inside and outside of the houses. HB catch were also done in inside and outside the houses. Larvae were collected using standard, 400 ml-capacity dipper; an eyedropper; turkey baster, tea strainer, modified bilge pump, white enamel plate, vials. Collected larvae and adult mosquitoes were killed with formaldehyde and chloroform respectively and identified morphologically in the field laboratory under stereoscopic microscopes within 12 hour after collecting samples using standard taxonomic keys (Christophers 1933; Puri 1960; Harrison and Scanlon 1975). Collected samples were transported to the Entomology Laboratory at Jahangirnagar University for the double-checking of species identification.

Species density of the mosquito was calculated according the number of mosquitoes collected in indoor and outdoor using light traps. In maps we showed low (per light trap per night capture <1), medium (per light trap per night capture 1-5) and high (per light trap per night capture >5) density in the maps. Infection rate is the malaria morbidity per thousand people.

Maps documented in this checklist are based upon our most recent surveys as well as the records from Cove1 (1927; 1930), Christophers (1933), Puri (1936; 1948), Ahmed *et al*. (2004; 2009), Bashar (2006), Jannat and Ahmed (2006; 2010), Alam *et al*. (2010; 2012), Chowdhury *et al*. (2011), Bashar *et al*. (2012 a,b). Maps have been drawn based on all of the known distribution data for each mosquito species.

Results and Discussion

A total of 36 Anophelines species have been listed from Bangladesh, and these species belong to either the sub-genus *Anopheles* or *Cellia*. Our research teams were able to confirm 30 of these species from the different regions of Bangladesh and an asterisk (Table 1) indicates these species. The classification scheme follows Knight and Stone (1977) and Knight (1978) and genera, sub-genera and species were arranged alphabetically in table 1.

Known distributions of different Anophelines species were presented in figures 2-10. Eleven *Anopheles* species; *peditaeniatus, aconitus, annulararis, culicifacies, jamesii, pallidus, philippinensis, pseudojamesi, subpictus, vagus* and *varuna* were distributed all over Bangladesh. Whereas, *An. aitkenii, baimaii, umbrosus* and *kochi* were found in Southeastern region. *Anopheles nivipes* and *An. turkhudi* were found only in Bandarban and Cox's Bazar areas respectively. *Anopheles sundaicus* were found limited number in the costal belt of Bangladesh.

Malaria is endemic to Bangladesh and vector diversity and density are very high. Total 13 out of 64 districts bordering India and Myanmar are severely affected by malaria (Bashar *et al*. 2012a). Among these, the districts of Chittagong, Rangamati, Khagrachari, Bandarban, and Cox's Bazar are hyper endemic, whereas the districts of Kurigram, Sherpur, Mymensingh, Netrokona, Sylhet, Sunamgonj, Moulvibazar, and Hobiganj are prone to low-level epidemics. Seven Anopheles species are the confirm vector in Bangladesh and there are more six species are suspected (Alam *et al*. 2010; Bashar *et al*. 2012a, b).

Since the 1930s, several researchers collected different species of *Anopheles* mosquitoes from Bangladesh. We recorded 30 Anophelines species during our study. Quraishiand Talibi (1956) reported 31species of *Anopheles* and they describe *An. annandalai*, *An. insulaeflorum*, *An. lindesayi*. However, these species never reported in Bangladesh by other researchers. These mosquitoes were collected from different region of Pakistan where the geography and environment are not same with Bangladesh. Aslamkhan (1971) recorded 27 species and 2 varieties of *Anopheles* mosquitoes in East Pakistan. However, many of these species have not been found in Bangladesh and some of these records may have been mistakenly assisted to East Pakistan rather than West Pakistan. Ahmed (1987) summarizes 32 species and 2 varieties of *Anopheles* mosquitoes in Bangladesh but in our new list, we reported 36 species because *An. turkhudi* and *An. nivipes* were newly recorded (Jannat and Ahmed 2006; Alam *et al*. 2012, Bashar *et al.* 2012b).

We illustrated the distribution of 34 Anophelines species in Bangladesh maps (Figures 2-10). This is the first time in Bangladesh where distribution map of different Anopheles species are shown at district level while other researchers reported the distribution of their recorded species in tabular form only. Especially Covel (1927; 1930), Christophers (1933) and Chowdhury *et al*. (2011) clearly described the density and distribution of Anophelines in Bangladesh in non-spatial formats.

As a pioneering work, this study reports complete distribution maps of *Anopheles* mosquitoes in Bangladesh. Our findings demonstrate that majority of the *Anopheles* species were found in Southeastern hilly parts of Bangladesh. However, *An. vagus*, *An. philippinensis* densely distributed all over Bangladesh. Potential malaria vectors, *An. baimaii* are completely confined within the hilly parts of the country. However, longitudinal entomological studies and vector surveillance are essential for better mapping of the *Anopheles* population.

The complete distribution maps will be very helpful for government and private organizations to take specific control measures according to the location to reduce mosquito population as well as malaria in Bangladesh.

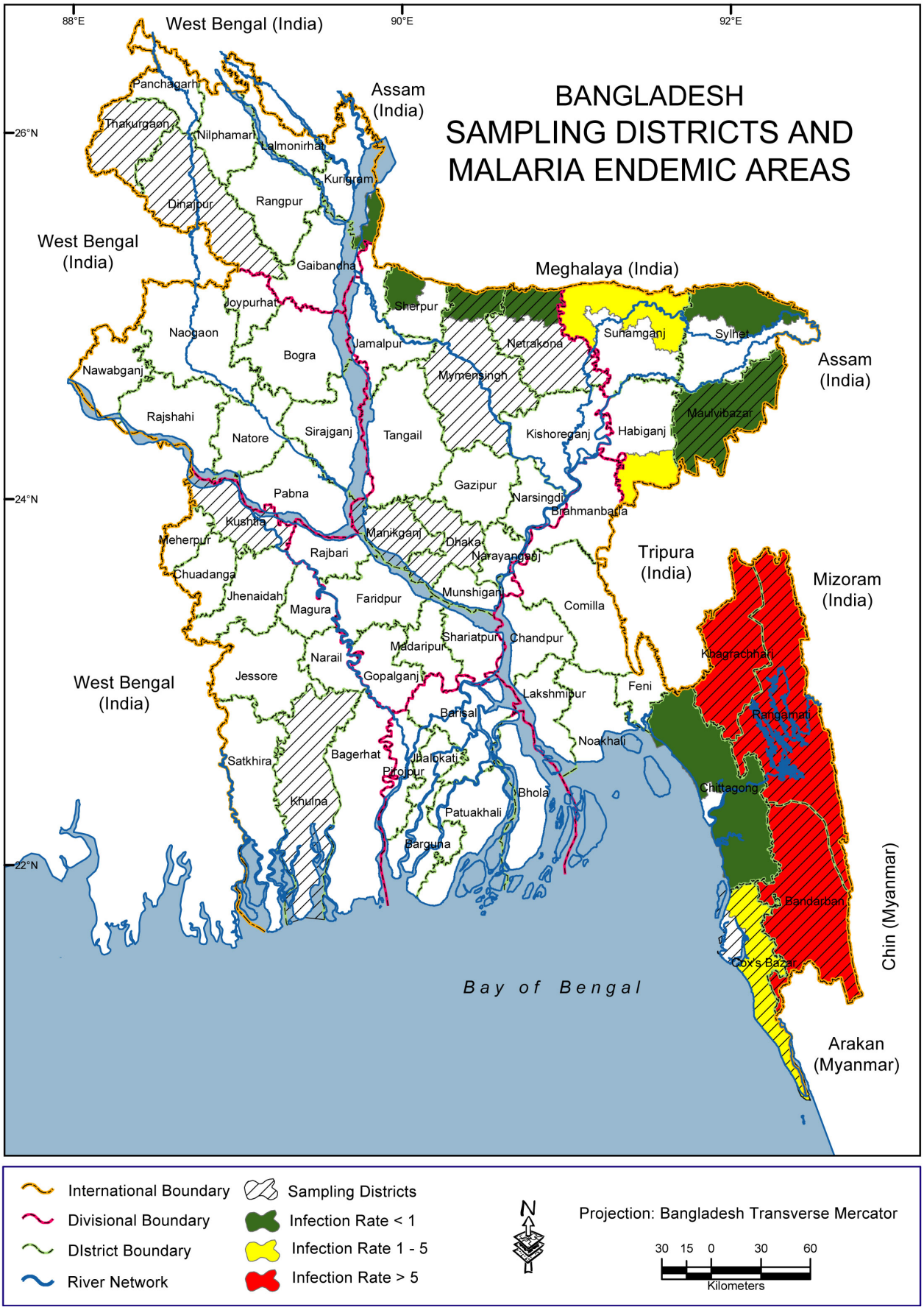

Figure 1. Sampling districts and malaria endemic areas in Bangladesh.

Table 1. List of the species of *Anopheles* found in Bangladesh.

***Anopheles* Meigen, 1818 (*Anopheles*)**
Anopheles aitkenii James, 1903* (Aslamkhan and Wolfe 1972; Ahmed 1987; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles baileyi Edwards, 1929 (Christophers 1933; Puri 1936; MEP 1960; Chowdhury *et al.* 2011)
Anopheles barbirostris Van der Wulp, 1884* (James and Liston 1911; Covel 1927; 1931; Christophers 1933; Puri 1936;1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles barbumbrosus Strickland and Chowdhury, 1927 (Rosenberg 1982)
Anopheles bengalensis Puri, 1930 (MEP 1960; Ahmed 1987)
Anopheles gigas Giles, 1901 (Christophers 1933; Puri 1936; Quraishi and Talibi1956; MEP 1960; Chowdhury *et al.* 2011)
Anopheles gigas var. *simlensis* (James) 1911 (Covel 1931; Quraishiand Talibi1956; Aslamkhan 1971)
Anopheles nigerrimus Giles, 1900* (James and Liston 1911; Covel 1927; 1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles peditaeniatus (Leicester) 1903* (Ahmed 1987; Ahmed *et al*. 2004; Jannat and Ahmed 2010; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles umbrosus (Theobald) 1903* (Covel 1927; Christophers 1933; Puri 1936; Quraishiand Talibi 1956; Aslamkhan 1971; Ahmed *et al*. 2009; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles (Cellia)
Anopheles aconitus Doenitz, 1902*+ (James and Liston 1911; Covel 1927; 1931;Christophers 1933; Puri 1936; 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles annularis Van der Wulp, 1884*+ (Covel 1927; 1931; Christophers 1933; Puri 1936;1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Bashar 2006; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles baimaii Sallum and Peyton, 2005 (*dirus* D Peyton and Harrison)*+ (Quraishi and Talibi 1956; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Rosenberg 1982; Ahmed 1987; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles culicifacies Giles, 1901* (James and Liston 1911; Covel 1927; 1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; Bashar 2006; Jannat and Ahmed 2006; 2010; Chowdhury *et al.* 2011)
Anopheles fluviatilis James, 1902* (Covel 1927; 1931; Christophers 1933; MEP 1960; Aslamkhan 1971; Khan and Talibi 1972; Ahmed 1987; Jannat and Ahmed 2006; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles jamesii Theobald, 1901* (Covel 1927, 1931; Christophers 1933; Puri 1936, 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; Jannat and Ahmed 2006; 2010; Alam*et al*. 2010; Chowdhury *et al.* 2011; Alam *et al*. 2012; Bashar *et al*. 2012a, b)
Anopheles jeyporiensis James, 1902*(Covel 1927; Christophers 1933; Puri 1936; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ahmed 1987; Ahmed *et al*. 2004; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles karwari (James), 1902* (Covel 1931; Christophers 1933; Puri 1936; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Ahmed *et al*. 2004; 2009; Alam *et al*. 2010, 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles kochi Doenitz, 1901* (Covel1927; 1931; Puri 1936; 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Ahmed *et al*. 2009; Alam *et al*. 2010, 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles maculatus Theobald, 1901* (Covel 1931; Christophers 1933; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles majidi Young and Majid, 1928* (MEP1960; Ahmed 1987; Chowdhury *et al.* 2011)
Anopheles minimus Theobald, 1901*+ (Covel 1931; Christophers 1933; Puri 1936; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Khan and Talibi 1972; Ahmed 1987; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles nivipes (Theobald), 1903* (Alam *et al*. 2012; Bashar *et al*. 2012b)
Anopheles pallidus Theobald, 1901* (Covel 1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Ahmed *et al*. 2004; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles philippinensis Ludlow, 1902*+ (Covel 1927; 1931; Barraud 1933; Puri 1936, 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Khan and Talibi 1972; Ahmed 1987; Ahmed *et al*. 2004; 2009; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles pseudojamesi (*ramsayi*) Strickland and Chowdhury, 1927* (Covel 1931; Christophers 1933; Puri 1936, 1948; Quraishi and Talibi1956; MEP 1960; Aslamkhan 1971; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2009; Chowdhury *et al.* 2011)
Anopheles splendidus Koidzumi, 1920* (Covel 1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Alam *et al*. 2012;)
Anopheles stephensi Liston, 1901(MEP 1960; Quraishi and Talibi1956; Aslamkhan 1971; Jannat and Ahmed 2010)
Anopheles subpictus Grassi, 1899* (Covel 1927; 1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles sundaicus (Rodenwaldt) 1925*+ (James and Liston 1911; Covel1931; Christophers 1933; Puri1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Ahmed 1987; Ahmed *et al*. 2009; Chowdhury *et al.* 2011)
Anopheles tessellatus Theobald, 1901*(Covel 1927; 1931; Christophers 1933; Puri 1936, 1948; MEP 1960; Aslamkhan 1971; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles theobaldi Giles, 1901(Covel 1927; Christophers 1933; MEP 1960; Quraishi and Talibi 1956; Aslamkhan 1971)
Anopheles turkhudi Liston, 1901 (Jannat and Ahmed 2006; Alam *et al*. 2012)
Anopheles vagus Donitz, 1902*+ (Covel1931; Christophers 1933; Puri 1936; 1948; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Aslamkhan and Wolfe 1972; Khan and Talibi 1972; Ameen and Moizuddin 1973; Ahmed 1987; Ahmed *et al*. 2004; 2009; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a,b)
Anopheles varuna Iyengar, 1924* (Covel 1927; 1931; Christophers 1933; Quraishi and Talibi 1956; MEP 1960; Aslamkhan 1971; Khan and Talibi 1972; Ahmed 1987; Ahmed *et al*. 2004; Jannat and Ahmed 2006; 2010; Alam *et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012a, b)
Anopheles willmori (James) 1903* (Covel 1931; Christophers 1933; Aslamkhan 1971; Alam*et al*. 2010; 2012; Chowdhury *et al.* 2011; Bashar *et al*. 2012b)

*Denotes species collected and identified by the authors and preserved in the entomology laboratory of Jahangirnagar University.
+ confirmed malaria vector in Bangladesh

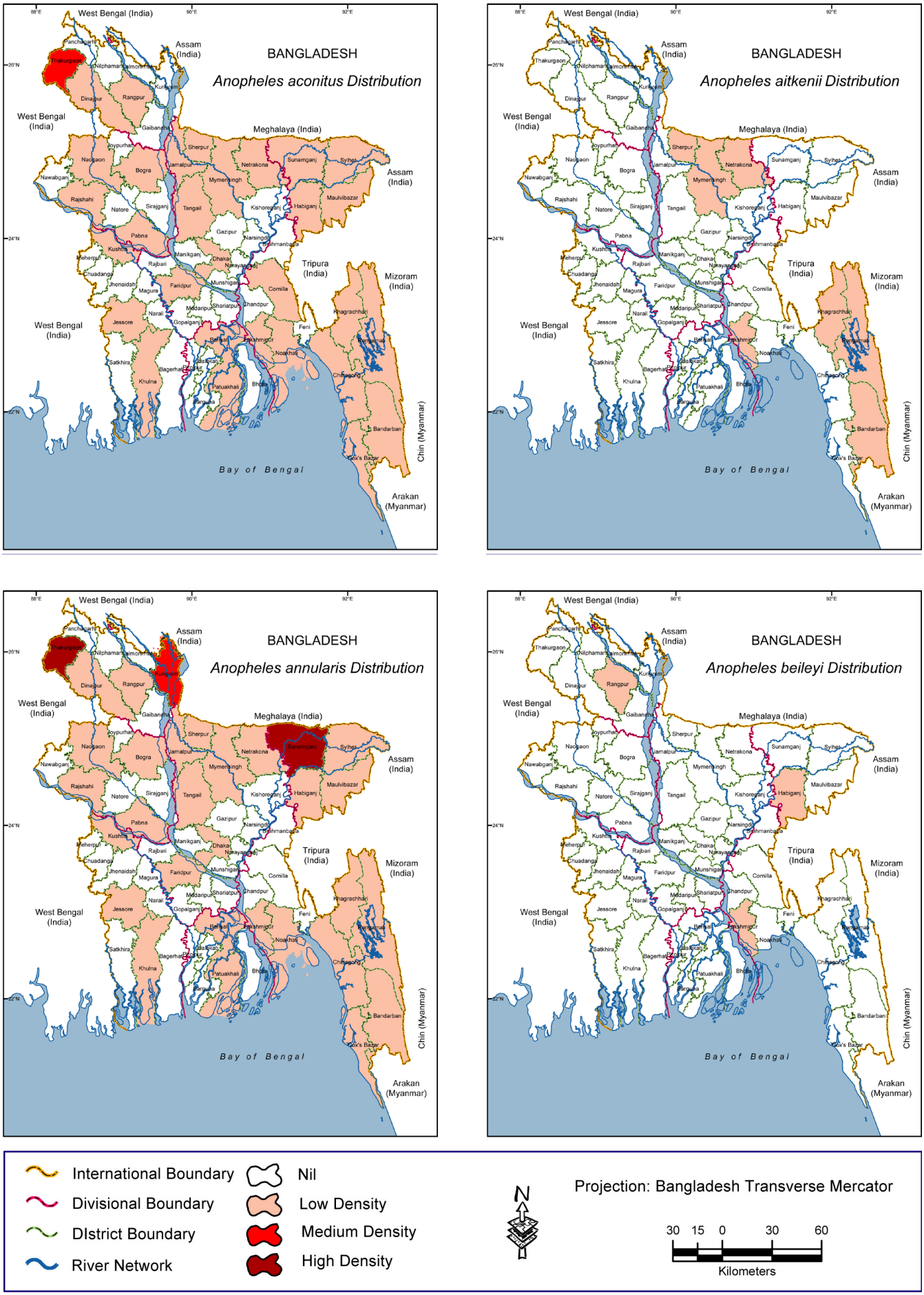

FIGURE 2. Distribution of *An. aconitus*, *An. aitkenii*, *An. annularis* and *An. baileyi* in Bangladesh.

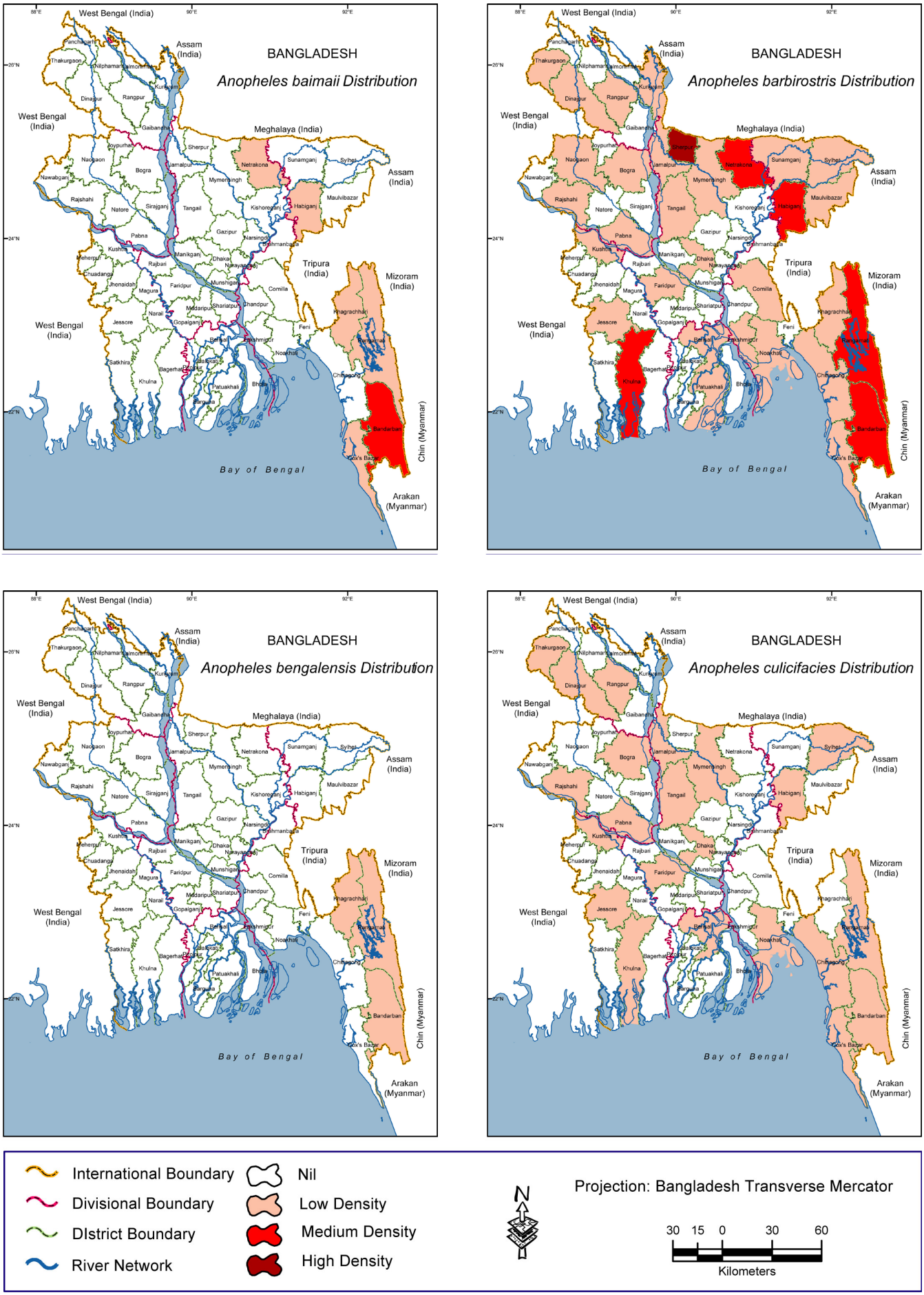

FIGURE 3. Distribution of *An. baimaii, An. barbirostris, An. bengalensis* and *An. culicifacies* in Bangladesh.

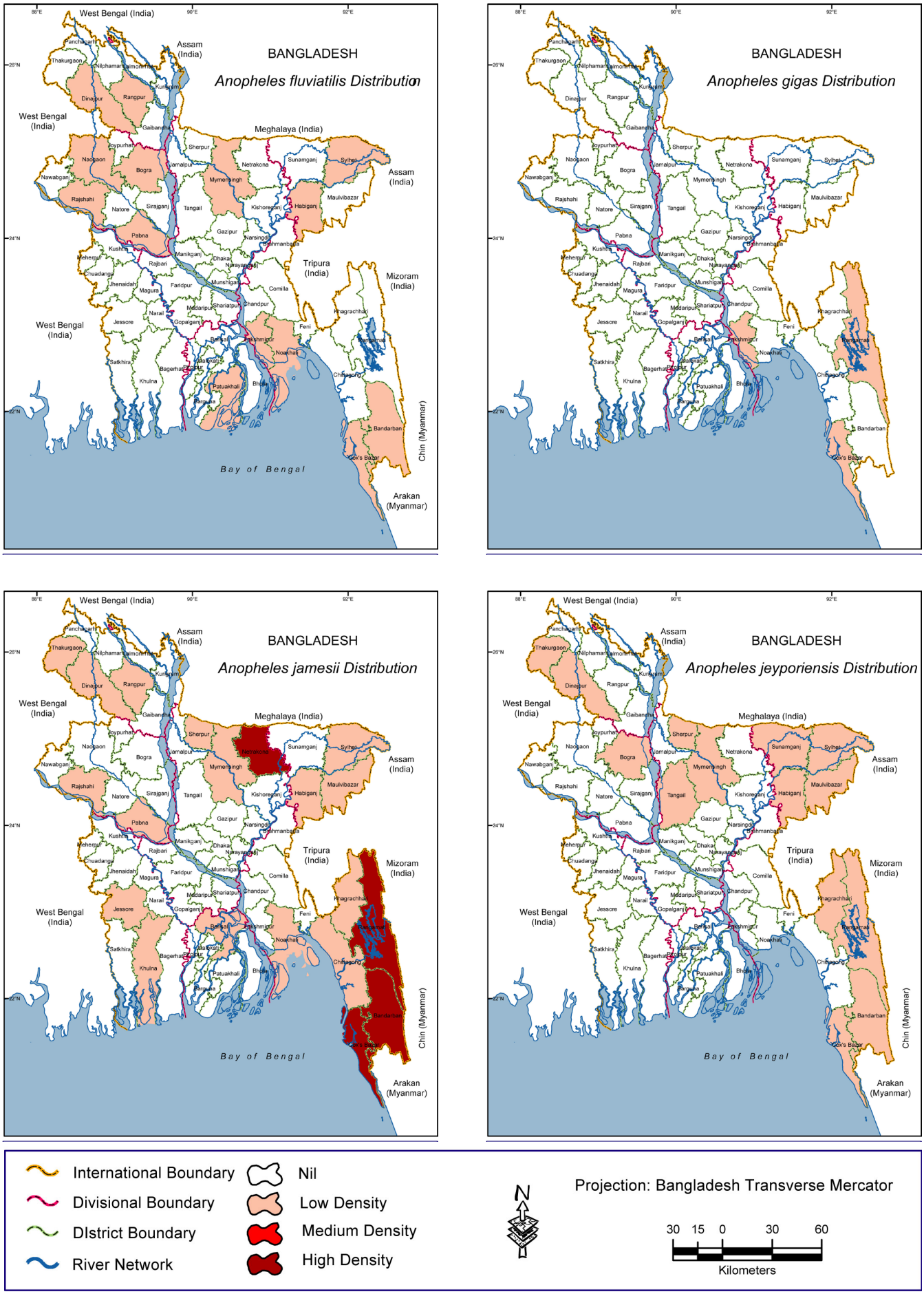

FIGURE 4. Distribution *An. fluviatilis, An. gigas, An. jamesii* and *An. jeyporiensis* in Bangladesh.

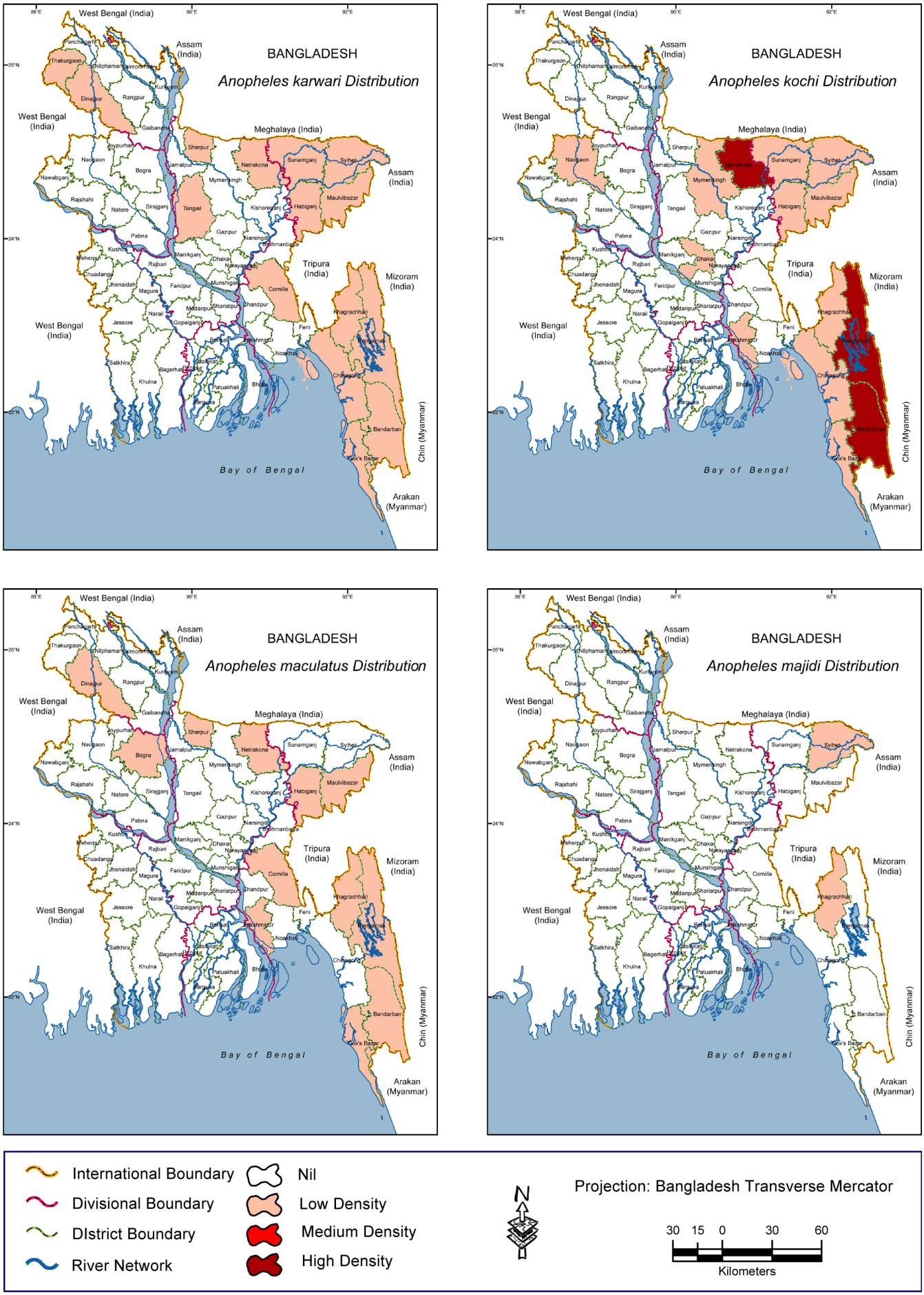

FIGURE 5. Distribution *An. karwari*, *An. kochi*, *An. maculatus* and *An. majidi* in Bangladesh.

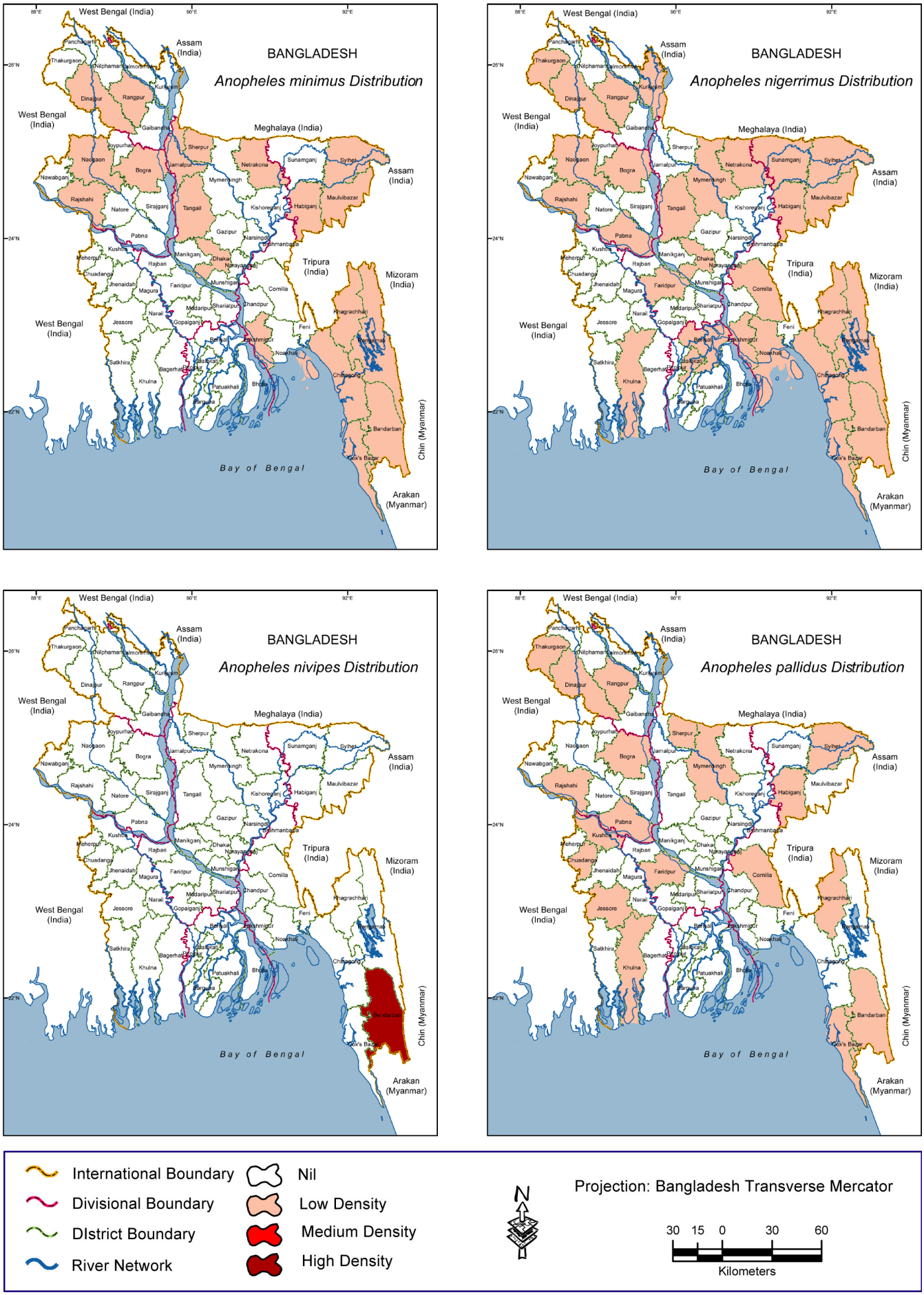

FIGURE 6. Distribution *An. minimus, An. nigerrimus, An. nivipes* and *An. pallidus* in Bangladesh.

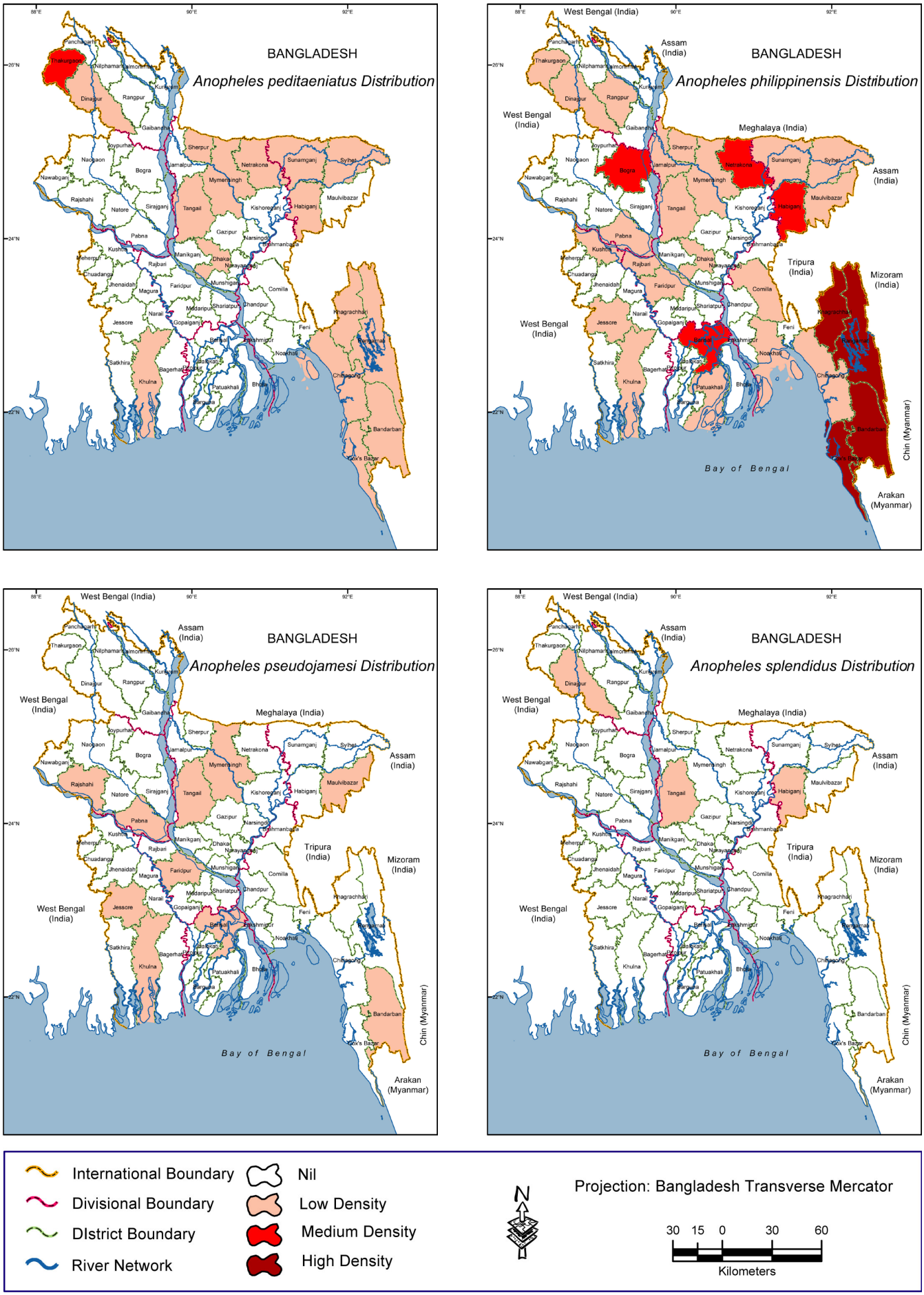

Figure 7. Distribution *An. peditaeniatus, An. philippinensis, An. pseudojamesi* and *An. splendidus* in Bangladesh.

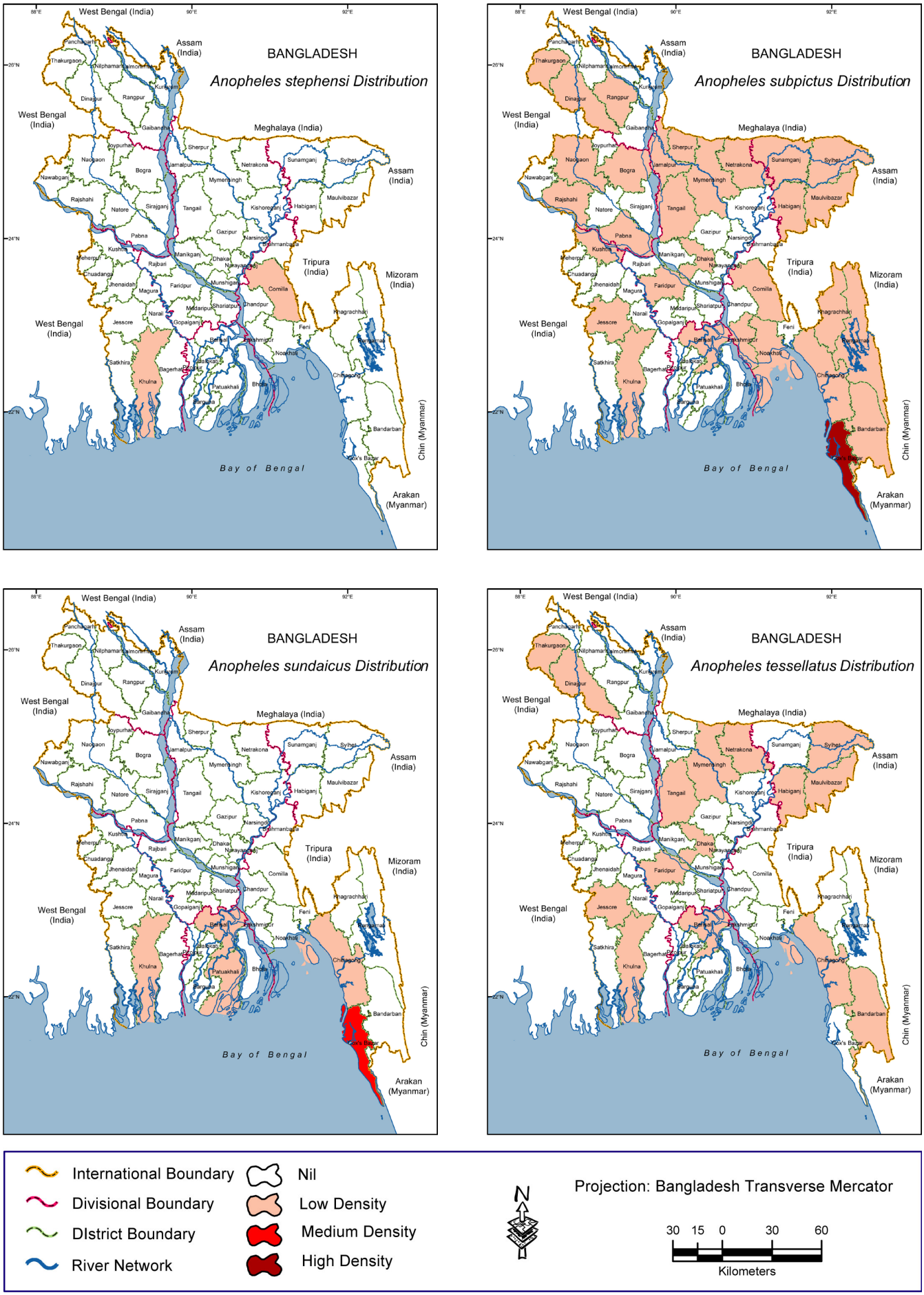

FIGURE 8. Distribution *An. stephensi, An. subpictus, An. sundaicus* and *An. tessellatus* in Bangladesh.

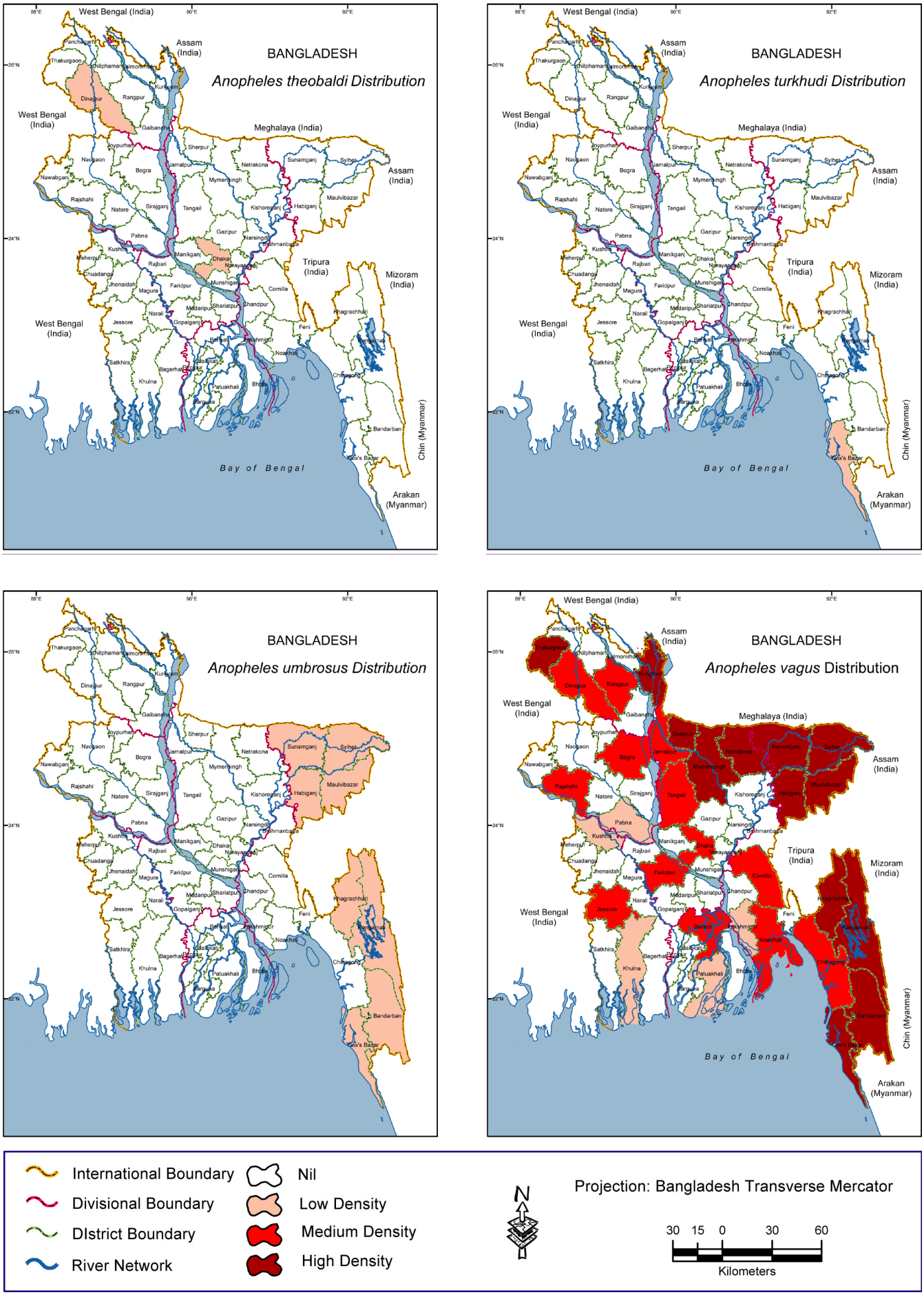

Figure 9. Distribution *An. theobaldi, An. turkhudi, An. umbrosus* and *An. vagus* in Bangladesh.

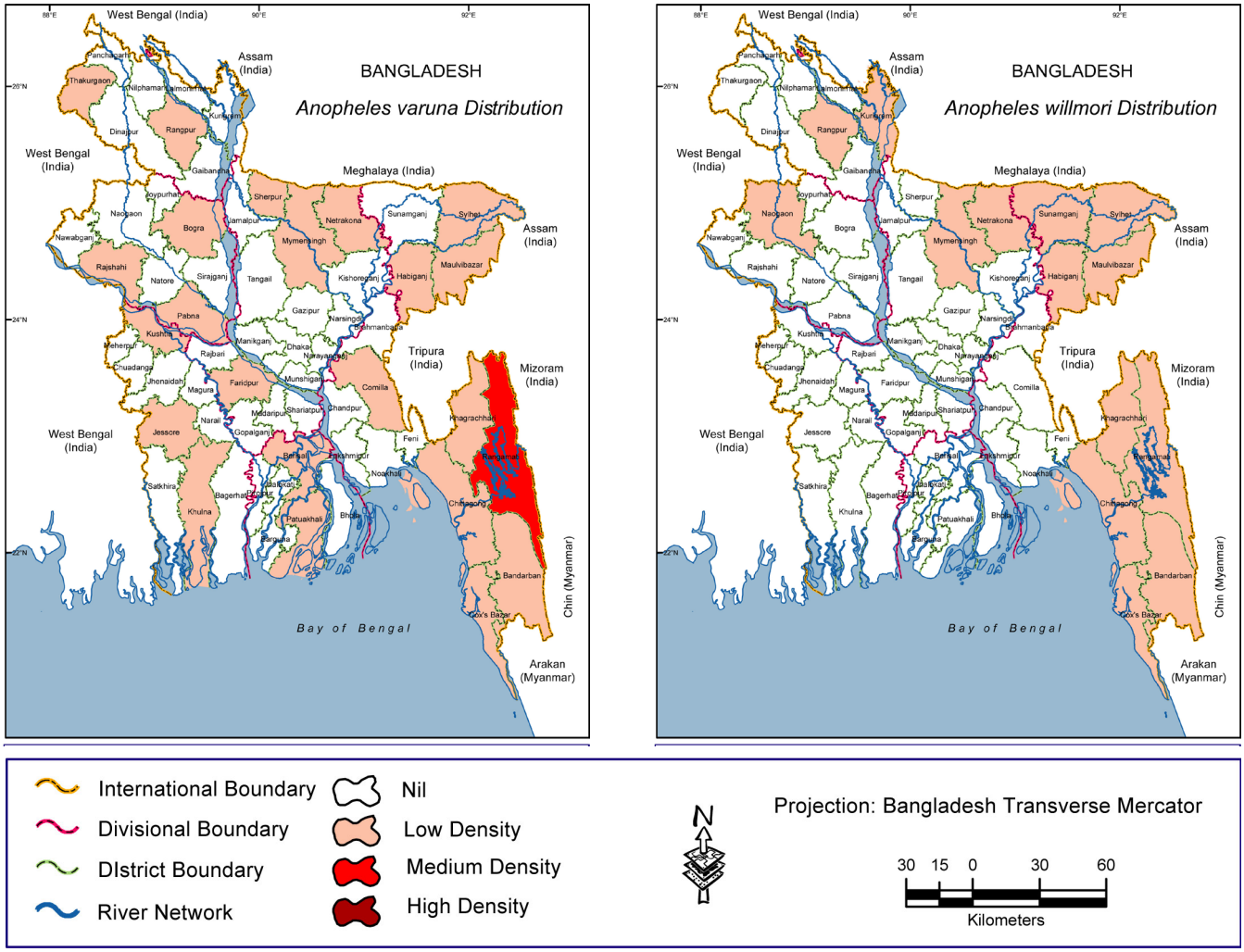

Figure 10. Distribution *An. varuna* and *An. willmori* in Bangladesh.

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