



POTENTIAL INVASIVE TERMITES IN INDIA AND IMPORTANCE OF INTEGRATIVE TAXONOMY

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ABSTRACT

Termites are ubiquitously abundant in the tropics and subtropics. Globally 28 species are considered invasive among the 2937 species in nine families known. Among the invasive species, most are considered nuisance organisms to humans in urban areas, and a few have invaded natural forests. Generally, the invasive termites share three qualities: (i) they eat wood, (ii) make nests in wood, and (iii) they quickly generate secondary reproductives. These qualities are the most common in the Kalotermitidae and Rhinotermitidae (Blattodea: Isoptera), which enhance their opportunities for producing viable and reproductively capable individuals. Species of the Termitidae cannot produce secondary reproductives, and this is attributed as a reason for their lack of invasiveness. The 28 species recognized as strongly invasive have the potential to widen their geographical range from their present distribution locations. According to available data, 10 out of the 17 recognized invasive species have expanded their area of occurrence since 1969. Among the 28, three are known in India, although their exact distribution data in the Indian subcontinent, the damage they inflict, and consequent economic loss are yet to be worked out in detail. Climate change, intensifying urbanization, and globalization, acting either individually or in combination, are likely to exacerbate ecological and economic effects. Strict quarantine measures and appropriate treatment of every wood material imported are imperative. Efforts have been made to list the potential invasive termites in India based on imported-wood material. Approximately 70 species reported in the GenBank database for about 300 species known from India, emphasizing a dire need for accurate morphological and molecular determinations. Gene sequences of some of the Indian termite species submitted are incorrectly identified, as their presence and distribution in India is doubtful. Therefore, in this article, I discuss the importance of the combined and efficient use of morphological and molecular taxonomy in determining termites in India.

Keywords: Identification, Kalotermitidae, Rhinotermitidae, traded commodity, woodeating, nest constructing, places of origin, invasives, number, Indian perspectives, NCBI accessions, threats to biodiversity

Exotic species invasion is one among the many of the world's serious environmental threats (Buczowski and Bertelsmeier, 2017). Although growing human population and their injudicious actions are the critical reasons for climate change and urbanization, invasions by exotic species can be traced back to mobility of humans and movement of products to meet human needs. Huge numbers of exotic, pestiferous insects are moving from continent to continent as a result of globalization and trade, resulting in substantial economic loss (Sharma et al., 2018). In the last decade, various invasive insects are known from India and have been found to be establishing in 'new' habitats (Kalleshwaraswamy et al., 2015; Sharanabasappa et al., 2018; Sundararaj et al., 2020) and termites are no exception (Evans et al., 2013). Many species of termites are serious nuisance organisms, inflicting damage to the wood used in both human-made

structures and agricultural and forest environments (Kalleshwaraswamy et al., 2018). They occur more abundantly in the tropical and subtropical regions of the world. We now know that the Isoptera have evolved from the subsocial Cryptocercidae (Blattodea: Blattoidea) (Inward et al., 2007; Evangelista, 2019). Hence, the termites are now classified under Isoptera, Epifamily Termitoidae within Blattodea. However, the family status of all extant termites is retained to avoid confusion arising out of this modified classification. About 3000 species of Isoptera were described from nine families in 2013 (Krishna et al., 2013) and from then onwards, a few new species have been added from different parts of the world. Among them, 1160 species are from the Oriental region. Two hundred and ninety-five species placed under 52 genera in six families are known from India. Among the 295, 188 are endemic to India (Rajamohana et al., 2019). Out

of *c.* 3000 species known around the globe, 366 affect human dwellings in different parts of the world. Yet, we need to recognize that these taxa are one among the many critical invertebrate decomposers in arid and semi-arid environments, and they contribute to improving the physical and chemical properties of soil by their activities and especially by the construction of structures such as mounds, galleries, sheetings with varying physical and chemical qualities (Jouquet et al., 2018). On an average, the termites increase water infiltration above the natural rate by a factor of 1 to 4, depending on their activity, soil type, and rainfall intensity (Kaiser et al., 2017).

Diverged from cockroaches (Cryptocercidae : Blattodea) *c.* 150 mya (late Jurassic), the termites developed advanced social nature and caste system, which their ancestors lacked. They live in colonies with a large number of workers and soldiers that are usually sterile. Colonies have fertile males, the 'kings', and one or more fertile females, the 'queens'. Pheromones maintain the caste system, preventing all but a few termites from becoming reproductives and the rest will remain sterile, assuring a division of labour (Simpson et al., 2011). Primary reproductives and secondary reproductives are the two types of reproductives found in the Isoptera. Nymphs give rise to adults, which mate and reproduce the primary reproductive, hemimetabolically. In some species, such as *Coptotermes*, when primary reproductives are either lost or immatures are separated from their parent colony, nymphs or workers (= pseudergates) can give rise to either a king or a queen, referred to as secondary reproductives (Myles, 1999).

With the increased trade of wood, more termites are becoming invasive in different countries; India is no exception. Therefore, anticipating this potential megaproblem strict policy measures are vitally necessary. In this article, I have made an effort to enumerate the potentially invasive termite species in India, based on wood import from different countries, especially in the recent past. Monitoring and treatment of wood material imported are critical to minimize entry of exotic Isoptera into India. Examples of success stories restricting the entry of nuisance species of Isoptera have also been highlighted in this article. The importance of both morphological and molecular taxonomy of Indian Isoptera for correct determination of taxa enabling better management is also indicated.

A. Characteristics of invasive termites

Although various termite species are considered

nuisance organisms of different crops (Rana et al., 2021), forest (Junqueira and Florencio, 2018) and urban ecosystems (Olaniyan et al., 2015), all of these are not invasive. Most of the invasive Isoptera have three qualities in common: (i) they eat wood, (ii) construct nests in the wood, and (iii) quickly generate secondary reproductives (Evans et al., 2013; Donovan et al., 2001). Many a time, in combination of the above, the termites have an increased likelihood of producing reproductively viable offspring. These qualities are especially common in the Kalotermitidae and Rhinotermitidae, which collectively constitute 23 species in the invasive termites list, in genera such as *Cryptotermes*, *Heterotermes*, and *Coptotermes* (19 species) (Table 1). The Termitidae comprising *c.* 70% of the Isoptera, includes only one invasive species, *Nasutitermes corniger*. The innate characters that make this species invasive need to be studied.

(i) Wood eating

In general, four types of food habits occur among the Isoptera (Donovon et al., 2001; Yamada et al., 2007; Jones and Eggleton, 2000; Kaur et al., 2013; Kaur et al., 2017). Type I and II eat undecomposed plant matter such as wood, grass, and leaf litter. Those of type III and IV eat decomposed plant matter; those of type III eat on the decomposing wood either covered with or embedded within soil (plant matter–soil interface), whereas those of type IV are exclusive soil feeders. Those of types III and IV make up *c.* 50% of all Isoptera. Wood eating is a common characteristic among the known invasives, that means they belong to either Type I or Type II.

(ii) Nest constructing

Nest construction is classified into four categories (Abe, 1987):

Single-piece nesters: Isoptera of this category nest and forage in either one piece of wood or wood pieces bound tightly together and feed within: *e.g.*, species of *Cryptotermes* (Kalotermitidae) and Archotermopsidae

Intermediate-piece nesters: Colonize a single piece of wood, but they move out searching food material and eat pieces of wood, where they construct nests and start new nests once the originally occupied piece of wood is completely eaten: *e.g.*, species of *Coptotermes* (Rhinotermitidae).

Separate-piece nesters: build a nest in soil or nest separate from their food and forage away from their nest to find food: *e.g.*, mound-building Macrotermitinae (Termitidae).

Continuously mobile (no permanent nest): Do not settle in a nest permanently and are mobile continuously. Found among the Type III and IV soil-feeders that eat their way through the soil.

A majority of the invasive species are either single-piece nesters (12— Archotermopsidae and Kalotermitidae) or intermediate-piece nesters (Rhinotermitidae) (Table 1). The possible reason is either presence of all the castes within the nest or the ability to produce viable secondary reproductives (explained in the following paragraph).

(iii) Can generate secondary reproductive

If the nymphs or workers develop as reproductives, they are collectively referred as the nymphoids and ergatoids, respectively. Here sexual maturity is achieved without attaining a fully winged adult stage, and hence they are 'secondary reproductives'. There may be a situation when an infested wood log is transported, a small number of nymphs may be carried from their original habitat, there is a chance that secondary reproductives produced from those nymphs in a new habitat, making that species invasive. These few nymphs carried from the infested material could act as propagules. Because of this trait, many termite species are potential invaders in new habitats even though primary reproductives are not transported.

B. Number of invasive termite species

Termites were not thought to be invasive previously, despite accounts of their spread away from their native ranges. A first worldwide enumeration by Gay published in 1969 recorded 17 species of termites as invasive with the evidence of their establishment in new habitats. All the 17 determined species appear to be associated with either buildings or cultivated crops. Presently 28 species of termites are considered invasive worldwide, (Evans et al., 2013). This implies that the numbers of invasive species have increased from 17 in 1969 to 28 today and are expanding their geographic locations. In the past 50 years, 14 species have been added to the list; 10 of them have extensive distributions and four have no reported changes in distribution, and three species are no more considered invasive (Evans et al., 2013). It appears among the invasive termite species, most are pestiferous in urban areas, although six species have been found to invade natural forests (Evans et al., 2013; Chouvenec et al., 2016).

C. Transportation of live stages of termites

Most wood feeding termites (Kalotermitidae,

Rhinotermitidae and Archotermopsidae) display the above-said three qualities and they can be transported from their original habitats to new habitats through the movement of wood. Many countries export wood and wooden material to different parts of the world. If the transported wood includes any developmental stage of the Isoptera, then they serve as propagules and become secondary reproductives (Evans, 2011; Myles, 1999). A recent report with dead stages of *C. gestroi* in the seaport of Goa (15.50° N, 73.83° E) (Venkateshan et al, 2021) from an imported wood consignment sends an alarm signal and seeks a close monitoring of the invasive Isoptera. Species-rich Termitidae cannot produce secondary reproductive, hence they lack the invasive capability.

D. Places of origin and continents invaded

Initial reports of termite invasion were mainly restricted to movement of Isoptera from continents to nearby islands (Gay, 1969). This is attributed to free trade of wood products. However, the reverse could be true, since species such as *Cryptotermes brevis* and *C. formosanus*, have reached the coast of Queensland, Australia, and Hawaii (USA) in the North Pacific Ocean and have invaded inland as well (Constantino, 2002; Austin et al., 2006; Jenkins et al., 2001). Among the 28 invasive species known to date a perusal of subcontinents or land mass from which the invasive species originated, Indo-Malayan region includes a maximum of seven species, indicating many endemic species have moved from this region to different parts of the world (Table 1). This is followed by South America (six), Australia (five), Africa (three), North America (two), the Caribbean Islands (one), East Asia (one), and Europe (one). *Heterotermes perfidus* and *Coptotermes truncatus* are of unknown origin.

Similarly, a perusal of invaded subcontinents indicates that the islands of the Pacific Ocean are the most invaded that include 13 species, followed by the Caribbean islands (nine), North America (eight), Indian Ocean (six), South America (five), Australia (four), Atlantic Ocean islands (four), East Asia (three), Africa (three), South and Southeast Asia (two), and Europe (one) (Evans et al., 2013). Coastal regions are more prone to invasion by the Isoptera and inflict damage to built-structures consisting of wood and crop ecosystems (Ferreira et al., 2013; Szalanski., 2004). The probable reason for this pattern is that the wood is mostly imported through sea-routes and the invasive Termitidae first establish themselves in coastal areas, and then propagate inwards.

Table 1. Invasive Isoptera, their country or bioregion of origin, and the country or continent invaded

Name of the species	Family	Native country or bioregion	Country or continent invaded and (probable year of invasion)	References
<i>Mastotermes darwiniensis</i>	Mastotermitidae	Northern Australia	Papua New Guinea (before 1959)	Gray, 1968; Thistleton et al., 2007
<i>Zootermopsis angusticollis</i>	Archotermitidae	Western North America	Hawaii (1999)	Haverty et al., 2000; Grace et al., 2002
<i>Zootermopsis nevadensis</i>	Archotermitidae	Western North America	Kawanishi, Japan (2000)	Kiritani and Morimoto, 2004
<i>Porotermes adamsoni</i>	Stolotermitidae	Southeast Australia	New Zealand 1941	Bain and Jenkins, 1983; Phillip et al., 2008
<i>Incisitermes immigrans</i>	Kalotermitidae	Pacific coast of Panama to Peru	Pacific Islands, Polynesia, Hawaii, Japan (1995)	Gay, 1969; Constantino, 1998; Grace et al., 2002; Kiritani and Morimoto, 2004
<i>Incisitermes minor</i>	Kalotermitidae	Southwestern United States and northern Mexico	Japan (1975), Eastern United States (1995); Toronto Canada (1989), Ninghai, Zhejiang Province, China (1937), Hawaii (1999)	Grace et al., 1991; Scheffrahn et al., 2001; Xie et al., 2001; Grace et al., 2002
<i>Kalotermes banksiae</i>	Kalotermitidae	Southeast coast of Australia	New Zealand (1942)	Bain and Jenkins, 1983
<i>Glyptotermes brevicornis</i>	Kalotermitidae	Southeast coast of Australia	New Zealand (Pre 1983), Fiji (pre 1942)	Gay, 1969; Bain and Jenkins, 1983; Evenhuis, 2007
<i>Cryptotermes brevis</i>	Kalotermitidae	Coastal deserts of Peru and Chile	Egypt, Queensland, Australia (\approx 1941), Azores (2002), Canary Island, Lisbon, Portugal (87)	Peters, 1990; Borges et al., 2007; Scheffrahn et al., 2009; Nunes et al., 2010; Ferreira et al., 2013
<i>Cryptotermes cynocephalus</i>	Kalotermitidae	Philippines	Throughout Southeast Asia, Australia (before 1942), Hawaii (2000), Sri Lanka	Gay and Watson, 1982; Scheffrahn et al., 2000; Hemachandra et al., 2012
<i>Cryptotermes domesticus</i>	Kalotermitidae	Southeast Asia	China, Australia (before 1942), Panama in Central America	Gay and Watson, 1982; Evans, 2010
<i>Cryptotermes dudleyi</i>	Kalotermitidae	Southeast Asia	India (Orissa in Lower Bengal) and Bangladesh (before 1950), East Africa, northern Australia (before 1942), Caribbean islands (Jamaica and Trinidad), South America (Panama, Costa Rica, Colombia and Brazil)	Williams, 1976; Gay and Watson, 1982; Constantino, 1998; Scheffrahn and Krecek, 1999; Constantino, 2002; Schabel 2006
<i>Cryptotermes havilandi</i>	Kalotermitidae	Tropical West Africa	Caribbean Islands, Brazil, East Africa, Tanzania, Indian Ocean (Madagascar), India and Bangladesh	Maiti, 1983; Bose, 1984; Constantino, 1998; Scheffrahn and Krecek, 1999; Schabel 2006; Scheffrahn et al., 2009
<i>Heterotermes convexinotatus</i>	Rhinotermitidae	South America, from Mexico to Argentina	Greater (Hispaniola and Puerto Rico) and Lesser Antilles (Antigua, Barbados etc) and in Gal'apagos	Peck, 2001; Szalanski, 2004
<i>Heterotermes perfidus*</i>	Rhinotermitidae	Unknown origin	south Atlantic Ocean	-
<i>Heterotermes philippinensis</i>	Rhinotermitidae	Philippines	Madagascar and Mauritius	Cachan, 1949
<i>Heterotermes tenuis</i>	Rhinotermitidae	Central America	Lesser Antilles; Trinidad and Tobago	Szalanski, 2004

(contd.)

<i>Heterotermes</i> sp.	Rhinotermitidae	Probably Caribbean Island	Miami, Florida	Szalanski, 2004
<i>Reticulitermes flavipes</i>	Rhinotermitidae	Eastern United States	Canada, Bahamas (1998), Europe (Vienna- 1837), Germany (before 1937),and Southwestern France (before 1840), South America (Uruguay -1960), Chile (1986)	Grace et al., 1991; Scheffrahn et al., 1999; Dronnet et al., 2005; Austin et al., 2005; Su et al., 2006
<i>Reticulitermes grassei</i>	Rhinotermitidae	Southwestern Europe (France and Spain)	Britain (Saunton, 1994), Faial Island of the Azores (2000)	Jenkins et al., 2001; DeHeer et al., 2005
<i>Coptotermes acinaciformis</i>	Rhinotermitidae	Australia	Auckland and New Plymouth, New Zealand (1930), Suva, Fiji (1939)	Phillip et al., 2008;
<i>Coptotermes curvignathus</i>	Rhinotermitidae	Southeast Asia	Southern China	Xie et al., 2001
<i>Coptotermes formosanus**</i>	Rhinotermitidae	Southern China and Taiwan	Continental United States (≈ 1950s), Japan (1700), Hawaii (1907), South Africa (1974)	King and Spink, 1969; Vargo et al., 2003; Sun et al., 2007
<i>Coptotermes frenchi</i>	Rhinotermitidae	Southern Australia	New Zealand	Miller, 1941
<i>Coptotermes gestroi</i>	Rhinotermitidae	Southeast Asia	Mauritius (1936), R'eunion Island (1957), Taiwan (2001), Hawaii (1963), Polynesia 1999) and Micronesia and Fiji (before 2009). Mexico (2000),Florida (1996), Greater Antilles and lesser Antilles (1937), India	Roonwal and Chhotani, 1965; Scheffrahn et al.,1994; Kirton and Brown, 2003; Tsai and Chen., 2003 ; Vargo et al., 2003; Scheffrahn and Su., 2005; Li et al., 2009
<i>Coptotermes sjostedti</i>	Rhinotermitidae	Tropical West Africa	Lesser Antilles (Guadeloupe Island, 1999)	Scheffrahn et al., 2005
<i>Coptotermes truncates*</i>	Rhinotermitidae	Unknown origin	Madagascar, Republic of Seychelles (1897)	-
<i>Nasutitermes corniger</i>	Termitidae	Central to South America and the Caribbean Islands	Abaco Island of the Bahamas, Florida (before 2001), New Guinea	Scheffrahn et al., 2005; Evans, 2010

*Not a valid species; **The establishment and spread of this species in the United States is the best-documented termite invasion

Buczkowski and Bertelsmeier (2017) employed two alternative representative concentration pathways (RCPs) to predict climate scenarios: RCP 4.5 and RCP 8.5, and two projection years (2050 and 2070 AD) to offer the first worldwide risk assessment for 13 of the world's most invasive termites. Representative concentration pathways (RCPs) are widely used to describe different climate future depending on the volume of greenhouse gases (GHG) emitted in the years to come and thereby predict population dynamics. Buczkowski and Bertelsmeier's findings reveal that, regardless of the climate or year, most of the species will have a substantial rise in their global spread by 2050 AD. The most appropriate places for invasion are the tropics and subtropics. All the continents have large land spaces and natural conditions suitable for more

than four species to coexist. Climate change, growing urbanization, and accelerating economic globalization, working singly or in concert, are anticipated to exacerbate the enormous economic and ecological damage caused by invasive termites.

E. Invasive termites: an Indian perspective

India, being one of the largest importers of wood and wood-related material, is vulnerable to Isoptera invasives. Its tropical and subtropical climates also support rapid multiplication of individuals after they arrive. Earlier *Cryptotermes dudleyi* (Kalotermitidae), *C. havilandi* (Kalotermitidae), and *C. gestroi* (Rhinotermitidae) were the invasives known in India. Among these, the taxonomic authenticity of *C. dudleyi* is confirmed presently. The incidence of

C. havilandi is questionable, in spite of its reported spread from India to Bangladesh (Maiti, 1983, Bose 1984). As per Krishna et al. (2013), a world authority on the Isoptera, it is distributed in West Africa (from Sierra Leone to Nigeria), Brazil, Trinidad, the Guianas, Barbados and other west-Indian Islands. Similarly, *C. gestroi*'s original locality is Myanmar (Wasmann, 1896) and its report in Assam (Roonwal and Chhotani, 1965) and in north-eastern Puducherry (Harit et al., 2014) needs validation by further collection and molecular determination. Not many serious efforts have been made to determine the taxonomic identity, distribution, and damage of these species in the Indian landscape. There is no NCBI sequence for this species submitted for specimens collected from India, which may offer a valid confirmation of its presence in India. Originally described from Myanmar, *C. gestroi* is considered to occur in north-eastern India and Thailand. This species inflicts serious economic losses by feeding on wood in built structures in other Asian countries, such as Malaysia, Taiwan, Indonesia and in Brazil, the Caribbean islands, and in the peninsular Florida, USA. *Coptotermes gestroi* is the predominant termite species attacking buildings in urban area of Taiwan (Sornnuwat, 1996). Up to 27% of the trees in the city of São Paulo, Brazil, found infesting contributed by four subterranean species of termites but *C. gestroi* (Wasmann) being the dominant species (Zorzenon and Campos, 2014). However, such a serious damage has not been reported from India and hence intensive surveys and data collection on damage by the Isoptera may shed light on its presence and its impact on the economy.

Venkateshan et al. (2021) offer substantial evidences of both morphological and molecular characters of *C. gestroi* collected from the wooden packing material of a consignment received in Goa coming from Harrisonburg, Virginia, USA. In another report made in December 2018, a few Isoptera were received for identification from Visakapatnam Plant Quarantine Station collected from the timber of *Maclora tinctoria* (Moraceae) imported from Guyana (South America). In July and September 2019, I received different specimens of Isoptera for determination intercepted from the wood of a species of *Gmelina* (Verbenaceae) in Tuticorin port (Tamil Nadu) imported from Columbia, *M. tinctoria* and a species of *Erythrophleum* (Fabaceae) wood logs from Suriname. Using morphological and molecular characters, the intercepted specimens were identified as *C. testaceus* and *C. sjöstedti*. *Coptotermes testaceus*'s 16S rRNA gene sequences were deposited with NCBI GenBank with accession numbers MK559590,

MK559591, MK559592, and MK559593. Whereas *C. sjöstedti* 16S rRNA gene got NCBI GenBank accession number MN540914 (Nagaraju et al., 2020). Such clarity is needed in taxonomy for identifying and reporting of any termites intercepted in India.

F. Potential invasive termites in India

The spatial spread of Termitidae is increasing due to trade, urbanization, and climate change (Buczowski and Bertelsmeier, 2017). Extrapolating this scenario, India could be invaded by another 8-10 species by 2050 AD as predicted in the RCP 4.5 scenario, indicating a greater risk and potential damage to urban and agricultural ecosystems. India imports timber from South America, Africa, southeast Asia and from the Caribbean Island nations as evident in the data of non-compliance report of pest interceptions (Directorate of Plant Protection, Quarantine & Storage website, updated monthly <http://plantquarantineindia.nic.in/PQISPub/html/ncrep.htm> (accessed on 10 December 2021). There is a need for a thorough scrutiny of every wooden log imported into India. The countries mentioned have a high diversity of invasive Isoptera, which have the potential to enter and cause serious ecological and economic damage in India (Table 2). A list of potential invasive species from where wooden logs were imported into India in 2019 is presented in Table 2. This list is not comprehensive but will serve as a base for an early detection of species and to look for the possible entry of potentially damaging species from those countries.

G. Scope of integrative taxonomy

Because of their wide distribution and intraspecific character variations, taxonomic validity of many species of the Isoptera remains unclear. For example, *Coptotermes*, currently includes 69 named species, and among them, only 21 are considered valid (Chouvenc et al., 2016). According to Chouvenc et al. (2016), most of the described Chinese species of *Coptotermes* are invalid and need revision. Species identification in the Termitoidae is principally based on the measurement of different body parts of soldiers and hence intraspecific variation is highly possible. Hence adapting molecular taxonomy using more than one mitochondrial gene, such as mtCo1, 12S rRNA, and 16S rRNA and nuclear genes such as 28S rRNA, 18S rRNA may provide better clarity on valid species. There is a dire need to barcode all the morphologically identified Isoptera. Currently, barcode sequences are available only for approximately 70 Indian taxa, out of more than 300 species known. In this article, efforts have been to list the available NCBI

Table 2. Potential invasive Isoptera into India*

Country	Native or invasive species distributed at present
Brazil	<i>Nasutitermes corniger</i> , <i>Incisitermes immigrans</i> , <i>Cryptotermes havilandi</i> , <i>Cryptotermes brevis</i>
Cameroon	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i> , <i>Cryptotermes brevis</i>
Central African Republic	<i>Coptotermes sjostedti</i>
Colombia	<i>Heterotermes convexinotatus</i> , <i>Heterotermes tenuis</i>
Congo	<i>Cryptotermes havilandi</i>
Costa Rica	<i>Incisitermes immigrans</i> , <i>Nasutitermes corniger</i>
Ecuador	<i>Incisitermes immigrans</i> , <i>Nasutitermes corniger</i>
Equatorial Guinea	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i>
Ghana	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i>
Malaysia	<i>Coptotermes curvignathus</i> , <i>Coptotermes gestroi</i>
France	<i>Reticulitermes flavipes</i>
Guyana	<i>Nasutitermes corniger</i> , <i>Termes hispaniolae</i> , <i>Cryptotermes brevis</i>
Mexico	<i>Incisitermes minor</i> , <i>Heterotermes convexinotatus</i>
Papua New Guinea	<i>Mastotermes darwiniensis</i> , <i>Cryptotermes cynocephalus</i>
Suriname	<i>Nasutitermes corniger</i> , <i>Coptotermes testaceus</i>
Trinidad and Tobago	<i>Cryptotermes brevis</i> , <i>Cryptotermes domesticus</i> , <i>Cryptotermes dudleyi</i> , <i>Cryptotermes havilandi</i> , <i>Coptotermes testaceus</i> , <i>Heterotermes tenuis</i> , <i>Heterotermes convexinotatus</i> , <i>Nasutitermes corniger</i> , <i>Termes hispaniolae</i>
USA	<i>Cryptotermes brevis</i> , <i>Coptotermes formosanus</i> and <i>C. gestroi</i>
Benin	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i>
*Ecuador	<i>Heterotermes sp.</i>
Gabon	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i> , <i>Cryptotermes brevis</i>
Honduras	<i>Incisitermes immigrans</i> , <i>Nasutitermes corniger</i>
Indonesia	<i>Coptotermes curvignathus</i> , <i>Coptotermes gestroi</i>
Kenya	<i>Cryptotermes dudleyi</i>
New Zealand	<i>Cryptotermes brevis</i> , <i>Kaloterms banksiae</i> , <i>Coptotermes acinaciformis</i> , <i>Porotermes adamsoni</i> , <i>Glyptotermes brevicornis</i>
Nigeria	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i>
Panama	<i>Incisitermes immigrans</i> , <i>Nasutitermes corniger</i>
Philippines	<i>Heterotermes philippinensis</i> , <i>Cryptotermes cynocephalus</i> , <i>Cryptotermes havilandi</i>
Sri Lanka***	<i>Cryptotermes cynocephalus</i> , <i>Cryptotermes domesticus</i> , <i>Cryptotermes perforans</i> , <i>Coptotermes formosanus</i>
Sudan**	<i>Coptotermes sjostedti</i>
Panama	<i>Cryptotermes dudleyi</i> , <i>Cryptotermes domesticus</i>
South Africa	<i>Coptotermes formosanus</i> , <i>Cryptotermes brevis</i>
Suriname	<i>Nasutitermes corniger</i>
Togo	<i>Coptotermes sjostedti</i> , <i>Cryptotermes havilandi</i> , <i>Cryptotermes brevis</i>
Uruguay	<i>Reticulitermes flavipes</i>

*Based on Evans et al. (2013); *Dahlsjö et al., 2020; **Pears et al., 1995; *** Hemachandra et al., 2015

submissions so far made from India. Apparently, the genes targeted were 12s rRNA and 16s rRNA, that are not robust for species delimitation. A few submissions are with Mt COI and Mt COII used universally for molecular identification of insects. Moreover, there is a need of high-throughput mtCOI or mt COII DNA extraction procedure so as to determine valid species of the Isoptera. Vidyashree et al. (2018) successfully sequenced 12 Isoptera species from the Western Ghats and developed a DNA extraction procedure. However, they reported for 12S rRNA and hence there is a need of

standardization of preservation technique of collected termite specimens and storage for successful DNA extraction.

The following example may clarify the imperative need for molecular data in resolving taxonomic confusions in the Indian species of *Coptotermes*. A total of seven species are known from India (Rajamohana et al., 2019): *C. beckeri*, *C. ceylonicus*, *C. gauri*, *C. gestroi*, *C. heimi*, *C. kishori*, and *C. premarasmii*. Among these, the presence and distribution of *C. gestroi* and

Table 3. NCBI GenBank database available for Indian Isoptera

Species	Gene	NCBI GenBank accession number	Authors	Remarks
<i>Anacanthotermes viarum</i>	28S ribosomal RNA	JQ957910	Deivendran et al., 2012	
<i>Glyptotermes ceylonicus</i>	12S ribosomal RNA	MZ191059	Joseph and Mathew, 2021	
	mtCOII	MZ191060	Joseph and Mathew, 2021	
<i>Neotermes koshunensis</i>	12S ribosomal RNA	KM657485	Ramya et al., 2014	
<i>Neotermes nilumburensis</i>	16S ribosomal RNA	MZ234128	Kalleshwaraswamy et al., 2021	
<i>Neotermes viraktamathi</i>	16S ribosomal RNA	MW699667	Kalleshwaraswamy et al., 2021	
<i>Coptotermes gestroi</i>	16S ribosomal RNA	MZ540797	Ranjith et al., 2021	
	mtCOI	MW575256	Ashika and Venkatesan, 2021	
<i>Coptotermes heimi</i>		KT828711, KT828711 KT828710, KT828709 KU665478 KR078331 KT820660 EU553818 EU553816 AY558908 MW680951	Mahapatro and Singh., 2016	
	12S ribosomal RNA	GQ422885 GQ422882 EU553817	Mahapatro and Singh, 2015 Mahapatro and Singh, 2015 Sobti et al., 2008 Sobti et al., 2008 Scheffrahn et al., 2004 Kalleshwaraswamy et al., 2021	
	16S ribosomal RNA		Salunke et al., 2009 Salunke et al., 2009 Sobti et al., 2008	
	28S ribosomal RNA	JQ957911	Deivendran et al., 2012	
<i>Coptotermes sjoestedti</i>	16S ribosomal RNA	MN540914	Mahadeva swamy et al., 2019	
<i>Coptotermes testaceus</i>		MK559593 MK559592 MK559591 MK559590	Mahadeva Swamy et al., 2019 Mahadeva Swamy et al., 2019 Mahadeva Swamy et al., 2019 Mahadeva Swamy et al., 2019	
	16S ribosomal RNA			
<i>Coptotermes</i> sp.	mtCOII	MN913607	Tiwari et al., 2020	
<i>Heterotermes balwanthi</i>	16S ribosomal RNA	KU574658	Vidyashree et al., 2016	
<i>Heterotermes indicola</i>	12S ribosomal RNA	KT820657 KF170428 KF769546 KM077441	Mahapatro and Singh., 2016 Mahapatro and Kumar, 2013 Poonia and Sharma, 2013 Poonia and Sharma, 2014 Mahapatro, G.K. and Kumar, 2013	
	16S ribosomal RNA	HF968496 MZ183973 KF170427 KF769554	Kalleshwaraswamy et al., 2021 Mahapatro and Kumar, 2013 Poonia and Sharma, 2013	
<i>Heterotermes malabaricus</i>	16S ribosomal RNA	KU574645 MZ540855 MZ558168 OK285073	Vidyashree et al., 2016 Ranjith et al., 2021 Santhrupthi et al., 2021 Joseph and Mathew, 2021	
	mtCOII	OK284904	Joseph and Mathew, 2021	

(contd...)

Table 3 contd...

<i>Hypotermes makhamensis</i>	<i>Mt CoI</i>	KT898536 KT898532 KT898526 KT724954	Patel and Jadhav., 2015	This species is not reported from India (native to Thailand, Vietnam and Cambodia). Hence needs collection details and morphological authentication
	<i>Mt CoI</i>	KY614388	Murthy and Lubna., 2017	
<i>Hypotermes xenotermitis</i>	12S ribosomal RNA	KY825251 KU687341 KY293420 KT224387 KX646190 KU687340 KT898553 to KT898566 KT898535 to KT898551	Murthy and Lubna, 2017 Murthy et al., 2016 Murthy and Lubna, 2016 Murthy et al., 2016 Murthy et al., 2016 Murthy et al., 2016	As per the authors, specimens were collected from south India. This species is not reported from south India (reported only from North India). Needs morphological authenticity and morphometry data.
	mtCOI	KT898527 to KT898531 KT898507 to KT898525 KT887698 to KT887717 16.KT879833 to KT879849 KT879830, KT724955, KT898533	Patel and Jadhav, 2015	
<i>Macrotermes convulsionarius</i>	16S ribosomal RNA gene	MZ540857	Ranjith et al., 2021	
	28S ribosomal RNA	JQ957912	Deivendran et al., 2012	
<i>Microtermes incertoides</i>	16S ribosomal RNA	MZ571483	Ranjith et al., 2021	
	12S ribosomal RNA	KU665477 KP765715 KP748241 KF769547	Mahapatro and Singh, 2016 Mahapatro and Singh, 2015 Mahapatro and Singh, 2015 Poonia and Sharma, 2013	
16S ribosomal RNA		KT820658 KM657479 JX263668 JX045651 EU553821 EU553819 KF769555 EU553822 EU553820	Mahapatro and Singh, 2015 Ramya et al., 2014 Singla et al., 2012 Singla et al., 2012 Sobti et al., 2008 Sobti et al., 2008 Poonia and Sharma, 2013 Sobti et al., 2008 Sobti et al., 2008	
	<i>Microtermes obesi</i>	12S ribosomal RNA	EU551158 KM657488 KT820661 MZ558085	Sobti et al., 2008 Ramya et al., 2015 Mahapatro and Singh, 2015 Santhrupthi et al., 2021
16S ribosomal RNA		EU306616 KU574654	Sobti et al., 2007 Vidyashree et al., 2016	
	mtCOI	EU242522 EU306614	Sobti et al., 2007	
	mtND1	EU306613 EU306615	Sobti et al., 2007	

(contd...)

Table 3 contd...

<i>Microtermes unicolor</i>	12S ribosomal RNA	JX263667	Singla et al., 2012	
<i>Microtermes</i> sp.	ITS-2	KX495579	Murthy et al., 2016	
	16S ribosomal RNA	KM275840	Poonia and Sharma, 2014	
	12S ribosomal RNA	KF703855	Poonia and Sharma, 2013	
<i>Odontotermes anamallensis</i>	16S ribosomal RNA	MZ562513	Santhrupthi et al., 2021	
<i>Odontotermes assmuthi</i>	16S ribosomal RNA	KF769556 KU574651 MZ558070	Poonia and Sharma, 2013 Vidyashree et al., 2016 Santhrupthi et al., 2021	
	28S ribosomal RNA	JF792835 FJ966379	Deivendran and Suresh, 2011 Suresh et al., 2009	
<i>Odontotermes bellahuniensis</i>	16S ribosomal RNA	KU574650	Vidyashree et al., 2016	
<i>Odontotermes bhagwati</i>	12S ribosomal RNA	KF769552 KM523663 KM523662 EU551161 KF769559	Poonia and Sharma, 2013 Ramya et al., 2014 Ramya et al., 2014 Sobti et al., 2008 Poonia and Sharma, 2013	
	16S ribosomal RNA	EU258632 EU258631	Kumari et al., 2007 Kumari et al., 2007	
	mtCOII	EU242525	Sobti et al., 2008	
	mtND1	EU262586 EU262585 EU262587	Sobti et al., 2007 Sobti et al., 2007 Sobti et al., 2008	
<i>Odontotermes boveni</i>	16S ribosomal RNA	MZ344981	Kalleshwaraswamy et al., 2021	
<i>Odontotermes brunneus</i>	12S ribosomal RNA	KT820659	Mahapatro and Singh., 2016	
	16S ribosomal RNA	KF792982 MZ540811	Poonia and Sharma., 2017 Ranjith et al., 2021	
	28S ribosomal RNA	JF792836	Deivendran and Suresh, 2011	
	12S ribosomal RNA	KF769549 JX263664	Poonia and Sharma, 2013 Singla et al., 20012	
<i>Odontotermes ceylonicus</i>	12S ribosomal RNA	KY908410	Murthy et al., 2017	
<i>Odontotermes escherichi</i>	12S ribosomal RNA	KY495155	Murthy and Lubna., 2017	Not reported from India (recorded only from Sri Lanka). Needs morphological authenticity
	mtCOI	KT224389 KY495154 KU947966	Murthy et al., 2015 Murthy and Lubna., 2017 Mahapatro and Singh, 2016	
<i>Odontotermes feae</i>	12S ribosomal RNA	KY908402 KY676779 KY908403 KR296660	Murthy et al., 2017 Murthy and Lubna, 2017 Murthy et al., 2018 Mahapatro et al., 2015	
	16S ribosomal RNA	KU574649	Vidyashree et al., 2016	
<i>Odontotermes gurdaspurensis</i>	12S ribosomal RNA	KM523667 KM523664	Ramya et al., 2015	

(contd...)

Table 3 contd...

<i>Odontotermes horni</i>	12S ribosomal RNA	EU551159	Sobti, et al., 2008		
		GQ422892	Salunke et al., 2009		
		GQ422890	Salunke et al., 2009		
		GQ422889	Salunke et al., 2009		
	16S ribosomal RNA	GQ422888	Salunke et al., 2009		
		GQ422887	Salunke et al., 2009		
		GQ422886	Salunke et al., 2009		
		GQ422879	Salunke et al., 2009		
		EU258629	Kumari et al., 2007		
		KU574646	Vidyashree et al., 2016		
EU258630	Sobti et al., 2007				
28S ribosomal RNA	JF792837	Deivendran and Suresh, 2011			
mtCOII	EU242523	Sobti, et al., 2007			
<i>Odontotermes obesus</i>	12S ribosomal RNA	KY908407	Murthy et al., 2017		
		KP410731	Mahapatro et al., 2015		
		EU551160	Sobti et al., 2008		
	16S ribosomal RNA	KU574648	Vidyashree et al., 2016		
		MZ423304	Kalleshwaraswamy et al., 2021		
	mtCOI	MN511317	Amina et al., 2019		
		KY474376	Murthy and Lubna, 2007		
mtCOII	MZ823814	Ranjith et al., 2021			
	EU242524	Sobti, et al., 2007			
<i>Odontotermes longignathus</i>	Mt CoI	EU262594	Sobti, et al., 2007		
		KY930907;	Murthy and Lubna., 2019	This species is not reported from India (native to south east Asia). Needs morphological authenticity	
	KY930908;				
KY775488					
12S ribosomal RNA gene	Mt CoI	KY495156;	Murthy and Lubna., 2017		
		KY563712			
		MN205551	Alina et al., 2019		
<i>Odontotermes parvidens</i>	12S ribosomal RNA	KF769551	Poonia and Sharma, 2013		
	16S ribosomal RNA	KF769558	Poonia and Sharma, 2013		
<i>Odontotermes redemanni</i>	12S ribosomal RNA	KF769553	Poonia and Sharma, 2013		
	16S ribosomal RNA	KU574647	Vidyashree et al., 2016		
<i>Odontotermes wallonensis</i>	28S ribosomal RNA	KF792983	Poonia and Sharma., 2017		
		JF792838	Deivendran et al., 2012		
<i>Odontotermes yadevi</i>	16S ribosomal RNA	KU574656,	Vidyashree et al., 2016		
		KU574655	Kalleshwaraswamy et al., 2021		
<i>Euhamitermes hamatus</i>	12S ribosomal RNA	MZ189521			
		KM657484	Ramya et al., 2015	Not reported from India (recorded only from Thailand, Malaysia, Singpur, Bangladesh). Needs morphological authenticity	
<i>Eurytermes buddha</i>	16S ribosomal RNA	MW678776	Kalleshwaraswamy et al., 2021		
	mtCOI	MW664866	Kalleshwaraswamy et al., 2021		

(contd...)

Table 3 contd...

<i>Ampouitermes wynaadensis</i>	12S ribosomal RNA	MZ044682 MZ044681	Kalleshwaraswamy et al., 2021 Kalleshwaraswamy et al., 2021	
<i>Grallatotermes niger</i>	16S ribosomal RNA	MZ262750	Kalleshwaraswamy et al., 2021	
<i>Nasutitermes anamalaiensis</i>	16S ribosomal RNA	KU574659 MW692352 MW694353	Vidyashree et al., 2016 Kalleshwaraswamy et al., 2021 Kalleshwaraswamy et al., 2021	
<i>Nasutitermes brunneus</i>	16S ribosomal RNA	MZ262702 MZ540856	Kalleshwaraswamy et al., 2021 Ranjith et al., 2021	
<i>Nasutitermes indicola</i>	16S ribosomal RNA	KU574660	Vidyashree et al., 2016	
<i>Nasutitermes kali</i>	16S ribosomal RNA	MZ262715	Kalleshwaraswamy et al., 2021	
<i>Nasutitermes octopilis</i>	12S ribosomal RNA gene	KM657478	Ramya et al., 2015	Not reported from India (recorded only from Africa-Guyana). Needs morphological authenticity
<i>Trinervitermes biformis</i>	16S ribosomal RNA	KU574657 MZ558074	Vidyashree et al., 2016 Santhrupthi et al., 2021	
<i>Trinervitermes togoensis</i>	12S ribosomal RNA gene And MtCo1	KY569523 KX711183	Murthy and Lubna., 2017 Murthy et al., 2016	This species is not reported from India (native to Africa). Needs morphological authenticity.
<i>Amitermes belli</i>	12S ribosomal RNA	KR078330	Mahapatro and Singh., 2015	
	16S ribosomal RNA	MZ269706	Priya and Gupta, 2021	
<i>Angulitermes sp.</i>	12S ribosomal RNA	KP780274	Mahapatro and Singh, 2015	
<i>Dicuspiditermes achankovili</i>	mtCOI	MT272760 MT272755 MT272750	Amina et al., 2020 Amina et al., 2020 Amina et al., 2020	
<i>Dicuspiditermes fontanellus</i>	16S ribosomal RNA	MZ270643	Kalleshwaraswamy et al., 2021	
<i>Dicuspiditermes graveleyi</i>	12S ribosomal RNA	MZ825163 MZ825164	Ranjith et al., 2021 Ranjith et al., 2021	
	16S ribosomal RNA	MZ270644 MZ823812	Kalleshwaraswamy et al., 2021 Ranjith et al., 2021	
<i>Dicuspiditermes obtusus</i>	16S ribosomal RNA	MZ270642	Kalleshwaraswamy et al., 2021	
<i>Homalotermes pilosus</i>	mtCOI	MT272758 MT272753 MT272747	Amina et al., 2020 Amina et al., 2020 Amina et al., 2020	
<i>Indocapritermes aruni</i>	mtCOI	MT272742	Amina et al., 2020	
<i>Krishnacapritermes thakuri</i>	mtCOI	MT272759 MN507713 to MN507729	Amina et al., 2020 Amina et al., 2019	
<i>Krishnacapritermes dineshan</i>	mtCOI	MN507708 to MN507712	Amina et al., 2019	

(contd...)

Table 3 contd...

<i>Labiocapritermes distortus</i>	16S ribosomal RNA	MZ558073	Santhrupthi et al., 2021	
		MT272756	Amina et al., 2020	
	mtCOI	MT272752	Amina et al., 2020	
		MT272744	Amina et al., 2020	
<i>Microcerotermes beelsoni</i>	12S ribosomal RNA	JX263665	Singla et al., 2012	
<i>Microcerotermes fletcheri</i>	16S ribosomal RNA	KU574652	Vidyashree et al., 2016	
<i>Microcerotermes pakistanicus</i>	16S ribosomal RNA	KU574653	Vidyashree et al., 2016	
		MZ414220	Kalleshwaraswamy et al., 2021	
<i>Pericapritermes topslipensis</i>		MZ427480	Kalleshwaraswamy et al., 2021	
		MT272762	Amina et al., 2020	
	mtCOI	MT272761	Amina et al., 2020	
		MT272749	Amina et al., 2020	
		MT272745	Amina et al., 2020	
<i>Procapritermes keralai</i>	mtCOI	MT272748	Amina et al., 2020	
		MT272757	Amina et al., 2020	
<i>Pseudocapritermes fletcheri</i>	16S ribosomal RNA	MW686909	Kalleshwaraswamy et al., 2021	
		MW687081	Kalleshwaraswamy et al., 2021	
		MT272754	Amina et al., 2020	
	mtCOI	MT272751	Amina et al., 2020	
		MT272746	Amina et al., 2020	
<i>Synhamitermes quadriceps</i>		MW672524	Kalleshwaraswamy et al., 2021	
	16S ribosomal RNA	MW680954	Kalleshwaraswamy et al., 2021	
<i>Neotermes koshunensis</i>	mtCOI	MW680303	Kalleshwaraswamy et al., 2021	
	12S ribosomal RNA gene	KM657485	Ramya et al., 2015	Not reported from India (recorded only from Japan). Needs morphological authenticity
<i>Rinacapritermes abundans</i>	mtCOI	MT274296	Amina et al. 2022	
<i>Rinacapritermes silvius</i>	mtCOI	MT274294	Amina et al. 2022	

C. travians are doubtful. Among the remaining five, taxonomic validity of *C. beckeri*, *C. ceylonicus* and *C. kishori* is uncertain, because they are possibly junior synonyms of *C. amanii*, *C. brunneus* and *C. kalshoveni* (Chouvenc et al., 2016). Among these, *C. amanii* is of African origin, *C. brunneus* is of Australian origin and *C. kalshoveni* is a serious nuisance organism in Indonesia and Malaysia. This example may throw light on the need for an integrated taxonomy of the Indian Isoptera. There is a greater need for extensive collection, morphological and molecular characterization of Indian Isoptera.

H. Threats to biodiversity

The ecological and economic importance of the Isoptera is extensive. The most positive environmental

relevance is their role as soil engineers. The most important negative relevance is their activity as nuisance organisms since they damage built structures and agricultural crops, a majority of them belonging to the Termitidae, Rhinotermitidae, and Kalotermitidae (Jouquet et al., 2018). In recent decades the tendency of expansion of the range of harmful Isoptera has led to an increase in economic damage.

Invasive termites spread with infested timbers and invade human environments, before spreading into natural ecosystems. A recent study utilized occurrence data and climate modeling to predict the potential habitats of *C. formosanus* and *C. gestroi* in Florida and demonstrated that future distribution projections for both species are influenced by urban development

and climate change (Buczowski and Bertelsmeier, 2017). Another negative outcome of increased Isoptera invasions is a potential increase in pesticide use in urban and natural landscapes. Although chemicals are hazardous to the environment, farmers and structural engineers all over the world use them extensively for the management of agricultural pests and in structures. Termites are eusocial, live in nests constructed with well protected soil or many inches below the soil surface and move in galleries which themselves protected from outside threats hence management of termites with termiticides is a difficult task. However, some termiticides such as imidacloprid, chlorpyrifos, fipronil, spinosad, chlorfenapyre, bifenthrin, cypermethrin, permethrin, disodium octaborate tetrahydrate, calcium arsenate, lindane, endosulfan, and chlorantraniliprole have been used worldwide for the management of termites (Ahmad et al., 2019). Leaching of termiticide is toxic to non-target organisms, due to indirect accumulation, which simultaneously affects human population through food chains (Arias-Estévez et al., 2008).

The known 28 invasive species have the potential to expand in the range of distribution, just as 10 of the 17 known invasive species have expanded between 1969 and today (Table 1). The spatial spread of the invasive Isoptera is a consequence of a combination of intrinsic and extrinsic factors that shape the population dynamics of the involved species. Intrinsic factors include dispersal, growth, survival, and reproductive constraints dictated by the species' physiological capabilities. Extrinsic factors include factors such as the spatial and temporal availability of suitable habitat for survival, growth, and reproduction. Human-induced environmental changes, most notably climate change and urbanization, are likely to affect both intrinsic and extrinsic factors. For example, invasive termites have been shown to adapt their reproductive phenology in response to climate change. In parts of Florida, the dispersal flight season of *C. formosanus* and *C. gestroi* has begun to overlap due to changes in local climate. Mating pairs of heterospecific individuals were observed in the field with *C. gestroi* males preferentially engaging in mating with *C. formosanus* females rather than females of *C. gestroi*. This leads to hybridization between the two species and the potential evolution of highly destructive "super-termites" due to hybrid vigour (Chouvenc et al., 2016).

I. Management of invasive termites

In most cases of invasive Isoptera, attempts were

made to eradicate them applying synthetic pyrethroids and organochlorine insecticides, and by baiting. Baiting has been a successful tactic using area-wide management strategy. However, many attempts to eradicate the invasive Isoptera have proved futile (Bravey and Verkrek, 2010). Thus, only instances of successful management refer to those of *C. formosanus* in South Africa and *C. frenchi* in New Zealand (Chouvenc et al., 2016). Therefore, monitoring their entry and successful management are the viable options presently.

At the time of shipment, log fumigation must reduce the risk of introductions. It is possible to use a less environmentally harmful fumigant like sulfuryl fluoride. A strict policy for the importing country and strict monitoring of imported material could minimize the intrusion into a new geographical region, reducing both economic and ecological risks. Imported wood should be fumigated with methyl bromide @ 48g/m³ for 24 h to destroy infestation to avoid their entry (<https://plantquarantineindia.nic.in/> accessed on 10 December 2021). The treatment is as per the Plant Quarantine (Regulation of Import into India) Order, 2003 which regulates import and prohibition of import of plant and plant products into India and amended recently (S.O. 3686 (E), dated 9 September 2021). The treatment should be endorsed on Phytosanitary Certificate issued at the country of origin or re-export (<https://plantquarantineindia.nic.in/> accessed on 10 December 2021).

CONCLUSIONS

Tropical, subtropical conditions of India are highly congenial for the rapid multiplication of termites. If any species is introduced accidentally, there is every chance of successful establishment. Hence monitoring, observation, reporting their identity and intervention to avoid the establishment is the need of the hour. Training and recruiting taxonomists with a centralized diagnostic centre is one possible solution to strengthen the activity of the quarantine stations.

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