Sap Beetles of Northeast India

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Systematics, Bionomics and Ecological Services

By

Jhikmik Dasgupta, Tarun Kumar Pal and V.D. Hegde

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Introduction and Background

As the threat of extinction has become more apparent in our changing world, biologists have recognized the urgency of studying various species before many are lost due to increasing threats to biodiversity. Insects, being the largest group in the animal kingdom, require special attention, particularly the beetles. Among the Coleoptera, the largest order within Class Insecta, the Nitidulidae family holds a significant position due to its structural and behavioral diversity.

The family Nitidulidae is part of the recently classified superfamily Nitiduloidea by Cai et al., 2022 (formerly placed in the superfamily Cucujoidea) and belongs to the suborder Polyphaga within Coleoptera. Commonly referred to as 'sap beetles' or 'pollen beetles,' they are also known by other names, such as 'picnic beetles,' 'dried fruit beetles,' and 'small hive beetles.' Nitidulid beetles exhibit a range of forms and sizes, measuring between 0.9 to 15.0 mm in length. Typically, they are oblong to ovate in shape, though some may be elongate and parallel-sided. They can be strongly convex or somewhat flattened, with colors ranging from brown or blackish to occasionally bicolored; they are predominantly covered with punctate pubescence, and some are rarely glabrous.

Due to their similar appearances, some nitidulids may be mistaken for members of other beetle families, such as Staphylinidae, Monotomidae, Histeridae, and Mycetophagidae. Representatives of the Nitidulidae family are characterized by a distinctive 3-segmented antennal club, with the exception of the subfamily Calonecrinae, which has a single-segmented antennal club. They lack a fronto-clypeal suture on the head and have a bilobed labrum, except for the genus *Brachypeplus*, where the labrum is not lobed. Their maxilla features a single lobe (only the lacinia), while the coxal trochantins are well exposed. The tibiae are often expanded at the apex and may be serrate or spinose. The elytra can be truncate or, in some cases, complete. The tarsi have a 5-5-5 configuration, with tarsomeres 1–3 featuring expanded setose lobes.

Historical Review

Description of the species, erection of genera, formation of supra-generic assemblages, characterization and constitution of the family Nitidulidae, and drawing their relationship and lineage within the Coleoptera passed through changes with time. Latreille (1802) erected the family 'Nitidulaires' under the order 'Coléoptères' and included 7 genera namely, *Dacné* Latreille, *Ips* Fabricius, *Thymale* Latreille, *Nitidule* Latreille, *Byture* Latreille, *Cerque* Latreille, and *Proteine* Latreille in two supra-generic divisions namely, 'Ips' and 'Nitidulides' within the aforesaid family. Latreille (1807) proposed three suprageneric categories under Nitidulaires namely, 'Peltides', 'Nitidulariae propriae', and 'Ipsides'. He (op. cit.) grouped several genera namely, *Thymalus* Latreille, *Colobicus* Latreille, *Nitidula* Latreille, *Cercus* Latreille, *Byturus* Latreille, *Dacne* Latreille, *Ips* Fabricius under these three categories. The genera under the above categories appear to be, in many cases, unrelated or distantly related. Gyllenhal (1808) placed 11 genera under family 'Nitidulariae' namely, *Engis* Fabricius, *Triplax* Fabricius, *Tritoma* Latreille, *Ips* Fabricius, *Nitidula* Latreille, *Catheretes* Gyllenhal, *Peltis* Fabricius, *Necrophorus* Latreille, *Silpha* Latreille, *Catops* Fabricius and *Sarrotrium* Illiger. Sahlberg (1820) included 11 genera namely, *Engis* Fabricius, *Triplax* Fabricius, *Tritoma* Latreille, *Ips* Fabricius, *Nitidula* Latreille, *Cateretes* Gyllenhal, *Peltis* Fabricius, *Necrophorus* Latreille, *Silpha* Latreille, *Catops* Fabricius, and *Sarrotrium* Illiger under 'Nitidulariae'. Zetterstedt (1828 and 1838) included 10 genera namely, *Engis* Fabricius, *Triplax* Fabricius, *Tritoma* Latreille, *Ips* Fabricius, *Nitidula* Latreille, *Cercus* Latreille, *Catops* Fabricius, *Peltis* Fabricius, *Silpha* Latreille and *Necrophorus* Latreille under family 'Nitidulariae'. Stephens (1830) included 9 genera under the family 'Nitidulidae'. Erichson (1842) erected a genus, '*Brachypeplus'* under the family Nitidulariae. Erichson (1843) divided the Family Nitidulariae into 6 groups namely 'Cateretes', 'Carpophilinae', 'Nitidulinae', Strongylinae', 'Ipinae', and 'Trogositinae' and included 42 genera under these groups. Erichson (1845) re-divided the family Nitidulariae into 6 groups namely, 'Brachypterinae', 'Carpophilinae', 'Nitidulinae', 'Strongylinae', 'Ipinae', and 'Peltides'. Fairmaire (1849) recorded two species of *Carpophilus* Stephens, and one species each of *Epuraea* Erichson, *Nitidula* Laterille, *Omosita* Erichson, and three species of *Dermestes* Linnaeus under ‘Clavicornes’ from Polynesia. Lacordaire (1854) divided the family ‘Nitidulaires’ into 6 tribes namely, ‘Brachypterides’, ‘Carpophilides’, ‘Nitidulides’, ‘Cychramides’, ‘Ipides’ and ‘Rhizophagides’. Jacquelin du Val (1858) divided Nitidulidae into 6 groups namely, ‘Brachypterites’, ‘Carpophilites’, ‘Nitidulites’, ‘Cybocephalites’, ‘Ipites’, and ‘Rhizophagites’. Redtenbacher (1858) re-described the genera of family ‘Nitidulides’ of Austria and provided key to the species without dividing them into subfamilies or tribes. Gutfleish and Bose (1859) divided the family ‘Nitidulidae’ into 6 groups and included 12 genera under these groups. Thomson (1859) while dealing with Scandinavian beetles, divided the ‘Nitidulidae’ into 9 tribes namely, ‘Ipina’, ‘Rhyzophagina’, ‘Brachypterina’, ‘Meligethina’, ‘Nitidulina’, ‘Thalycrina’, ‘Cychramina’, ‘Cryptarchina’, and ‘Neodendrina’. Leconte (1861) divided the family ‘Nitidulidae’ into 6 tribes namely, ‘Brachypterini’, ‘Carpophilini’, ‘Nitidulini’, ‘Cychramini’, ‘Ipini’ and Rhizophagini’. The family Nitidulidae, by this time, was almost a dumping ground of many unrelated beetle genera in the assemblage. Murray (1864) made an excellent monographic work on the ‘Nitidulariae’, characterized their adults and larvae, and divided the family into 5 tribes comprising 26 genera. Gemminger and Harold (1868) in their ‘Catalogue of Coleoptera’ prepared a catalog of Nitidulidae based on the classification of Murray (1864) and included 791 species of nitidulids belonging to 80 genera. Reitter (1873) divided the family ‘Nitidulariae’ into 5 groups namely, ‘Ipidae’, ‘Brachypteridae’, ‘Carpophilidae’, ‘Nitidulidae’ and ‘Strongylinae’ and made certain nomenclatural changes to his earlier groupings. Reitter (1875b) divided the Nitidulariae into 5 groups namely, ‘Brachypterini’, ‘Carpophilini’, ‘Nitidulini’, ‘Strongylidae’, and ‘Ipinae’. Horn (1879) made a revisionary work of the nitidulids of the United States. Everts (1881) divided Nitidulidae into 4 groups namely, ‘Brachypterini’, ‘Carpophilini’, ‘Strongylini’ and ‘Nitidulini’. Reitter (1884) divided Nitidulidae into 7 divisions namely, ‘Brachypterini’, ‘Carpophilini’, ‘Nitidulini’, ‘Strongylini’, ‘Cryptarchini’, ‘Rhizophagini’ and ‘Monotomini’. Fowler (1884) divided the Nitidulidae into 6 tribes namely, ‘Brachypterina’, ‘Carpophilina’, ‘Nitidulina’, ‘Cychramina’, ‘Ipina’ and ‘Rhizophagina’. Marseul (1885) divided Nitidulidae into 6 tribes namely, ‘Brachypterini’, ‘Carpophili’, ‘Nitiduli’, ‘Cychrami’, ‘Ipsi’, and ‘Rhizophagi’. Leconte and Horn (1883) divided Nitidulidae into 8 groups namely, ‘Brachypterini’, ‘Carpophilini’, ‘Nitidulini’, ‘Cychramini’, ‘Ipini’, ‘Cybocephalini’, ‘Smicripini’, and ‘Rhizophagini’. Kraatz (1895) studied the Nitidulidae of Togo (Africa) and recorded 23 species under 12 genera. Everts (1898) divided Nitidulidae into 3 subfamilies and 9 tribes.

Sharp (1890) gave a comprehensive account of Nitidulidae of Central America, described many genera and species under it, and divided the family into 6 subfamilies, namely, 'Brachypterinae', 'Carpophilinae', 'Nitidulinae', 'Strongylinae', 'Cybocephalinae' and 'Ipsinae'. Ganglbauer (1899) divided Nitidulidae into 6 tribes namely, 'Cateretini', 'Carpophilini', 'Nitidulini', 'Cybocephalini', 'Cryptarchini', and 'Rhizophagini'. Fauvel (1903) recognized 3 tribes: 'Carpophilini', 'Nitidulini', and 'Pityophagini' under Nitidulidae. Grouvelle (1894-1908a) made notable contributions to the knowledge of Nitidulidae of the Indian Subcontinent, described several new genera and species, and till date, these comprise the most comprehensive taxonomic account of the Indian Nitidulidae. Blatchley (1910) divided the Nitidulidae into 7 tribes namely, 'Brachypterini', 'Carpophilini', 'Nitidulini', 'Cychramini', 'Ipini', 'Cybocephalini' and 'Rhyzophagini'. Reitter (1911) divided Nitidulidae into 3 subfamilies namely, 'Cybocephalinae', 'Nitidulinae', and 'Rhizophaginae'. Grouvelle (1913a) published a world catalog of Nitidulidae where he divided the family into 6 subfamilies and 157 genera. Chatterjee (1924) published a catalog of the nitidulid beetles of India. Parsons (1943) gave a comprehensive account of the Nearctic Nitidulidae and described many species. Rebmann (1944) described two genera of Nitidulidae from China namely, *Osotima* and *Meligethopsis*. Hinton (1945) while dealing with beetles infesting stored grain products, redescribed many nitidulid species. Méquignon (1954) studied the genus *Epuraea* of France. Crowson (1955) divided Nitidulidae into 5 subfamilies namely, Cateretinae, Cybocephalinae, Cryptarchinae, Carpophilinae, and Nitidulinae. Dobson (1955) while dealing with the stored grain pests of *Carpophilus* Stephens, recorded 16 species, re-described a few species, and provided details about their host plants. Dobson (1956) described a species under *Carpophilus*. Hisamatsu (1961) described four species of Nitidulidae from Japan. In 1963, Hisamatsu differentiated the nitidulid species, *Carpophilus hemipterus* from other allied species. Gillogly (1962) studied the nitidulids of Micronesia and described several species. Jelínek (1965) studied the nitidulid genera *Ipidia* Erichson and *Stelidota* Erichson of the Palaearctic region. Spornraft (1967) gave an account of the Nitidulidae of Middle Europe. In 1969, Gillogly dealt with the nitidulids of the Philippine and Bismarck islands. Parsons (1972) made an account of the nitidulid genus *Amphicrossus* and differentiated a few nitidulid genera based on features of their mesosternum. Jelinek (1974–2001) described several species and genera from the Indian subcontinent and provided a systematic account of the genus *Stelidota* Er. from Asia. Kirejtshuk (1979–1980a and 1980b) described several species of the subfamily Meligethinae from Asia and Ethiopia. Endrody-Younga (1982) recorded 18 species of Nitidulidae from the Mascarene archipelago, in the Indian Ocean, near Madagascar; 5 species of Nitidulidae from Madagascar, and described two species of *Stelidota* Erichson from Réunion island, Mauritius, and Madagascar. Kirejtshuk (1981) described the genus *Ceratarhnia*, several subgenera, and species of Nitidulidae under the subfamily Cryptarchinae from the Afro-tropical region. Watrous (1982) described the genus *Colopteroides* from Panama and Brazil. Hisamatsu (1985) in his pictorial handbook of beetles of Japan, included many nitidulid species. Biswas and Mukhopadhyay (1991) recorded a species, *Macroura longipennis* (Motschulsky, 1858) {=*Aethina (Idaethina) orientalis* (Nietner, 1856)} from Lakshadweep Island. Audisio (1993) gave a comprehensive account of Nitidulidae of Italy. Audisio and Jelínek (1993) described two genera namely, *Taraphia* and *Megaucheniodes* from Indonesia (Borneo and Sumatra) of Oriental region. Kirejtshuk (1980-2011) worked on various genera of Nitidulidae from across the globe including several genera of the Oriental and Palaearctic regions. Kirejtshuk and Pakaluk (1996) dealt with the subfamily Epuraeinae from the Nearctic region. In 1999, Kirejtshuk published an account of the sap beetles of India where he included the geographic distributions of 53 genera under 8 subfamilies. Kirejtshuk and Lawrence (1999) gave a systematic account of the genus *Aethina*. Leschen and Marris (2005) studied the nitidulid genus *Carpophilus* of New Zealand. Ewing and Cline (2005) dealt with the adventive nitidulids of Hawaii. Jelínek and Audisio (2007) in the Catalogue of Palaearctic Coleoptera, listed several species which come within the Indian territory. Mifsud and Audisio (2008) studied the Nitidulidae of the Maltese archipelago in Southern Europe. Kirejtshuk (2008) divided the family into 10 subfamilies namely, ‘Calonecrinae’, ‘Maynipeplinae’, ‘Epuraeinae’, ‘Carpophilinae’, ‘Amphicrossinae’, ‘Meligethinae’, ‘Nitidulinae’, ‘Cillaeinae’, ‘Cryptarchinae’ and ‘Cybocephalinae’. Brown (2009) and Brown et al. (2012) dealt with the molecular phylogeny of the genus *Carpophilus* Stephens. Hisamatsu (2010) studied the occurrence of *Cryptarcha kapfereri* Reitter in Japan and differentiated another related species *Cryptarcha inhalita* Reitter from the former. Hisamatsu and Kirejtshuk (2013) described a species of *Epuraea* from Japan. Dasgupta et al. (2013) reported the species, *Carpophilus maculatus* Murray for the first time from the Indian mainland. Pal and Dasgupta (2014) recorded the genus *Colopterus* Erichson for the first time from India with a species from the Sikkim-Darjeeling region. Cline et al. (2014) made a molecular phylogenetic study of the family Nitidulidae where they took out Cybocephalidae as a separate family and considered Prometopinae as a subfamily under Nitidulidae. Dasgupta et al. (2015) re-described the genus and species of *Megauchenia* Macleay of India. Dasgupta et al. (2016a) described a species of *Epuraea* Erichson along with a re-description of the genus and species from Assam. Dasgupta et al. (2016b) redescribed the genus *Brachypeplus* Erichson along with the description of a species from Tripura, India, and commented on the occurrence of a *Brachypeplus* species, *B. omalinus* Murray from the Indian subcontinent. Dasgupta et al. (2016c) described a species of *Cryptarcha* from Sikkim along with a re-description of the genus and species from North-east India. Jelínek et al. (2017) revised the genus *Epuraea* from New Zealand with a new species description and new synonymy. Pal & Dasgupta (2017) reviewed the genus *Ipidia* Erichson of India. Dasgupta et al. (2018) studied the range of association of sap beetles with different flowers. Dasgupta & Pal (2019a) described two species of *Brachypeplus* Erichson from Northeast India. Lawrence (2019) reviewed the Australian Nitidulidae along with a description of new genera, new species, and new synonymy. Dasgupta & Pal (2019c) redescribed the genus *Amphicrossus* along with its description of three new species from Northeast India. Dasgupta & Pal (2019b) studied the seasonal incidence of sap beetles in nature in Kolkata and it was found that these beetles show maximum diversity during an optimal range of temperature and humidity. Dasgupta & Pal (2019d) and Dasgupta et al. (2021) described two species of *Brachypeplus* from Arunachal Pradesh and Tripura, respectively. Dasgupta & Pal (2021) studied the life cycle of a sap beetle species, *Epuraea ocularis* Fairmaire in laboratory conditions. Dasgupta & Pal (2022) reviewed the genus *Aethina* Erichson from Northeast India and revived the specific status of *Aethina vicina* and *A. nigrocastanea* as two distinctly different species. In recent phylogenetic studies by Cai et al. (2022) the former Cucujoidea has been divided into three superfamilies: Erotyloidea, Nitiduloidea, and Cucujoidea in which Nitiduloidea consists of families Nitidulidae, Kateretidae, Monotomidae, Protocucujidae, Sphindidae, Smicripidae and Helotidae; Cybocephalinae was re-incorporated within the Family Nitidulidae (op. cit.). However, we followed the classification scheme of Cline et al. (2014).

By far, about **350 genera and 4500 species** have been recorded from across the world (See Jelínek et al., 2010 and Zhang, 2011) of which about **45 genera and 177 species** are known from India. Of these, only **25 species under 10 genera** are hitherto known from Northeastern India (see Fig. 1). These represent about 14.12% of India’s and 0.55% of the world’s sap beetle fauna.

HABIT-HABITAT AND BIONOMICS

Habit-Habitat: There are various types of habitats where specialized sap beetle species can be found. The relationship between these beetles and their habitats has deep roots, likely evolving since the Cretaceous period. In an era of increasing anthropogenic land-use changes, including agriculture, plant breeding, and alterations to floral compositions, it is crucial to understand the impact of these changes on species groups that provide essential ecosystem functions. Furthermore, the mechanisms that drive the responses of these beetles to altered environments pose important questions for coleopterists.

Nitidulids exhibit diverse habits and inhabit a wide range of environments. They can be found in leaf litter, ripe and decaying fruits, flowers, seeds, rotting cacti, mushrooms, puffballs, cycad cones, fermenting bark, and even carcasses. Some species, such as *Epuraea (Micruria)*, *Epuraea (Haptoncus), Paraepuraea*, *Carpophilus*, *Neopocadius*, *Camptodes* and *Brachypeplus* are phytophagous. Additionally, several nitidulids are predacious.

Several species of *Carpophilus, Urophorus,* and *Glischrochilus* often damage stored grain products and dried fruits (see Hinton, 1945; Dobson, 1954–1956; Pellitteri and Boush, 1983; Basak and Pal, 2007). Several species of *Carpophilus* have been known to cause potential damage to corns. These species generally lay eggs between the kernels or under the husk. The larvae and adults feed upon corn ears. The adults breed in the decaying kernels and are often found in rice mills, sometimes, in swarms. The nitidulid beetles are attracted to corn fields about a fortnight after silking starts and sugar production begins inside the kernels.

Beetles of several genera (viz., *Carpophilus*, *Urophorus*, *Epuraea, Brachypeplus, Colopterus,* etc.) are attracted to overripe strawberries, tomatoes, sugarcane, mango, guava, etc., and usually enter into the fruit or crops through a place of wound or rupture. Quite often, the beetles take shelter inside the fruit and breed there (Figs. 13–15). Some nitidulid beetles infest plants of Araceae, viz., *Xanthosoma daguense* by inhabiting the infructescence and feeding upon fruits (García-Robledo et al., 2004). Quite a good number of nitidulid species are saprobionts and are associated with vegetation debris, such as piles of grass clippings, leaf garbage, haystacks, agricultural wastes, etc. (e.g. *Carpophilus*, *Urophorus*, *Brachypeplus*, etc.).

Several species of sap beetles play a crucial role in the pollination of flowers. Nitidulids, which are associated with flowers (a behavior known as anthophily), may be completely anthophagous, meaning they feed exclusively on flowers in both their immature and mature stages. Notable examples include *Amystrops*, *Macrostola*, some species of *Epuraea*, *Aethina*, *Carpophilus*, *Nitops*, and others.

Adults and larvae of the species *Brachypeplus barronensis* Blackburn, 1902, have been reported to inhabit the male and female cones of cycads as well as the tops of trunks between the bases of young leaves (Kirejtshuk, 1997a). In the inflorescences of *Alocasia macrorrhizos*, a long spadix is covered at its base by a large leaf sheet. The narrow spaces allow only small flat beetles, like *Brachypeplus kemblensis* Blackburn, 1902, to enter. As the spadix decays, it promotes fungal growth, creating a feeding substrate for nitidulid larvae (see Shaw and Cantrell, 1983).

Species of *Meligethes* are associated with several flowering plants from the Brassicaceae family, such as *Barbarea verna* and *B. vulgaris* (Börjesdotter, 2000). The cones of certain gymnosperms, like *Stangeria eriopus*, mimic the scent of fermented fruits, which attracts nitidulid beetles from the genera *Urophorus*, *Carpophilus*, and *Meligethes*, facilitating pollination (Proche and Johnson, 2009). Flowers of *Phytelephas* (Family Arecaceae) have been found to be pollinated by *Mystrops* sp. (Ervik et al., 1999). Additionally, nitidulid beetles pollinate flowers of *Annona* sp. (Gottsberger, 1989).

Species of *Colopterus* serve as pollinators for the flowers of *Anaxagorea prinoides* (Teichert et al., 2011). Species of *Meligethes* and *Aethina* primarily feed on the flowers of angiosperm plants, while *Pria* has been observed feeding on the pollen of Solanaceae flowers (Kirk-Spriggs, 1996). Species of *Camptodes* consume dead and decaying flowers of *Opuntia*. Many nitidulids are attracted to the flowers of Anemone, Sambucus, Papaver, and Rosa (Lovell, 1915). Additionally, species of *Carpophilus*, *Glischrochilus*, and *Colopterus* have been noted for their attraction to the flowers of *Calycanthus floridus* (Williams et al., 2008).

Many nitidulids are subcorticolous in habit, such as *Prometopia*, *Parametopia*, *Lobiopa*, *Axyra*, *Megauchenia*, *Ipidia*, *Platychora*, *Taracta*, *Psilotus*, *Perilopa*, *Pocadites*, *Hebasculinus*, *Atarphia*, *Aethina (Aethina)*, *Aethina (Circopes)*, *Lordites*, *Cillaeus*, *Cillaeopsis*, *Platynema*, *Ithyphenes*, *Colopterus*, *Brachypeplus*, *Conotelus*, etc. Some representatives of saproxylic sap beetles (subfamilies Cryptarchinae, Cillaeinae, Amphicrossinae, and Nitidulinae) feed on fermenting fluids, fungi, and yeast that are present in the subcortical space of trees. Fruit and fungal odors (Fig. 19) attract many sap beetles of the genus *Carpophilus* (Smilanick et al., 1978; Phelan and Lin, 1991). The fungal odor of *Saccharomyces cerevisae* on agar or banana attracts *Carpophilus hemipterus* (L.) (Phelan and Lin, 1991). Larvae and adults of *Eusphaerius* feed on coral fungus *Ramaria* (Leschen and Carlton, 1996). Some nitidulid beetles, like *Taraphia* and *Megauchenoides,* possess mycangia near the coxae to store fungal spores (Kirejtshuk, 2003). Few species of *Epuraea (Epuraea)* often feed on fungi growing on animal feces (Kirejtshuk, 1998).

Nitidulid beetle *Amphicrossus japonicas* Reitter has shown a gradual transition from a semi-liquid organic habitat to an aquatic habitat. These beetles breed in bamboo sap and enter the water-filled bamboo culms. They can breathe in that aquatic habitat with the help of a ventral air sheath held by hydrofuge pubescence. These beetles also serve as facultative predators of mosquito larvae (Kovac et al., 2007).

Many species of sap beetles also feed on rotten carcasses. Incidence of a few nitidulid beetles of *Glischrochilus*, *Meligethes*, *Nitidula,* and *Pocadius* were reported from deer carcasses (Melis et al., 2004). Fungi growing on carcasses also become a refuge to several species of *Nitidula* and *Omosita*.

Few species of *Amphicrossus* and *Amphotis* are myrmecophilous and have symbiotic relationships with ants (Kirejtshuk, 1998; Cline, 2005). *Amphotis orientalis* is associated with nests of *Crematogaster scutellaris* whereas *Amphotis marginata* is associated with ant colonies of *Lasius fuliginosus* (Olberg, 2015). *Amphotis* species can locate the ant nests by host-specific odors and pheromones. While their characteristic body shape is designed to protect against ant attacks, the ant workers often feed the adult beetles through regurgitation. They use their tactile sensory receptors (antennae) to mimic the ant's begging behavior, thereby eliciting a regurgitation response from the ants. (Lapeva-Gjonova, 2013; Olberg, 2015).

Some arboricolous species, such as *Epuraea (Epuraea)*, *Glischrochilus (Glischrochilus)*, *Pityophagus*, etc. also become facultative or obligatory predators of insect larvae and other soft invertebrates living under bark and wood. Quite infrequently, they become inhabitants of holes occupied by Scolytidae (Kirejtshuk, 1998). Larvae of *Nitidula*, *Pityophagus,* and *Glischrochilus* are known to predate on scolytids (Parsons, 1943).

The small hive beetle, *Aethina tumida* Murray, is native to South Africa and is known as a pest and scavenger of honey bee colonies. This beetle has now spread to North America, Australia, and South America (Arbogast et al., 2009; Toufailia et al., 2017). It has become a significant pest for the honey bee, *Apis mellifera*, as it feeds on brood, adult bees, and stored food (Hepburn and Radloff, 1998; Neumann and Ellis, 2008).

Additionally, the nitidulid beetle, *Cychramus luteus* Fabricius, has also been reported in association with colonies of *Apis mellifera*. However, unlike *Aethina tumida*, this species does not cause any damage to the colony; it merely seeks pollen or refuge within the hives (Neumann and Ritter, 2004).

Despite their broad habitat range and economic significance, there have been limited reports on the habits, behaviors, and ecological roles of Indian nitidulid fauna. Dasgupta et al. (2018) studied the variety of associations between sap beetles and different flowers. The present study focuses on the occurrence of various nitidulid species across different habitat conditions, as detailed in the following table:

Table 1: Records of sap beetles from different habitats in field conditions.

<table>
<tr><th>Family Nitidulidae (Name of species)</th><th>Hosts/habitats</th><th>Localities</th></tr>
<tr><td rowspan="2">Pria ceylonica Grouvelle</td><td>Flowers of Egg plant flower(Fam. Solanaceae) (Fig. 8)</td><td rowspan="2">Kolkata (West Bengal), Agartala (Tripura)</td></tr>
<tr><td>Sticky night shade (Solanumsisymbriifolium Lamarck) flower (Fam. Solanaceae).(Fig. 2)</td></tr>
<tr><td>Taenioncus cylindricus (Murray)</td><td>Gular fruit (Ficus glomerata Roxb.)</td><td>Kukrail Forest Area (Uttar Pradesh)</td></tr>
</table>

Urophorus humeralis Fab.	Flower of kadam tree {*Neolamarckia cadamba* (Roxb.) Bosser}	Garia, Narendrapur, Howrah (West Bengal)
	Rotten banana peel (Fig. 17)	West Bengal
	Rotten mango (Fig. 20)	Andaman Island
	Vegatable debris	Agartala (Tripura)
Epuraea (Haptoncus) ocularis Fairmaire	Flower of kadam tree (*Neolamarckia cadamba* (Roxb.) Bosser)	Garia, Narendrapur, Howrah (West Bengal), Kukrail Forest Area (Uttar Pradesh)
	Rotten and decomposing fruits of Banyan tree *(Ficus bengalensis* Linn.)	Howrah (West Bengal)
	Over-ripe fruit of Indian Medlar tree (*Mimusops* sp.*)*	Howrah (West Bengal)
	Under leaf sheath of bamboo	Arunachal Pradesh
	Flower of Datura	Chilka lake (Odisha)
	Fungus growing on fruits (Fig. 16)	West Bengal
Epuraea (Haptoncus) motschulskyi (Reitter)	Flowers of bottle gourd, *Lagenaria siceraria* (Molina)(Fig. 3) and pumpkin flower (Fam. Cucurbitaceae) (Fig. 11a, 11b)	West Bengal, Assam, Tripura, Manipur
	Flower of *Ipomoea* sp. (Fig.7)	Howrah (West Bengal)
	Flower of Datura (Fig. 4)	Haldia (West Bengal)
Epuraea sp.	Flowers of pea plant, rose, china rose. (Figs. 5, 6)	Bengaluru (Karnataka)
	Flower of Dahlia (Figs. 10a, b)	Dibrugarh (Assam)
Epuraea (Epuraeanella) fossicollis Grouvelle	Garbage of *Cryptomeria* Leaves	Darjeeling (West Bengal)

Amystrops nigripennis (Redtenb.)	Blossoming flower and fruit of *Pandanus* sp.	Dibrugarh (Assam)
Grouvellia picea (Reitter)	Blossoming *Pandanus* sp.	Dibrugarh (Assam)
Carpophilus hemipterus (Linn.)	Rotten fruits	Assam, Tripura, Manipur, West Bengal
	Keora and mahua seeds	Kolkata (West Bengal)
	Groundnut seeds	
	Maize	
Carpophilus obsoletus Erichson	Rotten fruits	Jharkhand, Assam, Tripura, Manipur, West Bengal
	Maize grain	Kolkata (West Bengal)
	Flour	
	Groundnut seed	
	Mahua seeds	
Carpophilus plagiatipennis Motsch.	Rotten Kamranga fruit (*Averrhoea carambola* L.)	Shantirbazaar (Tripura)
Carpophilus nepos Murray	Rotten Kamranga fruit (*Averrhoea carambola* L.)and ripe tomato	Shantirbazaar and Bishalgarh (Tripura)
	Tamarind, Fish baskets, gunny sacs	Kolkata (West Bengal)
Carpophilus truncatus Murray	Under bark of dead log	Dampa (Mizoram)
	Keora seeds	Kolkata (West Bengal)
	Groundnut seeds	
Carpophilus jahari Dasgupta & Pal	Under bark of Hollock	East Siang (Arunachal Pradesh)
Carpophilus bifenestratus Murray	Vegatable debris	Aizawl (Mizoram)
Urophorus humeralis (Fabricius)	Vegatable debris	Jirania (Tripura)
Aethina (Circopes) sp.	Flowers of Sitaphal /Custardapple (*Annona* sp.) (Fig. 9)	Bengaluru (Karnataka)
Aethina (Circopes) subquadrata (Motschulsky)	Flower of Flat bean	Lumding (Assam)

Carpophilus marginellus Motschulsky	Flowers of Sitaphal (*Annona* sp.)	Bengaluru (Karnataka)
	Wheat bran	Kolkata (West Bengal)
	Flour	
	Maize grain	
Carpophilus sp.	Rotten Cashew fruit (Fig.19)	Calicut (Kerala)
Phenolia sp.	Flower of kadam tree (*Neolamarckia cadamba* (Roxb.) Bosser)	Kolkata and Howrah (West Bengal)
Aethina (Idaethina) orientalis (Nietnar)	Flower of *Ipomoea* sp. (Fig.7)	Bengaluru (Karnataka), Imphal, Churachandpur (Manipur)Uttar Pradesh
	Flower (Fam. Convolvulaceae)	Imphal, Churachandpur (Manipur)
Aethina (Idaethina) subrugosa (Grouvelle)	Flower	Jecko (Arunachal Pradesh)
Epuraea (Micruria) viraktamathi Dasgupta et al.	Flower of tea	Jorhat (Assam), Darjeeling (West Bengal)
Epuraea (Haptoncus) luteola Erichson	Rotten fruits (Figs. 14, 15)	Assam
	Rotten kamranga fruit (*Averrhoea carambola* L.) (Figs. 13a, b)	Havelock (Andaman Islands)
Amphicrossus kabitae Dasgupta & Pal	Rotten patch on living tree Trunk	Rajmahal (West Bengal)
Prometopia quadrimaculata Motsch.	Under bark of log	Keibul Lamjhao National Park (Manipur),Jirania (Tripura), Jorethang (Sikkim)
Megauchenia angustata (Erichson)	Under bark of *Shorea robusta* Roth	Garo hills (Meghalaya)
Ipidia spp.	Under bark of dead log	Namdapha, Zero Valley (Arunachal Pradesh), Dibrugarh (Assam), Darjeeling (West Bengal).
Colopterus	Under bark of a tree (*Terminalia* sp.)	Darjeeling (West Bengal)

robertopoggii Pal and Dasgupta	Under bark of *Schima wallichi* (DC) Korth	Darjeeling (West Bengal)
	Under bark of *Mangifera indica* L.	Jorethang (Sikkim)
Colopterus sp.	Rotten oranges and plum	Jokai Forest (Assam)
Brachypeplus riang Dasgupta et al.	Rotten carambola fruit (*Averrhoa carambola* L.)	Shantirbazaar and Jampui Hills (Tripura)
Brachypeplis rugisternus Dasgupta & Pal	Under bark of dead log	Namdapha WLS (Arunachal Pradesh), Ramnagar (Uttar Pradesh)
Brachypeplus pallidus Dasgupta & Pal	Rotten carambola fruit (*Averrhoa carambola* L.)	Silchar (Assam)
Cryptarcha raychaudhurii Dasgupta and Pal	Under leaf sheath of bamboo	Rotung (Arunachal Pradesh)

Bionomics

Species of sap beetles inhabit a variety of habitats and microhabitats, adapting to their surroundings while displaying differences in feeding behaviors and fulfilling essential ecological roles. As a result, various species have developed distinct living strategies. Cline et al. (2014) identified the Nitidulidae family as one of the most biologically diverse groups of beetles, encompassing members with varied life history strategies such as predation, fungivory, herbivory, frugivory, and necrophagy.

Although sap beetles have a wide range of food sources, most primarily rely on the oozing sap of plants and fruits, as well as nectars and pollens. Food selection is a crucial aspect of feeding for both adult and immature beetles, involving specific behavioral responses and the utilization of sensory organs. Adult beetles are often competent fliers, capable of traveling long distances. They tend to be attracted to and gather around food sources. For example, certain chemicals found in honey volatiles have been shown to attract small hive beetles, *Aethina tumida* (Murray) (Torto et al., 2005). These beetles are drawn to volatiles emitted by honey bees in the hive, freshly collected pollen, unripe honey, and slum gum (Suazo et al., 2003). Additionally, the fermentation of honey by the yeast *Kodamea ohmeri* produces volatiles that attract hive beetles (Teal et al., 2006).

In our field studies, we have observed that ripe and fermenting fruits, along with fermenting plant saps in shaded areas, effectively attract sap beetles in significant numbers, demonstrating their strong olfactory senses. The assimilation of carbohydrates, particularly sugars, appears to be vital for the longevity of these beetles (Dadd, 1985). Notably, small hive beetles can survive without food and water for approximately 5 to 9 days (Pettis and Shimanuki, 2000; Ellis et al., 2002).

Most sap beetle species are effective fliers and can cover several kilometers (Somerville, 2003). This ability facilitates their dispersal across large areas. Occasionally, the beetles swarm, allowing them to infest new habitats (Tribe, 2000). When inside a nest or food source, adult beetles often hide in small cracks. They tend to remain relatively motionless while feeding in larger food sources, such as overripe fruits and dense inflorescences, where species like *Epuraea (Haptoncus)*, *Carpophilus*, *Phenolia*, and *Urophorus humeralis* can be observed. However, in more spread-out food sources, such as rotten Kamranga fruit, rotten tomatoes, or banana spreads, the beetles have been seen moving slowly from one hiding spot to another nearby location. This behavior is typical for species like *Brachypeplus*, *Colopterus*, *Epuraea* (*Haptoncus*), *Carpophilus*, and *Urophorus*. None of the sap beetle species have been observed to be fast movers. When threatened or attacked, the beetles adopt a defensive posture; they become non-motile, tucking their heads beneath the pronotum as far as possible, with their legs and antennae pressed tightly against their bodies.

LIFE HISTORY

The information on the reproduction and metamorphic stages of sap beetles is not quite extensive, but life histories of a few species were studied elsewhere (see Dickason, 1957; Gough and Hamacek, 1989; Galford et al., 1991; Carlton and Leschen, 2007; Cline et al., 2013; Cuthbertson et al., 2013;). Westwood (1840) gave an account of nitidulid adults and larvae. Chapuis and Candèze (1853) in their Catalogue of the Larvae of Coleoptera described the larval characters of a few species of Nitidulidae. Perris (1877) described the immature stages (larval and pupal stages) of a few species of Nitidulidae. Böving and Craighead (1931), based on larval characters, divided Family Nitidulidae into 4 subfamilies *viz.*, Nitidulinae, Meligethinae, Prometopinae, Cateretinae. Hofeneder (1935) described the larva of *Cychramus quadripunctatus*. Connell (1956) had put forward a key to the Nitidulidae of Delaware based on adult and larval characters. Rozen (1963) made a systematic study of the pupal stages of Family Nitidulidae and described the pupa of several genera of Nitidulidae. Hayashi (1978) described and illustrated larvae of fifty species of the Nitidulidae occurring in Japan and segregated them into 24 genera belonging to six subfamilies. He (op. cit.) also provided a key to the species based on larval characters. Galford et al. (1991) dealt with the biology and hosts of *Stelidota ferruginea* and gave insight into the artificial rearing of beetles. Currie et al. (1996) studied the life history of *Epuraea obliquus* Hatch on western gall rust. Kurochkin and Kirejtshuk (2003) described pupae of some species of *Epuraea*. Kurochkin (2005) studied the pupae of *Carpophilus marginellus* and *Carpophilus pilosellus*. Kirejtshuk et al. (2007) studied the immature stages of the genus *Nitops*. Kurochkin (2007) and Osborne (2009) studied the taxonomy of immature stages of *Meligethes*. Carlton and Leschen (2007) described the larvae of *the Soronia* complex of New Zealand along with a note on their life history. Cline et al. (2013) described the larval stage of *Brachypeplus glaber* LeConte. To develop a better understanding of the reproductive behavior of the adult nitidulids and their developmental stages the adult nitidulids were exposed to simulated field conditions in the laboratory. This study (see Dasgupta & Pal, 2021) of the life cycle of *Epuraea (Haptoncus) ocularis* Fairmaire gave an insight into the living strategy and biology of the beetles (see Fig. 573). The beetles became sexually mature at about 6–7 days following emergence from pupae in soil. Adult males rode on females during copulation. Adult females oviposited in good numbers in clusters, in cracks in food substrata after 2–4 days. Eggs are usually elongate-elliptical and off-white in color. The eggs hatch in about 1 to 2 days. The first instar larvae were creamy white and emerged from eggs by a slit at the anterior end of the eggs. The larvae are voracious feeders and move gently over the food substrates, especially during the daytime, and gradually grow in size. There are at least four instars and the larval stages last for about 12 to 17 days. The lifecycle as observed, is summarized in the following table:

Table 2: Duration of developmental stages in the life cycle of *Epuraea (Haptoncus) ocularis* Fairmaire reared on banana pelts for the month of November-December, 2016 at 26ºC to 30.8ºC (maximum temperature), rainfall l0to 0.1mm, relative humidity 63.5% to 69.5% (Dasgupta & Pal, 2021):

LIFEHISTORY STAGE	DURATION
1.Pre-ovipositionperiod	2-4days
2.Oviposition/egglaying	1to2days
3.Egghatching	1-2days
4.1stto 2nd larval instar	2-3days
5.2ndto3rdlarval instar	3-4days
6.3rd to 4th larval instar	3-4days
7.4th larval instarto pupa	4-6days
8.Pupato imago	4-5days
9.Eggto imago	17-24days

Mostly the mature larvae move at dusk in search of a suitable pupation site in soil. They usually pupate in burrows/spaces slightly beneath upper surface of soil in slightly moist condition (Figs. 574, 579). Well-fed last instar larvae reach a wandering phase before dropping down to or entering into soil for suitable pupation substrates. The pupation stage lasts for about 4 to 5 days. Young pupae are creamy white and gradually they become darker in color. Adults emerge by tearing open the pupal skin with the movement of its head and legs. It has been apparent that all the eggs laid could not reach the adult stage. There was considerable mortality in the larval stages and not more than 30 percent of the 1st instar larvae could transform into adult stage.

SEASONAL INCIDENCE

An important aspect of studying the community structure of beetles is understanding their distribution in natural habitats (spatial distribution) and the fluctuations in their populations over time (temporal distribution). To achieve this, it is essential to grasp the fundamental ecology of beetles, including species composition, abundance, and the influence of environmental factors on seasonal variations. The population dynamics of beetles are affected by various environmental factors such as temperature, rainfall, humidity, and certain physical factors like soil properties, vegetation structure, and pollution. Additionally, biological factors, including interactions with other animals, also play a role. A large majority of the sap beetle fauna thrives on decaying fruits and vegetables, and their populations exhibit significant seasonal fluctuations throughout the year.and biological factors like other associated animals, etc. A large majority of the sap beetle fauna thrives on rotten fruits and vegetables and their populations show considerable seasonal fluctuations over the year.

Kehat et al. (1983) studied the seasonal abundance of sap beetles in date plantations in Israel. Gough and Hamacek (1989) studied the seasonal incidence of *Macroura concolor* (Macleay) and their relationship with bud falling in *Hibiscus rosasinensis* in Southern Queensland, Australia. James et al. (1995) studied the Nitidulid fauna and their seasonal abundance in four stonefruit orchards in Australia using fermenting bread and aggregation pheromones as traps. Bakke (1999) studied the diversity of saproxylic beetles in a forest in Norway and compared the efficacy of different trapping methods in sampling the adult population of the sap beetles. Juzwik et al. (2004) studied the seasonal abundance of sap beetle species visiting fresh wounds on healthy oaks in Minnesota. Zeran et al. (2006) studied the diversity of sap beetles in managed and old-growth forests in southeastern Ontario, Canada. Alinvi et al. (2007) studied the species assemblage and diversity of saproxylic sap beetles using various sieving techniques and traps.

Atmospheric temperature plays a significant role in the development of the sap beetles. De Guzman and Frake (2007) noticed a total development period of 23 days in the life cycle of *Aethina tumida* at 34º C temperature.

The length of developmental cycle has been observed to be 41.32±1.34 days at a range 18º C– 25º C (Mürrle and Neumann, 2004); and that becomes 49.0±0.11 days at a range of 17º C– 24º C (Neumann et al., 2001). Annand (2011) reported that temperatures of ≤ 15º C and > 45º C prevented oviposition of *A. tumida*. Meikle and Patt (2011) recorded the minimum temperature for development of eggs of *A. tumida* was 13.5º C. Very dry atmospheric conditions impact adversely on the reproduction of sap beetles. Annand (2011) reported that the RH of ≤ 34 percent prevented survival of the eggs of *A. tumida*. The soil moisture and soil texture effect upon pupal survivability. De Guzman etal. (2009) found that pupation rates and beetle survivability were more in silty clay and silty loam soils compared to sandy loam or loam soil areas. Torto et al. (2010) reported that larvae of *A. tumida* burrow deeper into the soil for pupation during drier seasons. Hopkins and Ekbom (1999) noted that in *Meligethes aeneus*, a female searching for a host plant will be conditioned to accept a host which is of inferior quality for her offspring if there is a large egg load.

The seasonal occurrence of sap beetles in nature was not studied earlier in India and studies of abundance and richness of these beetles in other parts are also not too many. Our study (Dasgupta & Pal, 2019b) aimed to identify the species composition of sap beetles, their seasonal incidence, and population fluctuations in food bait traps in Kolkata, India for a period of two years. A total of 632 specimens of sap beetles intercepted in bait trap belonged to 6 species (see Tables 7 and 8) and they showed prevalence in the post-monsoon season. The species richness was highest in an optimum range of atmospheric temperature and relative humidity. Out of six species, a single species (*U. humeralis*) was represented by at least 56% (Fig. 592) of individuals (denoting the highest occurrence), while three species (*Carpophilus maculatus, C. jelineki, and C. marginellus*) were represented by not more than 1% of individuals (denoting lowest occurrence). Two other species (*Epuraea ocularis* and *E. luteola*) are represented by 21% and 20% of individuals (denoting moderate occurrence). The number of specimens and species captured in each month over the span of two years when plotted together, the graphical representations reveal that the majority of species and specimens were captured during the months of September-October and February (Figs. 593, 594).

The biodiversity indices like Shannon Weiner Diversity Index (SWDI) and Simpson's Diversity Index (SDI) were calculated to be 1.11 and 0.60 respectively. SWDI of 1.11 indicated that species richness and evenness are moderately low. This might be due to inadequate sampling and collection from a single site. The SDI of 0.60 indicated that the sample diversity (in terms of evenness) is quite high and the dominance is low. Berger-Parker index of dominance for the most abundant species (*Urophorus humeralis*) was calculated to be 0.56. Margalef's index of species richness was calculated to be 0.78 (see Table 3).

Table 3: Diversity indices (Shannon and Weaver, 1949, Simpson, 1949, Margalef, 1968 and Berger and Parker, 1970) calculated using PAST3 software

DIVERSITYINDICES	VALUE
Simpson's Index of Diversity (SDI)	0.60
ShannonWeiner Diversity Index (SWDI)	1.11
Margalef's Index (D_{mg})	0.78
Berger-Parker Index of dominance(d)	0.56

The meteorological data viz., temperature, relative humidity and rainfall when plotted along with number of species and specimens for a period of two years (Figs. 595, 596), the graphical representations showed that the number of trapped specimens and species-richness became maximum in an optimum range of atmospheric temperature and relative humidity.

The study revealed variations in the capture of sap beetles across different seasons; however, a direct correlation between environmental factors and the abundance of sap beetles could not be established. It was observed that a temperature range of 22º C to 29º C and a relative humidity between 62% and 86% (most conducive when between 82.5% and 86%) created favorable conditions for the growth of the sap beetle population. While light rainfall appeared to increase their occurrence in nature, continuous heavy rainfall negatively impacted their abundance.

Additionally, different species of sap beetles were found to enter the food bait trap in succession as the food fermented. *Epuraea* spp. were captured within the first 12 hours. *Carpophilus* spp. appeared in the next 12 hours when the food began to soften due to fermentation. *Urophorus humeralis* Fabricius was predominantly found in the later stages when the bait trap food was significantly decomposed. It seems that the chemical signals released by the fermenting banana bait changed over time, attracting different species of sap beetles. The timing of when various species became active in response to these chemical changes varied.