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Ecological studies on Odonates of Kangra and Adjoining areas

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Abstract

Odonates are unique in the insect world. They are well-known and fascinating insects that include some of the most ancient and beautiful insects that ever roamed Earth, as well as some of the largest flying invertebrates ever to have lived. Although less known than butterflies or moths, they form a most conspicuous feature of the world landscape and are common to all parts, even the most arid areas. Their beauty and elegance of flight, their charming colours and their infinite number, especially during the monsoon months force their presence on the tardiest observer. Popularly they are known as dragonflies and damselflies. Dragonflies, as a diverse group of insects, exhibit a broad spectrum of behaviours influenced by environmental factors, predator interactions, social dynamics, and intrinsic biological traits. This study explores the ecological aspects of Odonates in Kangra and its neighbouring regions, focusing on their preferred habitats, feeding behaviours, foraging strategies, predation patterns, thermoregulation, mating rituals, breeding habits, and dispersal tendencies. The research delves into specific species, such as *Pseudogrion rubricips rulriceps, Pseudagrion microcephalum, Ceriagrion coromandelianum, Agriocnemis pygmaea, Neurobasis chinensis chinensis, Brachydiplax sobrina, Diplacodes trivialis*, and *Trithemis aurora,* unravelling their distinct habitat choices and breeding preferences. Notably, territorial behaviour among male dragonflies and damselflies, as well as the common practice of depositing eggs in aquatic plant stalks, emerged as recurring themes across the studied species. This comprehensive exploration enhances our understanding of the intricate ecological relationships and adaptations that contribute to the remarkable success and enduring stability of dragonflies over millions of years.

Keywords: breeding habits, dragonflies, ecological habitat, odonates, Kangra

1. Introduction

In the intricate tapestry of Earth's evolutionary history, Odonates, belonging to the order Odonata within the class Insecta, emerge as ancient inhabitants that have gracefully navigated the currents of time for approximately 245 million years. Alongside mayflies and cockroaches, they represent resilient survivors of a bygone era, evolving into adapt hunters capable of swiftly decimating populations of their prey [1]. Distributed across all geographical realms, the true zenith of Odonate diversity unfolds within the lush landscapes of the tropics. Globally, approximately 7,000 species spanning 630 genera and 28 families have been documented, with India contributing significantly to this wealth with 500 species and subspecies across 140 genera and 17 families. The verdant expanse of Kerala alone hosts 46 species of dragonflies and damselflies, as reported by researchers [2].

Odonates, the captivating aerial acrobats of the insect world, are classified into two distinct groups: the robust and sturdy dragonflies, and the slender and delicate damselflies. These predators, exhibiting prowess in both their adult and nymphal stages, are integral components of terrestrial ecosystems. Adult Odonates, with their mesmerizing flight patterns, are often found near aquatic havens such as ponds, lakes, streams, tanks, and marshes. Yet, their life cycle remains intricately tied to water, where eggs hatch, and nymphs thrive before metamorphosing into airborne wonders. Remarkably adaptable, some odonate species showcase awe-inspiring migratory feats, covering hundreds of kilometres over land and sea. Among them, males frequently exhibit terrestrial behaviour, staking their claim along stretches of water bodies in a display of territorial prowess. These ancient insects, with a design honed over millions of years, possess an arsenal of adaptations facilitating hunting, agile flight, thermal regulation, and reproductive success. Endowed with two large compound eyes and three simple eyes, their keen eyesight serves them well in the pursuit of prey or evasion of predators. Dragonflies, in particular, are opportunistic predators, demonstrating a broad diet ranging from other dragonflies to small humming birds [3]. Dragonflies are remarkably unaltered despite their long evolutionary history, which is evidence of the efficacy of their evolutionary strategy. An exploration of the realm of odonates reveals a story characterized by tenacity, flexibility, and enduring sophistication, wherein the time-honoured choreography of these arthropods resonates with the natural cycles, imparting a message that has endured for eons. They comprise a head, thorax, and abdomen and are comparatively large in size. They are equipped with four wings and six legs. The odonate life cycle is comprised of the following three stages: egg, larval (nymphal), and adult. The intermediate pupal stage is not present between the adult and larvae. The dragonfly larval stage is exclusively submerged in water, whereas the adult stage is predominantly observed on land or in flight. The mature will return to the water shortly to oviposit and mate. During the prehistoric era. The time of dinosaurs' global distribution, Odonata were comparable in size to raptors. Fossils of odonates have been excavated in Siberia, Kansas, and numerous other regions across the globe. They measured approximately thirty inches in wing span and were the largest insects in history. Odonata have been subjects of widespread superstition. The odonata have acquired monikers such as "devil's steelyard" and similar descriptors due to their resemblance to massive implements. Although odonates are predators, they are advantageous in that they can be utilized to control vermin. Odonates provide a limited capacity for monitoring environmental quality because their presence is significantly influenced by a variety of factors, including vegetation, water flow, and pollution. Odonate larvae are occasionally employed as lures by fishermen, while in certain nations, adults are considered a minor food item. Odonates exhibit a wide range of behavioural patterns, among which the reproductive behaviour of adults holds considerable importance. Numerous researchers have examined the reproductive behaviour of odonates [4].

History of Odonata

Dragonflies living today evolved during the Mesozoic period, during the time of the dinosaurs. They evolved at the same time as *Archaeopteryx*, the first reptile bird. The order of insects is extremely ancient, with fossils

dating back over 300 million years ago [5]. Dragonflies are undoubtedly larger insects, both in the present and the past, but they were far larger in ancient times. They are considered to be the offspring of protoodonata, a predecessor to the group that is currently no longer in existence. The most ancient fossils now known originate from upper Carboniferous deposits in Europe, which were produced approximately 325 million years ago. The proto-odonates encompassed the meganeuridae family, which consisted of exceptionally large species. Similar to contemporary dragonflies, the proto-odonata possessed rapid flight capabilities and utilized their spiny legs to potentially aid in grabbing the prey. The species *Meganeura monyi* possessed a wingspan of up to 75 cm (30 inches). The groups go extinct during the Triassic period, coinciding with the emergence of dinosaurs. The meganeuridae exhibited several distinctions from contemporary Odonata: the absence of a nodus (a notch in the wing) and ptero stigma (wing characteristics), as well as their remarkable size in comparison to present-day species. The initial odonata fossils were discovered in layers dating back to the lower Permian period, which is more than 350 million years old. These fossils are not as colossal as the carboniferous fossils. They are members of small protoanisopteran and zygopteran species [6]. The latter seemed to have seen few changes in both its construction and appearance since that time. The presence of aquatic larvae in proto odonata and older Odonata species, similar to all current species, is uncertain due to the absence of confirmed Paleozoic larvae fossils. According to several workers, it is believed that Odonata developed an aquatic larval stage in the lower Permian period, may be because their prey resided in aquatic environments [7]. With a wing span of 19.1 cm (7.52 inches) and a body length of 12 cm (4.72 inches), the damselfly (zygoptera) *Megalo caerulata* from Costa Rica is now the largest dragonfly in the world. *Tetracanthagyna plagita*, found in Borneo, holds the distinction of being the largest anisopteran, commonly known as a real dragonfly. The species with the smallest wingspan is likely *Agriosnemis naia,* which measures 1.76 cm. The study of Odonata has its origins in primordial times. The first reference to an Indian dragonfly can be found in the Sangam literature, a collection of Tamil texts dating back to before the 8th century A.D. [8]. The fauna of India is thought to have mainly borrowed from the Indo-Malayan region, or more specifically, the Indian odonate fauna has borrowed from Malaysia and the Palaearctic to a lesser extent. However, it is abundant in endogenic groups, some of which have distinctly unclear origins. Similar to the northeastern frontier, the Western Ghats include a diverse array of flora, some of which are native to the region. While Keylong is similarly rich in this regard, it exhibits some similarities to the southern Indian fauna [9].

2. Methodology

Data Collection:
A systematic survey was conducted in Kangra, Himachal Pradesh, to observe Odonates, focusing on dragonflies and damselflies. The standard sampling techniques were employed, including sweep netting for adult specimens and dip netting for nymphs, ensuring comprehensive coverage of diverse habitats.

Habitat Characterization:
Various habitats such as ponds, lakes, streams, and marshes were assessed in the study area. The key habitat features, including vegetation types and surrounding landscapes, were documented.

Environmental Monitoring:
The environmental parameters during surveys, such as temperature, humidity, and light conditions, to correlate with Odonate behaviour were recorded.

Species Identification:
The specimens were photographed, identified and classified to the species level using taxonomic keys and under expert guidance. During the study, the diversity of dragonflies and damselflies encountered was documented.

3. Results and Discussion

Distribution:
The spatial distribution of odonates is significantly influenced by the characteristics of the environment and

water bodies. Eggs are laid in aquatic media by them. They favor humid tropical climates. They are situated more in a tropical region. There are fewer species in areas without arid or permanent water bodies than there are in areas with perennial or permanent water bodies. In the absence of vegetation, they avoid saline water. Additionally, they serve as markers of a high-quality setting. They avoid contaminated environments. Thus, although odonates are found around the globe, they are most numerous and diverse in hot, humid regions. These insects are tropical in nature. There are over 7000 Odonata species known to exist worldwide, organized into 630 genera and 28 families. The zygoptera and anisoptera are well-established tropical taxonomic groupings. In India, there are over 500 species and subspecies belonging to 140 genera and 17 families; 137 of them are distributed among 79 taxa and 12 families, with Kerela hosting some of these species and subspecies. Only 47 species are supported by the perennial water in the Andaman and Nicobar Islands due to limited water supplies, compared to 91 species and sub-species in Arunachal Pradesh. There are sixty species and subspecies in Calcutta [10].

Morphology of Odonata:

Odonata, like other insects, possess a body divided into three main parts: the head, thorax, and abdomen.

Head:

The head of an odonate is equipped with various components, including the labrum (upper lip), labium (lower lip), clypeus, frons, vertex, vesicle, eyes, ocellus, and occiput. Notably, they exhibit a remarkable development of compound eyes, containing a high number of facets (10,000 to 28,000). The head is movable, capable of twisting sideways up to 180°, bending backward up to 70°, and tilting forward and downward around 40°.

Thorax or Synthorax:

The thorax, located in the middle part of the body, consists of three segments: prothorax, mesothorax, and metathorax. Wings are attached posteriorly due to the fusion of mesothorax and metathorax. The legs are adapted for capturing insects, featuring spines. Odonates can adjust their center of gravity between the wing bases, enabling backward flight, vertical ascent like a helicopter, or halting mid-flight. Species identification is facilitated by markings on the thorax.

Abdomen:

The abdomen is slender, and at its tip, genitalia and anal cerci or appendages are present. Male odonates transfer sperm to the accessory genitalia in the second abdominal segment before breeding. Some species exhibit courtship behaviour, where the male clasps the female's neck with anal appendages, forming a wheel to receive sperm. The abdomen is long, flexible, and divided into 10 segments. Both sexes have clasping organs at the abdomen's end, with females having an ovipositor for egg-laying and males possessing secondary genitalia.

Wings:

Damselflies have nearly identical forewings and hindwings, held vertically over the body at rest. Dragonflies, in contrast, have dissimilar forewings and hindwings, spreading them at right angles when resting. Wing characteristics include hyaline or coloured wings, specialized venation, and distinct parts such as costa, node, pterostigma, nervures, discoidal cell, sub-node, ante nodal, post nodal, arc, cubital space, anal bridge, anal crossing, radials, radial sector, r2, r3, r4, r5, and medius.

Ecology and behaviour of odonates

Dragonflies, belonging to the order Odonates, have specialized characteristics for hunting, nimble flight, thermoregulation, and reproductive purposes. Over a span of 200 million years, they have undergone evolution and transformed into adapt predators capable of rapidly reducing the population of their prey. Dragonflies are versatile predators that exhibit opportunistic feeding behaviour, consuming a wide range of prey. They can capture a wide range of prey, including other dragonflies and even small humming birds. They engage in aerial hunting, pursuing and capturing their prey while in motion. The habitat in which dragonflies reside can exert a significant influence on their behaviour. Certain animals that reside in temperate Climate engage in migration to alternate regions for the purpose of reproduction [11].

The environment plays a vital role in the survival and well-being of the female members of a species. For the juvenile larvae to survive, it is necessary for them to deposit their eggs underwater. Dragonflies rely on thermal regulation for their survival. They exhibit several actions, like as sunbathing, wing whirring, and obelisking, to control their body temperature. The anatomical configuration of the male reproductive organs in certain species of the odonatan order enables them to engage in post-copulatory sexual competition with other males in order to secure mates. Hence, the behaviour of dragonflies is significantly influenced by both biological and environmental factors. Dragonflies exhibit behaviour that is significantly shaped by their environment and the specific role they occupy within it [12]. Their behaviour is additionally shaped by their biological constitution. Dragonflies and damselflies belong to the taxonomic order Odonata, which is part of the insect class. Dragonflies have existed for millions of years and have demonstrated a highly effective anatomical structure. Dragonflies, being descendants of ancient ancestors, are considered to be generally unspecialized insects and have undergone few changes throughout their evolutionary history. These insects are of substantial size and are composed of a head, thorax, and abdomen. Every aspect of survival, including obtaining food, reproducing, and evading predators, relies on the ability to fly swiftly and with agility. Dragonflies possess large compound eyes, which enhance their vision and assist them in manoeuvring during flying. Dragonflies undergo a life cycle that has three distinct stages: the egg, the larval (nymph), and the adult stage. Notably, there is no intermediate pupil stage between the adult and larval stages. Dragonflies undergo an aquatic larval stage and a terrestrial or airborne adult stage. Dragonflies are carnivorous predators that opportunistically consume any prey they can capture and consume. Adult dragonflies engage in vigorous pursuit and consumption of their prey, whilst the larvae adopt a sedentary behaviour, awaiting potential predators. They remain immobile and patiently await the approach of prey, subsequently seizing them. The capture of prey is made easier by the utilization of a prehensile labium that may rapidly stretch towards the prey [12,13]. A comprehensive analysis was conducted on the diverse array of behaviours exhibited by dragonflies during their daily activities. These activities encompass a wide range of behaviours, including hunting, regulating body temperature, mating, laying eggs, flying, and engaging in combat.

Biology and ecology of dragonfly mating behaviour:

Male in numerous dragonfly species exhibits vigorous competition for favoured breeding and mating territories. Only the majority of males are given the chance to reproduce, while the rest are forcibly expelled. Male-male competitions encompass a range of activities, including combat, aerial battles, and showcasing vivid colours on the abdomen or wings. Female dragonflies do not engage in sexual competition like males, but they do compete with each other for the best feeding areas. Before mating with a receptive female dragonfly, a male dragonfly engages in a procedure known as sperm transfer. During this process, the male transfers sperm from his testis, which is located on the underside of abdominal segment 9, to the hamulus, which is placed on the underside of segments 2 and 3. This transfer is accomplished by flexing the abdomen until the relevant segments come into touch. Mating initiation is usually carried out by the male, who skilfully utilizes his legs to grip the female's head and thorax, resembling a wrestler's technique. Bending his abdomen forward, he utilizes his cerci and lower epiproct as a clamp, fastening the female at the posterior part of her skull. The term used to describe this stance is "Tanden." During the mating process, the male bends his abdomen downward, while the female similarly bends hers towards the male's hamulus. Once linked, the duo takes on the role of the wheel position, often known as the "copula." While maintaining their connection, they frequently move upwards to the secure area of the upper branches for reproduction, but certain species engage in sexual intercourse while in flight. The male initiates a procedure of cleansing the female's genital opening by employing the hamulus to remove any residual sperm from previous copulations with different males. This guarantees the male's genetic input to the group of eggs that the female will imminently deposit. The time of fertilization exhibits considerable variation, spanning from a brief 15 seconds to a significantly longer period exceeding an hour.

Guarding and laying of egg:

Once copulation is over, the pair may break up, or they may stay together until the eggs are laid. In certain species, the male assumes the role of protecting the female from the competition posed by other rivals and potentially even from predators. In other species, the female is alone in her egg-laying process. There are various ways in which guarding can be implemented. Contact guarding is the simplest form of guarding, in which the male remains linked to the female throughout the entire process of depositing eggs. Hover guarding is a method where the male positions himself above or near the female while she is in the process of producing eggs. From this advantageous position, he can launch an offensive and expel intruders from his area. A male engaged in hover-guarding behaviour may endeavour to safeguard multiple egg-laying females simultaneously. Additionally, there exists a scarce kind of protection referred to as karate guarding, in which the defending male firmly seizes an intruding male, similar to how he would grasp a potential mate, and restrains him until the protected female has deposited her eggs. Dragonflies utilize a variety of oviposition procedures to lay their eggs. Several female darners employ their spear-shaped ovipositors to deposit eggs into plant stems, *Sphagnum* moss, decaying wood, or damp soil. However, the majority of dragonfly species have ovipositors that are not functional. During flight, the female dips the tip of her abdomen into a body of water, such as a lake, pond, river, or stream, to wash off the eggs. Some dragonflies possess unique flanges positioned next to their genital opening, enabling them to deliberately strike the water's surface and release eggs into it. Certain females submerge the complete apex of their abdomen into mud or silt to lay eggs. The water mite (*Hydracarina* species) is the most prevalent parasite that can infest dragonflies. The larvae mites adhere to the larval dragonflies and consume their host's bodily fluid. Water mite larvae can kill very young nymphs and unhatched eggs, but larger dragonfly larvae can withstand this attack and may serve as hosts for several water mites.

Life as an aquatic larva:

The fact that the regal and vibrant dragonfly spends the majority of its life as a dismal, unsettling-appearing larva in the water astounds many individuals. Dragonflies endure an incomplete metamorphosis, consisting of three phases of development, in contrast to butterflies or mosquitoes, which have a complete four-stage metamorphosis. Dragonflies do not undergo a pupal stage during their life cycle. Incomplete metamorphosis comprises three stages: the egg, the larval (nymph), and the adult. Following the hatching of the egg, the mobile aquatic larvae undergo a single moulting process before commencing their ravenous hunting activities. As the larvae develop, they will undergo multiple moulting events. The majority of dragonfly larvae undergo a maturation process that lasts from one to three years before reaching adulthood. The migratory wandering glider undergoes rapid development, taking only four weeks from egg to adult. In contrast, several Asian species require up to 8 years to reach adulthood. Certain species found in the northern regions have a lengthier maturation period compared to the same species found in southern areas. The duration of maturity is influenced by elements such as water temperature and the length of the growth season. To withstand such a powerful attack and perhaps harbour several water mites, additionally, observe the small crimson organisms present on the limbs and thorax of fully-grown dragonflies. Before transitioning from the aquatic to the aerial form, the larva enters a period of diapause, or dormancy, during which the last modifications occur within the larval exoskeleton. Occasionally, they may rest with a portion of their head exposed above the water to aid in the process of transitioning to breathing air.

Emergence:

Emergence, the process of transforming from an aquatic larva to an adult dragonfly, typically occurs in the early morning. During this time, the dragonfly attaches itself to a vertical or diagonal surface, such as a plant stem, rockface, tree trunk, dock, or bridge abutment. However, some species of dragonflies may emerge from a horizontal posture. Once in position, the larva firmly attaches its claws on the perch. Following a brief period of repose, the skin on the posterior part of the head ruptures, allowing the thorax to emerge from the larval skin. The rupture expands towards the posterior region,

causing the head, squeezed wings, legs, and a portion of the abdomen to protrude. The dragonfly once again comes to a rest, curving its body backwards and suspending itself from its unexposed abdomen. During this period, the legs undergo a process of hardening. The dragonfly seizes its discarded larval exoskeleton with its newly developed limbs and extracts its abdomen. The abdomen elongates, and the wings expand as they become filled with haemolymph (blood). Following a brief while, the haemolymph is reabsorbed into the body, and subsequently, the young dragonfly, known as a teneral, rests while allowing its wings to dry for around an hour before attempting its initial flight. The discarded exuviae, which is the empty shell left behind by the larva, will stay in place until it is either blown away by the wind, washed away by rain, or taken by an inquisitive naturalist. Upon its inaugural flight, a dragonfly has already reached its complete, mature dimensions. Dragonflies are not juveniles; they are mature adults. There will be no further shedding of skin after they abandon their larval casing. Dragonflies experience a high level of vulnerability during the process of transformation. A population has seen mortality rates as high as 90% owing to bird predation. A multitude of dragonflies are prepared to take flight shortly after sunrise. It is a potentially effective tactic employed to evade predation by the early risers. Spiders and ants also consume a significant amount of juvenile dragonflies.

Larval stage:

Foraging:

Before reaching the adult stage, *Aeshna juncea* dragonfly larvae go through a three-year growth cycle [14]. The body sizes of the larvae vary greatly, with the older ones often being larger than the younger ones. The larvae exhibit indiscriminate predatory behaviour, preying on a wide range of organisms that they can acquire [15]. Odonates of various age groups frequently coexist in the same habitat and regularly interact with one another. In the wild, the eldest larvae exhibit cannibalistic behaviour by preying on their younger and smaller counterparts nearby. There is intense competition among the different size classes. The larvae exhibit aggressive behaviour towards conspecifics as well as heterospecifics, and cannibalism is prevalent among them. Both the large and small larvae frequently consume comparable sorts of prey. Field studies have revealed that chironomid larvae were the predominant prey discovered in the faecal remains of *Aeshna juncea*, present in 89% of the population. Ostracods were also identified in the faecal remains, albeit in a lower proportion of the population, specifically 70% [16]. Additionally, little larvae have been observed consuming smaller organisms, such as water mites, that are lower in taxonomic rank. The bigger larvae consume both comparable taxa and larger prey such as ants and wasps. The food of larger larvae exhibits a considerably wider range compared to that of smaller larvae. Larval dragonflies exhibit distinct adaptations to thrive in a population that is organized based on size. The smaller larvae exhibit diurnal feeding behaviour to minimize interaction with the larger larvae. The presence of large larvae in the same habitat significantly reduces the fitness of smaller larvae, mostly due to resource competition and cannibalism. Smaller larvae tend to reduce their time spent in open areas when they are in the company of larger larvae. The deprivation of essential foraging time resulted in reduced growth rates for the smaller larvae compared to those that were properly fed. Johansson and Suhling (2004) [17] found that dragonflies have slower growth when their foraging capacity is reduced. The behaviour of the smaller larvae alters in the presence of larger ones, causing them to become more covert and nervous. Younger and smaller larvae primarily feed during the day to avoid interacting with larger larvae, which often feed at night. They do this to minimize the chances of encountering sizable larvae, despite the fact that nocturnal feeding is more advantageous to the larvae compared to diurnal eating. Nocturnal conditions increase the larvae's likelihood of successfully capturing prey. The larvae of *Aeshna juncea* remain stationary and patiently await predators. The larger larvae exhibit greater mobility during the intervals between hunting for prey, whereas the smaller larvae tend to remain motionless for extended periods while awaiting their prey. Feeding observations have indicated that the little larvae exhibited greater levels of concealment and displayed less mobility compared to the large larvae.

Adult stage:

Foraging:

Dragonflies are recognized as opportunistic predators, exhibiting a feeding behaviour characterized by consuming a wide variety of prey that they can capture. Dragonflies are recognized for consuming a diverse range of small airborne insects, including other dragonflies. There have been recorded instances of dragonflies consuming larger prey, such as humming birds [18]. The eating behaviour of the dragonfly *Pachyliplax longipennis* has been extensively described by Baird and May [19]. The muscles utilized during aerial locomotion need a substantial quantity of energy. Consequently, the dragonflies are compelled to engage in regular foraging. The foraging flights begin and end at a stationary location. These flights are brief and specifically target the location of the prey [19]. Eighty percent of the observed foraging flights were directed towards the prey, moving forward and at angles of 45 degrees or greater. This immediately correlated with the dragonflies' highest-quality vision field. The males of this species exhibit strong territorial behaviour over water during mating and vigorously protect this specific location, incurring significant energy expenditure. They sustain these territories for extended durations with minimal hunting activity. This necessitates the presence of energy storage that is capable of enduring the entire duration of these flights. The females only frequented these locations for copulation and oviposition. Egg generation necessitates a substantial expenditure of energy and compels females to engage in increased foraging activities during the egg-laying process. Typically, males exhibited a higher tendency to react to a group of prey and showed greater aggression in acquiring this prey compared to females [19]. The duration of both flight and aggressive interactions among dragonflies was observed to be extended in the presence of water. The prey's availability exerted a significant impact on all foraging behaviours exhibited by the dragonflies. The foraging rates were observed to be maximum when there were big swarms of prey present. Dragonflies are more prone to having elevated levels of prey. The presence of large numbers of prey also influenced the dragonflies' choice of perching locations. Competing dragonflies also vie for perch positions near abundant prey swarms of superior quality. Dragonflies lacking a nearby perch site in the vicinity of a swarm were prone to attempting to seize the perch site of another dragonfly in close proximity to the swarm. Dragonflies seldom pursue exceedingly huge prey; they typically choose animals of a more manageable size. Engaging in the consumption of sizable prey will only yield benefits to individuals who possess the necessary capabilities to manage it. Dragonflies also refuse to capture prey that is too minuscule to be worth the effort. As an individual moves farther away from the perch site, the probability of hunting larger prey increases. The situation was increasingly dire. After a dragonfly hunts and captures its victim, it typically consumes one prey item completely before pursuing further prey. The likelihood of successfully capturing and consuming prey decreased when there were extensive contacts with other dragonflies [20]. Successful foraging rates were lowest when prey numbers were low. Dragonflies exhibited reduced predation success in habitats with lower prey populations. Research has revealed that solar radiation also impacts foraging behavior. The number and duration of foraging flights rose in direct correlation with the rise in sun radiation. Dragonflies initiate hunting immediately upon taking flight and persist until the foraging region is enveloped in shade during the late afternoon. Foraging was infrequent at frigid temperatures, although it occurred when there was sufficient sun radiation. *Pachydiplax longipennis* was only found in the shady feeding grounds when the temperature exceeded 24 degrees Celsius. The dragonfly can tolerate temperatures as low as 13 degrees Celsius in the presence of intense sunlight. During the afternoon, when the sun began to descend, a majority of the dragonflies would depart in response to elevated temperatures [20]. At sunset, when the shadow increases, the dragonflies abandon their lower resting spots and move up a tree to find higher resting spots that receive more sunlight.

Thermoregulation:

Dragonflies use a diverse array of behaviours to regulate their body temperature. Dragonflies have air sacs in their thorax which helps to regulate their body

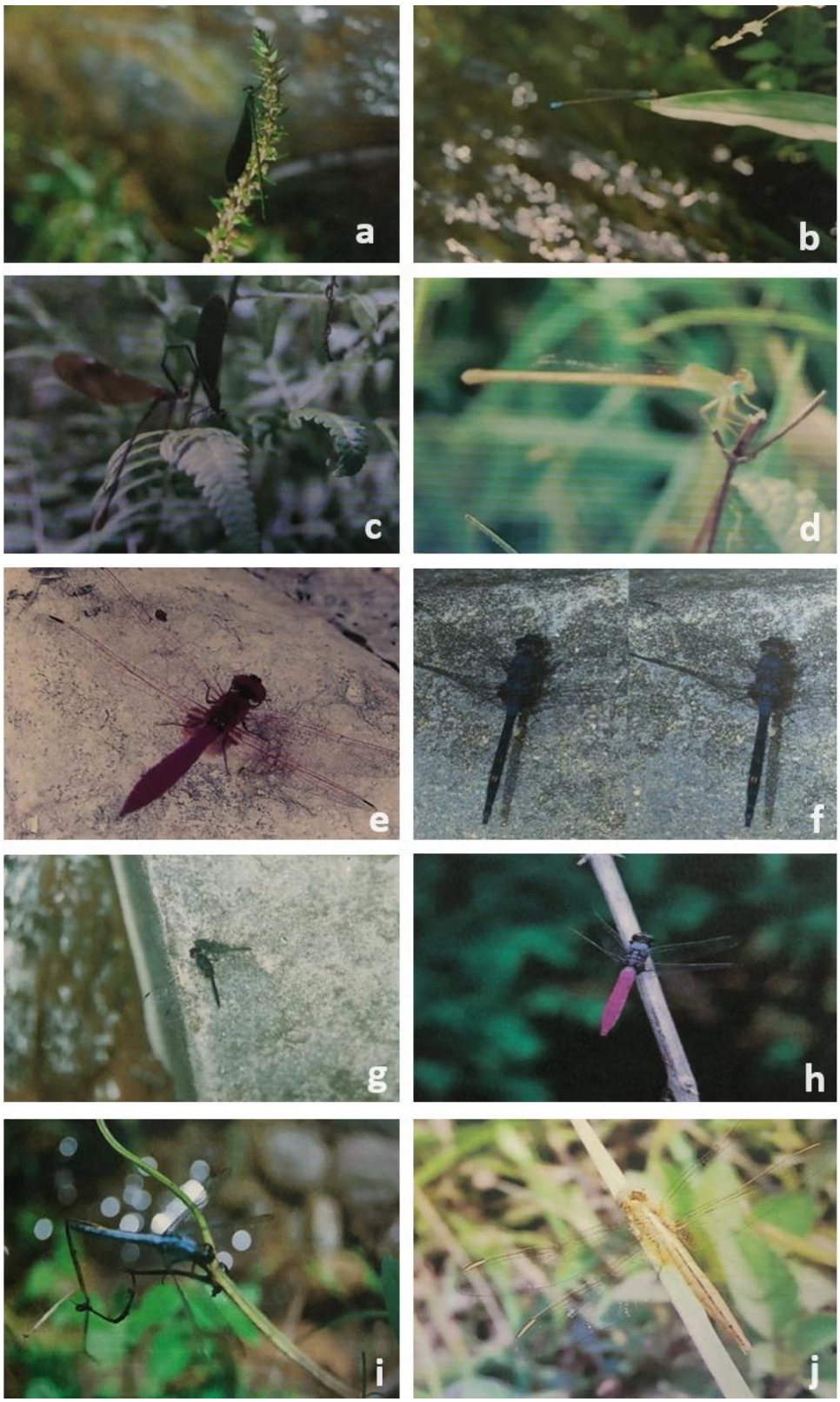

Fig1:(a) *Agriocnemis pygmaea* **(b)** *Pseudagrion rubriceps rubriceps* **(c)** *Neurobasis chinensis chinensis* **(d)** *Ceriagrion coromandelianum* **(e)***Trithemis aurora* **(f)** *Bradinopyga geminata* **(g)** *Brachydiplax sobrina* **(h)** *Orthetrum pruinosum neglectum* **(i)** *Diplacodes trivialis* **(j)** *Brachythemis contaminata*

temperature. They regulate their body temperature by facilitating blood circulation from the colder regions of their body to promote cooling. Subsequently, they return the blood to the abdomen and discharge it. Their bellies function as a thermoregulator, dissipating surplus heat acquired during flying [21]. During hot weather, birds abandon extended flights and instead opt for resting in shaded areas to lower their body temperature [19]. The capacity to roost in shaded areas or sustain extended periods of flight leads to significant autonomy in regulating body temperature, irrespective of the ambient temperature. Dragonflies can survive in environments that would otherwise be too severe for them due to their capacity to adjust their body temperature. For example, extended durations of flying over sweltering tropical regions [22].

Details of individual species studied:

Ceriagrion coromandelianum:

This species was found around ponds, tanks and streams. The females were commonly found in scrub jungles near the water bodies. Breeding takes place in weedy water conditions, having two or three generations in a year. Oviposition is endophytic and eggs are laid irregularly in the submerged vegetation while oviposition females stay in tandem.

Pseudagrion microcephalum

Pseudagrion microcephalum was found in plain areas. It was found near both temporary and permanent water bodies. It was found to breed in stagnant marshy waters and streams. Oviposition was endophytic, inserting eggs in submerged aquatic vegetation. A spurt in population was noticed during the September and October months.

Pseudagrion rubriceps rubriceps

Pseudagrionrubriceps was found amidst the vegetation. Eggs were laid above water level or in submerged vegetation, on twigs or the under surface of leaves, in transverse rows. This species was found to breed in perennial and temporary ponds, marshy streams and stagnant waters. It is a multivoltine species having three generations in a year.

Agriocnemis pygmaea

Agriocnemis pygmaea was found near water bodies and amidst vegetation. It was found to breed in temporary ponds, also in slow-running streams.

Neurobasis chinensis chinensis

Neurobasis chinensis was found near the densy shady streams. It was found to breed in streams of the area.

Brachydiplax sobrina

Brachydiplax sobrina was found perching on twigs in scrub forests, near the larval habitat. It was found to breed in small weedy tanks and ponds.

Orthetrum pruinosum neglectum

Orthetrum pruinosum was found around forest streams. Breeding takes place in slow-running streams, paddy fields, cemented tanks, and perennial and seasonal ponds.

Bradinopyga geminata

Bradinopyga geminata was found to show cryptic colouration, often found settled on cemented tanks and granite rocks, towards dusk many of these insects have the habit of invading verandahs. It was found to breed in cemented tanks and large steel drums containing water.

Diplacodes trivialis

Diplacodes trivialis was found to be one of the common dragonflies found in the area under present investigation. It was found to wander far from water and found settled in open spaces. Breeding was noticed to take place in swampy lakes.

Trithemis aurora

Trithemis aurora was found to be a common fly in the area. Adult males can be seen resting and males always found taking rest away from water. It was found to breed in sluggish streams and irrigation channels, rather than in ponds and streams.

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