



## REVIEW ARTICLE

# Promoting the utilization of weeds – A way forward

Nimal R. Chandrasena

Received: 25 October 2024 | Revised: 6 November 2024 | Accepted: 9 November 2024

### ABSTRACT

The utilization of ‘weedy’ colonizing species for direct human benefits and other practical applications is a much-neglected area within ‘Weed Science’. It results from an inadequate ‘eco-literacy’ (*i.e.* ecological understanding of weeds), which author call ‘weed-illiteracy’. Most weed scientists have been brought up hearing a flawed myth that ‘*all weedy species are bad all the time*’, and some may even engulf the world. Humans present the greatest threat to biodiversity, of which people and weedy species are constituent parts. However unpalatable this message is, it needs to be given much more publicity to achieve a better balance between human greed, the development aspirations of nations, and global biological diversity. A change in attitude and a focus shift are required to redress the issue. The *Boundary Object* concept provides an opportunity to have meaningful discussions about weedy taxa that have been used as a scapegoat for too long to hide human follies (related to disturbances caused by land-clearing, deforestation, inappropriate forms of agriculture, and excessive population growth). Consensus helps but is not always necessary for cooperation in successfully conducting investigative research. The boundary object approach allows collaborations on investigations of weedy species without always agreeing on divergent viewpoints. These may help ease the tensions and *change our perceptions* of colonizing species. It will also allow weed scientists, trained to think negatively about weeds, to explore the benefits of a positive relationship with a vast array of such taxa and their unique capabilities. Weeds should not be accused as guilty (of harm) until proven innocent! Colonizing species could assist in achieving the *U.N.’s Sustainable Development Goals (SDGs)* and Millenium Development goals, whose visions have been renewed. These globally-accepted frameworks seek to re-align investments and direct research efforts to improve societal benefits. Seeking ways to derive benefits from weedy taxa should be the basis of their fuller integration into societal needs. Instead of waging an unwinnable war against weeds, there is a convincing case for *living with weeds* for societal and environmental benefits.

Weed Science education must be re-aligned to increase ‘weed literacy’ by providing a much deeper biological and ecological understanding of weeds among agriculturists and environmentalists. Fast-growing and robust weedy taxa are at the forefront of providing *ecosystem services* in all habitats they occupy. Their ecological roles, including pollination and stabilization of degraded landscapes, are much undervalued within Weed Science. There is also compelling evidence that calls for broadening the mandate and the direction of *Weed Science* research to include the utilization of colonizing taxa. A ‘re-think’ on how we perceive weeds and weed research should be a priority for everyone concerned about the Planet’s future and preserving its biological integrity and diversity.

**Keywords:** Colonizing species, Utilization of weeds, Weeds, Weed Science, Weed research

## THE COLLIDING ‘WORLDVIEWS’ ON WEEDS

Most weed scientists are trained from their early careers to ‘see’ weedy species as ‘enemies’ and to fight them so that agriculture can be made profitable. This pessimistic ‘worldview’ on weedy species was purely from an agricultural perspective. The view that we must declare *war* on weeds and ‘exterminate’ them from our lands was first mooted by William Darlington 1859 in the mid-19<sup>th</sup> Century. However absurd the thought was, it became entrenched in the early decades of the 20<sup>th</sup> Century (Evans 2002, Falck 2010, Chandrasena 2014, 2019, 2020, 2021).

However, not everyone hated weeds, even in the mid-19<sup>th</sup> Century. Despite the farmers’ concern about the *unpredictable* crop losses from pests and weeds, a relatively benign attitude towards weeds also prevailed, at least within some sections of society in North America. For instance, a famous American Poet – James Russell Lowell (1863) wrote:

‘One longs for a weed, here and there, for variety, though a weed is no more than a flower in disguise, which is seen through at once if love gives a man eyes...’

Another influential naturalist, Ralph Waldo Emerson (1979, p. 8), praised weeds in a famous lecture delivered in Boston, USA, in 1878:

‘What is a weed? A weed is a plant whose virtues have not yet been discovered’.

Such statements show that sections of American society had no qualms about boldly expressing the positive side of weeds. At this time, the USA was emerging from the traumatic Civil War years (1861-65), which had ravaged much of agriculture in the conflicted South-Eastern States of the country. There were other naturalists also in the latter half of the 19<sup>th</sup> Century, such as George Perkins Marsh (1867), Gerald McCarthy (1892) and Asa Gray (1879), whose sympathetic views on weeds preceded our ecological understanding of the strengths and capabilities of colonizing taxa.

*Weed Science*, as a discipline in agriculture, first received significant national recognition in the USA and Europe only in the mid-1940s (Burnside 1993). The almost simultaneous discovery of herbicides 2,4-D (2,4-dichloro-phenoxy acetic acid) in the USA and MCPA [(4-chloro-2-methyl-phenoxy) acetic acid] in England during the *World War II* years (1941-42), revolutionized the field of selective weed control.

For the first time in history, around 1944, the selective activity of the auxin-mimic herbicides in controlling broad-leaved weeds in grass turf was demonstrated in the USA and U.K. This led to much excitement and the release of the first commercial herbicides (Duke, 2005). More or less, at the same time, the absurd idea of a ‘*War With Weeds*’ took root (Evans 2002, Falck 2010, Dwyer 2011).

This misguided attitude has been a bane of *Weed Science* and has been around for more than 70 years. From that time, this slogan has been like a *mantra*, repeatedly heard at various weed conferences. The war metaphor, a concocted narrative, believes *humans could win a war against weedy enemies*. The primary ‘weapons’ of war (herbicides) expanded rapidly as many new molecules were discovered and developed as commercial products in the 1950s and ‘60s decades. *Weed Science*, as a discipline, flourished in those decades (Duke 2005, Timmons 2005).

Somewhere along the way, we lost track of what we were dealing with. *Weedy species are a small cohort of the Planet’s rich biological diversity*. The species we label ‘weeds’ are ecologically nothing but ‘colonizing plants’. They comprise about 9-10% (about 3000 of 375,000 known plants worldwide). The taxa originated under a natural environment and in response to newly opened habitats or imposed habitat constraints to ‘colonize’ the vacant habitats. The evolutionary driver has been the opportunities created by disturbances and the availability of vacant niches. The genetic makeup of these extraordinary plants was formed more than 100 million years before humans walked on the Earth.

Herbicides initially provided highly effective weed control across agriculture and many other areas where weedy taxa posed problems, such as golf courses, infrastructure, public spaces and rights-of-way. These chemicals were considered ‘saviours’ and not problems. However, within two decades, the overuse of herbicides for weed control in agriculture and other situations presented a significant difficulty in the USA, U.K. and Western Europe.

More than six decades ago, ecologists and biologists warned that weeds would most likely evolve resistance to the repeated use of herbicides on the same land (Harper 1956). The incredible success of herbicides in killing weeds and the profits that could be made by the chemicals led to these warnings being largely unheeded. It also prompted *Weed Science to be derided as ‘Herbicide Science’* (Burnside 1993, Appleby 2005). The excessive focus on weed control and herbicides hampered the discipline from broadening an understanding of how people should integrate colonizing species more effectively and profitably into their lives.

Despite those enlightened views on weedy taxa, the opportunities to utilize their strengths were not realized for another 100 years until the latter part of the 20<sup>th</sup> Century. Water hyacinth [*Pontederia crassipes* Mart.] and other aquatic weeds were the first taxa to be seriously examined for utilization for societal benefits, mainly in the USA and for promotion elsewhere, especially in developing countries (Wolverton and McDonald 1976, 1979).

The objective in this essay is to explore avenues by which the utilization of colonizing taxa can be promoted, giving their human adversaries a chance to ‘re-think’ and adjust their positions – if that is warranted. Herein, discussions have been made on some ideas, concepts, and a framework that might help shift attitudes on weeds towards a more balanced ‘middle path,’ a doctrine that humans would do well to embrace.

### THE ‘BOUNDARY OBJECT’

The *Boundary Object* is an analytic concept of ‘scientific’ objects or entities inhabiting several intersecting and potentially conflicting social worlds. The idea was first explored by Susan Star and James Griesemer (Star and Griesemer 1989) in a seminal paper published in the *Social Studies on Science* journal. From my viewpoint, the terms ‘weeds’ and ‘utilization of weeds’ can be both ‘boundary objects’ because they divide people’s opinions by an invisible boundary. Weed Science history knows that disagreements about some weedy taxa can be robust among scientists who deal with them.

Nevertheless, from the original concept, boundary objects can link communities together as they ‘allow different groups to collaborate on a common task’ without agreeing on every issue. The ‘common task’ for which people must ‘collaborate’ is to understand the beneficial aspects of colonizing species and manage them without causing further damage to fragile ecosystems.

A few definitions and interpretations of a boundary object show this possibility (**Figure 1**).

‘A Boundary Object is an entity (**artifact, object, document, vocabulary**) that can help people from different communities build a shared understanding. Various communities will interpret boundary objects differently. Acknowledging these differences enables a shared experience to be formed.

‘A boundary object **allows coordination without consensus** as they can allow an actor’s local understanding to be reframed in the context of a wider collective activity’.

‘Cross-disciplinary collaborations require negotiation across disciplinary work boundaries, rather than working separately at the edges of the shared boundary’.

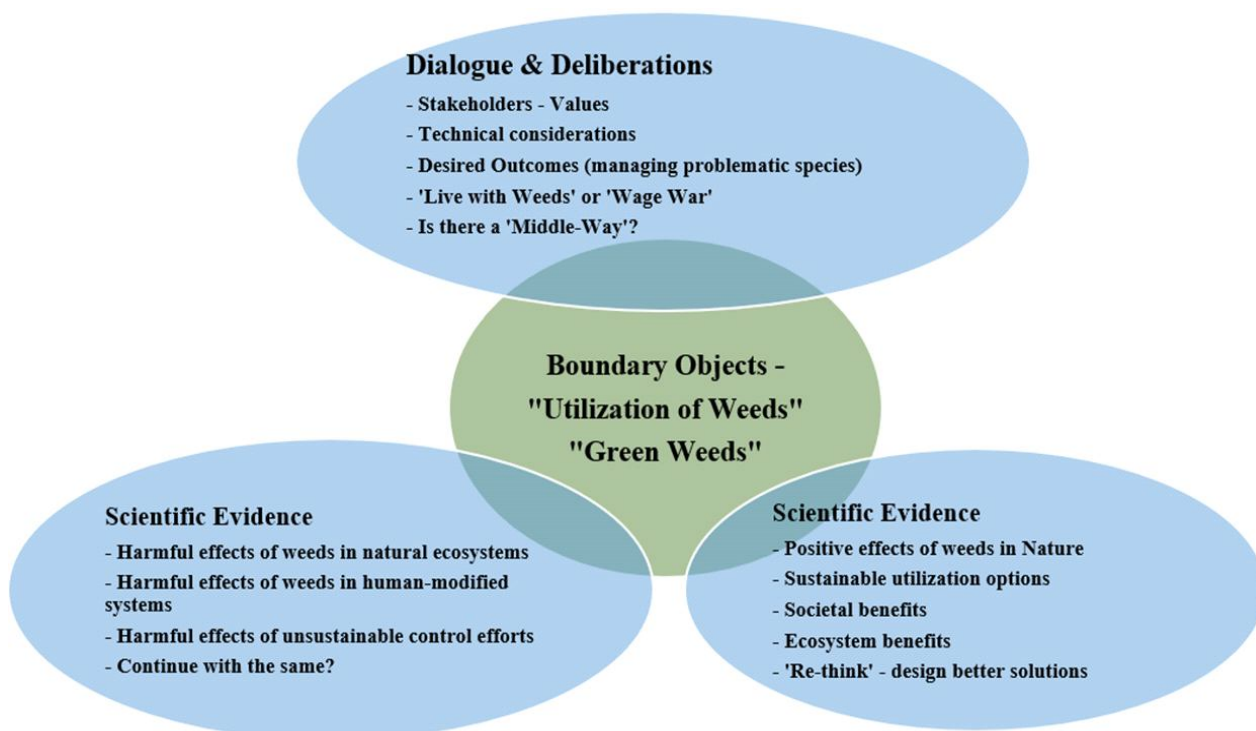
‘Boundary Objects are **learning objects**. This understanding acknowledges their role in ‘making meaning’ and better communications across diverse social groups’.

‘Objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity’.

How could weed scientists apply the boundary object concept as a *learning object* and a *tool* to improve communications between parties with different worldviews? A better ecological and evolutionary understanding of the species in question would reduce the tensions between those who *despise* weeds and others who *admire* them.

What happens when humans excessively disturb and modify their habitations and natural ecosystems is well known. Ecologists expressed six decades ago that *weeds are not the cause but a symptom of our inability to and failures in managing our living environment* (Bunting 1960, Baker 1965, Baker and Stebbins 1965). Weeds show us how plant succession occurs in new habitats after natural or human-caused disturbances. These taxa also highlight the evolutionary forces in Nature through their adaptations (see Baker 1965). With more than 120 million years of evolution in their genes, weedy taxa are far more successful in every sense as organisms than their human adversaries.

Using the ‘boundary object’ concept, those who admire weedy taxa could explain their strengths, weaknesses and virtues while asking for sustainable approaches to managing weeds where they may pose



**Figure 1.** ‘Utilization of Weeds’ as a Boundary Object in facilitating deliberate discussions without agreeing on every issue but aiming for rational discussions and collaboration between different stakeholders

problems to humans. These may include preventative, cultural and biological weed control, conservation farming, regenerative agriculture and ecological restoration methods. This side of the debate should also present evidence of the failures of overkill and the results of the overuse of herbicides (water and soil pollution, resistance development in weeds, biodiversity losses and public health issues).

Those with a relatively benign but still adversarial relationship with weeds will undoubtedly and justifiably re-iterate the losses of crop yields, farming profits, and other harmful effects of weeds, including potential habitat degradation and biodiversity losses (largely unproven). Those with hard-nosed attitudes towards weeds (i.e. *Invasion Biologists*) and those who follow such a narrative without challenge will continue to defend their robust actions to protect ‘natives’ against ‘alien invasions’.

The virulent undertones of this debate hamper the coordination of workable weed management solutions across landscapes. The more balanced position might be a ‘middle-way’ (Jordan and Davis 2017) to show the progress of *integrated weed management* (IWM) approaches, which are well-developed. All weed scientists and agriculturists know that IWM focuses more on preventative, cultural and biological weed control methods, which minimize the ecological disturbances caused by other methods, such as the excessive use of mechanical weed control or herbicides.

### Are Weeds ‘Guilty until proven Innocent’? Not So

E O Wilson’s book (1992) popularised the notion that ‘invasive species’ are the ‘second greatest threat in the world’, following ‘habitat loss’. The contentious idea ignited the emergence of *Invasion Biology* as a subject, expanding the ideas expressed in Charles Elton’s book (1958). The simple but fraught ecological process of ‘colonization’ by which highly adaptive taxa are established in new areas was misconstrued with a fear-invoking term ‘invasion’. Despite the lack of consensus (Hall 2003, Shackelford *et al.* 2013), many taxa are used as scapegoats for human follies and blamed as ‘*Invasive Alien Species*’ (IAS) that might engulf our Planet (Mooney *et al.* 2005, Rejmánek *et al.* 2005).

Nevertheless, many biologists have challenged the false assumptions in the ‘invasions’ and ‘native’ versus ‘alien’ viewpoints (Davis and Thomson 2000, 2001; Daehler 2001, Theodoropoulos 2003, Davis 2005, Larson 2005, Shackelford *et al.* 2013). These were followed by solid objections by philosophers (Sagoff 2002) and environmental historians (Chew and Laubichler 2003, Chew and Carroll 2011, Dwyer,

2011, Chew 2015, Guaiu and Tindale 2018). Writing to *Nature*, Davis and 18 others (Davis *et al.* 2011) complained about the nebulous concepts and narratives that blamed introduced species for human follies and objected to using fear-invoking terms in public discourses.

Defence against *invasions* became a primary goal of conservation biologists, who claim that the ‘impacts’ of IAS present a dire threat to biodiversity. In this narrative, any form of *colonization* of a new location by plants or animals is viewed as a problem (Chew 2015). Introduced species are accused of driving out the ‘natives’ all the time, an unproven claim in many landscapes. The ecological evidence that ‘non-native’ species seldom compete successfully with ‘natives’ in relatively undisturbed ecosystems is lost in this debate.

Disagreements about these views hinder the utilization of many species with unique capabilities that can be harnessed to help societies. Regrettably, the ideas were embedded in the *Convention on Biological Diversity* (CBD 1992) without much challenge. This inhibits people from thinking more positively about colonizing species and the advantages they may offer to society. The absurd assertion that all introduced species should be treated as ‘guilty’ until proven innocent took the maligning of weedy taxa to unjustified depths.

To say that: ‘all weeds must be guilty until proven innocent’ is a form of populism at its worst. The reversal of the universally accepted concept that everyone is ‘innocent until proven guilty’, so clearly enunciated for the public good, is intellectually dishonest. The quicker we stop using such divisive language, the better we will be as a society.

A large number of species, including some ‘farmer-friendly’ weeds, are listed as IAS, deserving lethal killing for merely occupying human spaces. In the confusion created by the IAS branding, one can excuse the public, scientists and policymakers for being misled. Many have been brainwashed to think that all ‘weedy’ species are plunderers of our resources, moving across geographical barriers to engulf continents. Changes to such irresponsible typecasting will come with time as attitudes change.

Discussions on weed discourses would do well to jettison the politically evocative terms - ‘alien’, ‘feral’, ‘invaders’ and ‘invasions’ and revert back to ‘introduced species’ (Chandrasena 2021). The boundary object concept can provide the framework for such a change, allow rational discussions, and work towards collaborations without necessarily agreeing on every aspect of the entity.

Those concerned with the environment must understand that the *Invasion* narrative was designed to create public awareness of the potential risks of introducing species across continents and countries. Undoubtedly, the powerful terms used influence the public's thinking and prevent positive relationships with weedy taxa. Critics (Theodoropoulos 2003) point out that the *invasion* narrative has nothing to do with a genuine interest in saving the world from *invaders*. The claim appears to be hyperbole to get more funding *for managing such invaders*.

Historical usage of the terms shows that the concept of '*nativeness*' lacks reliable ecological content. It simply means that a species under scrutiny has no *known* history of human-mediated dispersal and may have been a resident of a given biogeographical area for centuries (Chew and Carroll 2011, Hall 2003). Ecologists are responsible for prong that '*non-native species seldom compete successfully with 'natives' in intact and relatively undisturbed ecosystems. Human influences, i.e. deforestation, excessive land clearing for urban developments, nutrient enrichment in waterways, unsustainable levels of pastoralism and altered fire regimes, are some of the most significant causes that facilitate the spread of introduced species.*

When moved across geographical barriers and continents, only a mere handful can successfully establish themselves without help from humans. Also, only a few grew so much that they caused problems for humans and natural ecosystems. Moreover, many global examples indicate that not all species' introduction to new areas, regions, or continents is so dramatically detrimental, as conservationists and the media prefer to claim.

Ecology teaches us that given the variety of life cycles, reproductive strategies, and the dispersal means that plants and animals have, species can move about and spread on their own, crossing geographical boundaries. Many are assisted by natural vectors (wind, cyclones, water, landslides) to spread, establish, and colonize new areas. They also benefit from the disturbances that humans and other animals cause. However, *not all species, moved about by humans or other vectors, can succeed in all habitats in their new environments* (Watson 1847, 1870; Dunn 1905, Parker *et al.* 2013).

#### **'GREEN WEEDS' AS A BOUNDARY OBJECT**

How valid is the term 'green weeds' when used as a boundary object? The terms 'green economy', 'green technologies' and 'green living' are already well-entrenched boundary objects in the global

environmental discourses. As a result, the term 'green' is no longer ambiguous because it has a definite meaning when used in the proper context.

The term 'green' arose from citizen-driven, environmental movements in the 1960s and '70s. For centuries, people arguably lived more or less in balance with their surroundings. But a burgeoning population and economic booms in industrialized and developed countries put unbearable pressure on the Planet's climate as well as its natural environment and resources, including forests, waterways, soil, animals, and plants. The 'green' movement has now captured the attention of a significant population of ecologically-minded people in almost all countries. Climate change uncertainties have renewed the interest in 'green' and sustainable living, in harmony with the environment and 'eco-friendly' technologies. The scientific basis of 'green' living includes less consumption, less demand, fewer ecological perturbations, renewable energy, and recycling all biological and non-biological resources.

The green movement must also be recognized as a diverse scientific, social, conservation, and political movement that broadly addresses the concerns of environmentalism. It encompasses political parties, organizations, and individual advocates operating on international, national, and local levels. These groups are broadly unified 'across their boundaries' by a desire to protect the Planet's environment and Nature's capital (plants, animals, soil, air and water resources). If not for this common goal, many groups are diverse in philosophies, strategies and actions they champion.

Despite obstacles, the 'green movement' has succeeded in heightening public awareness of environmental issues that cause distress to the Planet and its inhabitants. Its growth reflects widespread social and scientific concerns about the degradation of the Earth's bio-physical environment. Everyone needs to realize that 'Going green' implies changing peoples' awareness about how their behaviour and consumption patterns contribute to unsustainable ecological harm to the Planet.

'Green enlightenment' aims to create or increase ecological awareness (*eco-literacy*) in societies. It seeks to cause lifestyle changes and reduce individuals' and collective societies' ecological footprint. These moves must be seen as in the right direction to save a planet in peril. As discussed below, I find 'green weeds' to be an appropriate adjective that can be readily lined up with well-established global concepts and efforts to improve the Planet's well-being.

### Ecosystem services and biodiversity

The Millennial Ecosystem Assessment (MEA 2005) defined *ecosystem services* as the direct and indirect contributions of ecosystems to human well-being, survival and quality of life. The concept of an ecosystem provides a valuable framework for analyzing and acting on the links between people and their environment. Ecosystem services can be categorized into five main types (MEA 2005):

**Provisioning services** – these are the products obtained from ecosystems, such as food, fresh water, wood, fibre, spices and medicines.

**Regulating services** – those defined as the benefits obtained from the regulation of ecosystem processes, such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control.

**Habitat services** highlight the importance of ecosystems in providing habitat for migratory species and in maintaining the viability of gene pools.

**Cultural services** include non-material benefits that people obtain from ecosystems, such as spiritual enrichment, intellectual development, recreation and aesthetic values.

**Evolutionary services** including benefits, such as genetic resources that evolve due to selection pressure exerted by humans and nature.

Biodiversity is the source of many ecosystem goods, such as food and genetic resources, and changes in biodiversity can influence the supply of ecosystem services. *Colonizing species are crucial members of global biodiversity and contribute to all of the five types of ecosystem services.*

### Sustainable development goals

Within the ‘greening’ ethos, I propose using the term ‘green weeds’ deliberately as a *semiotic* (a sign) to create an impression of opportunities. Can ‘green weeds’ be a part of human efforts to save the Planet? The evidence is compelling to say yes. However, weed scientists need to be convinced and encouraged to change their deeply-held views about the harm to human endeavours caused by weedy taxa. As discussed in this essay, ‘green weeds’ could help in many ways that would reduce the ecological impacts of humans and redress some damage that has already occurred on the Earth.

Historical facts and existing global knowledge illustrate that our weedy colonizers undisputedly contribute heavily to societal development in several critical areas, such as (1) Food and nutritional security and sustainable diets; (2) Sustainable

livelihoods; (3) Poverty alleviation, (4) Women’s empowerment, and (5) Gender equity.

Nevertheless, given the need to break down barriers and get people to ‘re-think’ their entrenched beliefs and lead them to have a balanced and rational discussion on the contribution weedy species can make to society, frameworks are needed. One important tool on which to base a balanced discussion is the United Nation’s *Sustainable Development Goals* (SDGs), which have been updated for 2030 (U.N. 2024). The latest update encourages signatory countries to pursue with vigour 17 goals (**Table 1**). Based on widely published information, data, and results over at least seven decades, a vast array of colonizing taxa can contribute significantly to achieving these goals.

At a UN summit in September 2015, 193 countries agreed to work towards the 17 Goals with the aim of improving the lives of all people and the Planet we inhabit. I propose using these Goals as a driver to promote the utilization of weedy taxa and thinking prompts, as shown in **Table 1**. To illustrate, I used an arbitrary scoring system from 0-5 to comment on the potential of weedy species to deliver benefits in achieving the UN-declared SDG goals. In this scoring, numerous, palatable edible weeds, which form a part of the diet in most countries, will score high in their potential to end hunger and achieve improved nutrition for societies (SDG Goal 2). *Sustainable diets* are diets with low environmental impacts that contribute to food and nutrition security and a healthy life for current and future generations.

Medicinal weeds that can be commercially extracted for pharmaceutical benefits need no further elaboration. Most societies also appreciate the dual benefits (nutritional and medicinal) that some taxa provide. Knowledge about such weeds dates back many millennia, well before the Christian Era, and must be an integral part of human society’s future development (see **Appendix 1** for examples).

The SDG Goal 1 – Ending poverty relies on all forms of employment that can increase peoples’ income and living standards. A great many weedy taxa, particularly multi-purpose, fast-growing shrubs and trees, already form the basis of cottage industries. These range from cellulose, fibre, dyes and essential oil extractions to paper and pulp industries. The production of innumerable saleable items by craftspeople and artisans using weed species as raw material is well established.

The products based on weedy species extend from baskets and mats to the globally-popular water hyacinth furniture. In addition to contributing

**Table 1. Potential Contribution of Colonising Species to Sustainable Development Goals (U.N., 2024) [Score 0-1 = Low; 2-3 = Medium; 3-5 = High]**

Goal No.	Goal purpose contribution	Score	Comments
1	End poverty in all its forms	3-4	Cottage industries, medicinal and edible weeds, food and fodder for livestock
2	End hunger, achieve food security and improve nutrition via sustainable agriculture	4-5	Edible weeds, market gardens, diversified crops, multi-purpose trees
3	Ensure healthy lives and promote well-being for all at all ages	3-4	Those mentioned above, plus Nature-based solutions (NSBs) and education
4	Ensure inclusive and equitable quality education and promote lifelong learning for all	1-2	Nature-based solutions and education
5	Achieve gender equality and empower all women and girls	3-4	Cottage industries, especially crafts
6	Ensure availability and sustainable management of water and sanitation for all	0-1	Water treatment wetlands for water quality improvement
7	Ensure access to affordable, reliable, sustainable, and modern energy for all	3-4	Many biofuel crops and potential taxa are weedy (i.e. high biomass grasses and those that yield oils (such as jatropha and castor-oil).
8	Promote inclusive and sustainable economic growth, productive employment and decent work for everyone	4-5	Small-scale and/or cottage industries, especially handicrafts, based on a large number of weedy raw materials with women's participation.
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	3-4	Industries such as essential oils, perfumes, dyes and a wide variety of value-added products from weedy species
10	Reduce inequality within and among countries	0-1	No direct effect
11	Make cities and human settlements inclusive, safe, resilient, and sustainable	1-2	Urban greening with fast-growing and resilient species, water-sensitive urban designs and stormwater treatment wetlands
12	Ensure sustainable consumption and production patterns in societies	3-4	Backyard market gardens with edible weeds provide food supplements and raw materials for sustainable consumption and production
13	Urgent action to combat climate change and its impacts (U.N. Convention on Climate Change)	4-5	Resilient landscapes, diversified farming
14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development	0-1	It may include fish farming and food from Azolla, Lemna, etc.
15	Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	4-5	All fast-growing species, including grasses, legume trees and others, restore vegetation via succession processes.
16	Promote peaceful, inclusive societies for sustainable development, with access to justice for all and build effective, accountable institutions.	0-1	No direct effect
17	Strengthen the means of revitalizing the Global Partnership for Sustainable Development.	0-1	No direct effect

U.N. (2024). Take Action on Sustainable Development Goals (<https://www.un.org/sustainabledevelopment/sustainable-development-goals/>).

significantly to poverty alleviation, cottage industries empower women (gender equity) and provide life-long learning to children and youth of the future while supporting families, livelihoods and the well-being of societies (SDG Goals 3, 4, 5, 8 and 9).

SDG 6 relates to sustainable management of water resources and sanitation. Colonizers, such as water hyacinth, cattails (*Typha* L. spp.), common reed [*Phragmites australis* (Cav.) Trin. ex Steud.] and many others are crucial components of wastewater treatment systems and constructed wetlands used to extract nutrients from stormwater draining large areas. Without such resilient species

with robust growth and wide ecological amplitudes, pollution reduction in waterways is not achievable. The phytoremediation potential of colonizing aquatic taxa, which is well demonstrated by a large variety of heavy metal accumulators, also falls under this goal. Some of the best examples are given in Appendix 1.

SDG 7 aims to promote affordable, reliable, sustainable and 'green' energy for all. This means renewable energy sources, including biofuel crops. Many fast-growing grasses, such as arundo (*Arundo donax* L.) and oil-yielding weeds, such as jatropha (*Jatropha curcas* L.), are at the forefront of contributing to this global goal.

Colonizing species are crucial contributors to SDG 8 (Promoting inclusive and sustainable economic growth and, productive employment and fair work for all) and SDG 9 (Building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation). Similarly, pioneer species are indispensable components of urban greening, water-sensitive urban designs, urban stormwater treatment wetlands and other Nature-Based-Solutions (NSBs). Resilient, liveable and sustainable cities (SDG 11) cannot be constructed with only slow-growing natives without fast-growing and resilient ‘weedy’ species.

SDG 12 sets goals to ensure sustainable consumption and production patterns. Cultivating beneficial weed species in backyard market gardens will provide supplementary food, balanced diets, and sustainable raw materials, contributing to lifestyle changes, sustainable consumption and production.

SDG 15 seeks to protect and restore damaged terrestrial ecosystems. Attaining the goal requires action towards sustainable forest management while expanding revegetation of large landscapes to combat desertification. The goal also encourages action to halt and reverse land degradation and prevent biodiversity losses. These objectives are unlikely ever to be attained without selecting and promoting resilient, fast-growing species, including multi-purpose trees from which societies could benefit greatly in the longer term<sup>5</sup>.

### Can the two colliding worldviews be reconciled?

The essential question we need to answer is how the conflicting worldviews of weedy species can coexist without adversely affecting each other. The boundary object concept allows scientific collaborations without consensus on any aspect. Ultimately, all parties need a way forward to manage the adverse effects of weeds while balancing control efforts with their practical and bioresource values.

A vast knowledge base in *Weed Science* confirms weeds’ actual and potential adverse effects on agricultural crops and non-agricultural situations. The adverse effects depend on many factors, including the levels and nature of the disturbances, the specific species and/or the weed community.

Whether the weedy species grow unchecked also determines their success in modifying ecosystems by their sheer abundance and pertinacity. However, not all such species are harmful in all situations. Regrettably, ecological knowledge about plants, animals, microbes and how complex biological systems work on this fragile Earth is not a high priority for most people. As a result, making

people understand the virtues of weeds is a considerable challenge. The uses and opportunities of the species remain under-explored (Jordan and Vatovec 2004, Chandrasena 2008, 2014). For some weed scientists, the utilization of weedy taxa seems like an *idealistic position* rather than a realistic and attainable goal. A few, surprisingly, have gone even further, believing that the *utilization of colonizing taxa is the future!*

With some species, such as water hyacinth that can be exploited for innumerable practical uses, as well as arundo and jatropha that can potentially be expanded as biofuel crops, utilization may present modest but manageable risks. Herein, I invoke Colorado State University’s Emeritus Professor Robert Zimdahl’s thoughts on what a ‘good observer’ would be (*pers. comm.* Nov 2020):

“What we need are good observers. A good observer sees what they are looking for when it is there, does not see what they are looking for when it is not there and sees what they are not looking for when it is there”.

‘*Good observers*’ and good researchers in Weed Science should not miss possibilities of utilization of weedy taxa. I would also add that all good observers need to *observe as objectively as possible* and have an open mind in acquiring new knowledge. We owe that to Science and our training.

### ‘Responsibility’ – a Virtue

Responsibility is counted as an environmental virtue in ethics and is often expressed as a good character trait. With compassion and benevolence, a ‘good human being’ will take responsibility for behaving appropriately towards the environment, including all other species (Thompson 2011).

Extending from such ideas, individuals and a collective society *must* take *responsibility* to obtain an enhanced ecological understanding of the interactions between humans, other species and the environment. This awareness is critical in dealing with colonizing taxa. When and where the excessive growth of a weedy species or a community becomes a problem, whether in agricultural or non-agricultural settings, we must manage them using well-developed tools, tactics, and strategic approaches. We must also do so without harming the environment or other organisms that rely on the colonizing taxa. This is being good environmental stewards.

The echo of the misinformation – that humans can win a war against weeds - reverberated through the discipline in the 1960s, ’70s and ’80s decades. The message was heard loud and clear by public officials, land managers and volunteers, who



enthusiastically joined the ‘forces’ against weeds. More ecological understanding and common sense should have alerted ecologists, weed scientists and environmental scientists that it is foolish to believe in such a myth just because we have an arsenal of herbicides in our possession. As a result of accepting the pervasive myth, most weed scientists have become wary of evaluating the ecological roles that weedy taxa play in Nature and exploring the opportunities to integrate them into our lives.

These days, most media stories blare out the sensational message: *All weeds are bad news*. Disappointingly, thousands of weed research articles, even in recognized weed science journals, also give the same negative message. Many weed scientists are still too busy ‘*battling*’ the evolving weedy taxa to think about concepts and practical applications of utilization that weedy taxa offer. A major obstacle is the shallowness of the discourse and prevailing ‘*weed-illiteracy*’. Ideas regarding ‘*beneficial*’ or ‘*tolerable*’ weeds run contrary to killing weeds. Any ideas about utilization are thwarted by the ‘*fear*’ in people’s minds regarding weedy species, presented as ‘*aliens*’ ready to engulf the world.

*Hiding the positive attributes of the accused is part of this story of misinformation.* The ease with which proponents spread falsehoods about colonizing taxa inhibits a better relationship with them. *Our societies are poorer for this mistake.*

The frameworks and concepts for managing a potential risk posed by a specific species are well-developed within Weed Science and related scientific disciplines. Given this, we have a moral responsibility to change our attitude towards colonizing taxa so that suitably targeted action to manage them can be taken on a *case-by-case* basis, *where, when and if required*. The experience of ecological restoration projects is that taking drastic and lethal action against any widespread species in most habitats is often unnecessary and futile.

Devine-Wright *et al.* (2022) recently argued: ‘*The learnings from Social Sciences prove that placing people at the centre of solving the problems they have created is essential*’. Additionally, actions by individuals and society are crucial, as humans face a precarious future under a changing climate.

The resolution of most environmental conflicts lies in people’s power over issues that concern them. The vexed issue of *colonizing taxa*, which are accused of being a constant problem in agricultural land, home gardens, public spaces or nature reserves, falls into this category. There can be no doubt that sustainable solutions need to be found for problems

that weedy taxa may create by their sheer abundance in specific situations. However, people can only find lasting solutions with a sympathetic attitude and enlightened ecological understanding. Developing practical solutions will require balancing the harmful effects of colonizing taxa with their positive effects, previously discussed.

Zimdahl and Holtzer (2021) have argued that in all our activities, we should worry about the *ethics* of what we do. Humanity has a moral responsibility to ‘*do no harm*’ to the environment, biodiversity and the Planet. In their view, profits alone must not be the critical driver in agriculture or all other productive endeavours. The *environmentally responsible* person will be disposed to acquire the knowledge to achieve and execute that know-how.

It is also important to note that, as climate change adaptations show, *science and technology alone cannot solve complex societal problems*. All our actions should be undertaken with an eye on protecting the Earth and sharing resources with billions of other animals and plants. A priority must be to conserve what *Mother Earth* has endowed us with. However, we must allay our fears of the so-called ‘*Aliens*’ or ‘*Invasive Alien Species*’.

Regardless of our capacity to kill weeds in most situations, by their sheer tenacity and abundance, pioneering species give us several messages. The paramount message they give is their capacity to adapt rapidly to climate change and to any other selection pressures humans may apply on them. *Despite our undoubted ingenuity, do humans have that adaptive capacity? The answer is no.*

Notwithstanding the inconveniences weeds may cause humans, they will always be there, now and in the future, as part of the Earth’s rich biodiversity. *We should be thankful that these pioneer species exist and are unlikely to go extinct.* The time is upon us to enter into a peaceful co-existence with colonizing taxa and learn how to live with them.

Contrary to the alarmists’ view, colonizing taxa *will not take over the world*. It should hardly be necessary to point out that *the Earth has no feral future!* The distortions of what science has taught us are driven by the feeding frenzy of the twenty-four-hour news cycles. Sensational messages consume us day-in-day-out. Science writers, looking for attention-grabbing stories, put their own spin and often get the message wrong.

The echo chambers of negative messages on weeds are primarily designed to obtain more funding to manage the *invasion* threats. But they skew our

thinking, make people feel powerless, and often debilitate our rational thought processes concerning the true Nature and virtues of colonizing species. Public servants who deal with policies on weeds and natural resources, feeling the need to protect their jobs, prefer not to be too vocal in support of weedy taxa and their uses. Some convince themselves that what they do is correct, and the alternate view - promoting the utilization of weeds for any ecological or societal benefit - will go against the grain.

Since the mid-1990s, substantial weed research funding has been spent in Australia, unimaginatively, to ‘manage’, more or less, the same list of species, with limited success. The absence of funding for exploring potential uses of colonizing taxa in such calls for research reflects how the discourses have been hijacked by the more powerful (negative) voices. *Use-inspired, utilization research funding, whether basic (pure) science or applied science, will only come with determined campaigning by concerned citizens, researchers, scholars and academics, who seek better solutions.*

In dealing with weedy taxa, governments often take a ‘we-know-it-all’ attitude, which leads to ‘top-down’ enforced approaches. Such approaches fail because it does not adequately foster collaborations and community-based weed management. The availability of funding for on-ground weed management is also influenced by privileged stakeholder groups whose voices are more powerful than those of environmental groups and advocates of conservationist agendas.

Compared to countries with diverse and mature cultures, the European mindset on weeds is an impediment to exploring the utilization of colonizing taxa as bio-resources in Australia. The fear of weeds, stealing resources from crops and drawing energy out of human endeavours is deeply ingrained in the population. Unfortunately, the knowledge of the extensive use of weeds as biological resources within Australia or by other traditional cultures extending to nearby Oceania has not penetrated deeply into the society’s worldview.

The low population density in the large Australian continent does not help. Generally, low-density regional communities are too small to economically utilize the large biomasses of colonizing taxa, spread across vast and mostly arid landscapes. Another powerful reason is the relative affluence of the population, given Australia’s mining-based economy. Most people are wealthy, deriving income from manufactured goods and services rather than from biological resources. The affluence creates little incentive for people to utilize natural resources for

their livelihoods. This is especially true for plant resources unless that use is directly related to profitable pastoralism (*i.e.* fast-growing grasses as fodder, and N-fixing ground-covers or shade trees). A large portion of wealthy Australians also have no reason to develop sympathetic attitudes toward Nature, which they believe is there to be exploited. *In this social milieu, weedy taxa are cast aside as unimportant, or worse still, to be killed off at every opportunity.* The disconnect between sectors in the community and the environment is also a contributory factor that creates conflicts with species.

In Australia, pastoralists derived enormous benefits from N<sub>2</sub>-fixing legume trees and leguminous cover crops, introduced over a Century ago to improve grazing lands and animal fodder. But it did not take long for the same farmers to despise these species as they spread across vast, arid rangelands. Although the judgements of wealthy landowners and pastoralists with vested interests are flawed, they form solid political constituencies, and their voices drown opposite views on specific species.

*Science is not enough* to answer whether we can ever coexist with weeds. Value judgements, societal considerations and democratic decisions are involved. These should be underpinned by scientific and non-scientific knowledge and a commitment to Nature. Non-scientific knowledge comes from traditional knowledge, as well as the personal experiences, intuition, logic, and authority of individuals in a society. Scientific knowledge, on the other hand, relies on hypothesis-testing and research findings obtained by following the scientific method. Weed scientists are responsible for engaging more with people working on ‘weed policies’ or focusing on the *social ecology* of weeds. Weed scientists across the globe must also take responsibility for a better understanding of colonizing taxa before embarking on developing unsustainable and lethal solutions. We must learn lessons from how weedy taxa rapidly evolved resistance to the continuous use of herbicides (Heap 2022).

If our genuine desire is to protect the Planet’s environment from the ravages allegedly caused by ‘colonizing taxa, blamed as the ‘*second greatest threat to biodiversity*’, we must find more funding to prove this claim more convincingly. We also need better measures and ecological data to inform our understanding of the effects of colonizing species across varied landscapes and time scales. In the long term, most weedy species will *coexist* with the so-called ‘natives’ without completely displacing the latter or causing irreparable harm.

By writing many articles on weeds, one should not expect the public to understand weeds or weed-related issues of concern. Suppose researchers care about how their findings influence public opinion and government policies. In that case, they must redress this ‘communication gap’ and ‘translational deficit’. This deficit, evident in many *Weed Science* articles, is possibly due to inadequate *ecological literacy* and, often, poorly selected research topics with only an academic interest but little practical value to society.

The *translational deficit* regarding the practical applications of specific research findings and insights can only be remedied by balancing scientific evidence with societies’ priorities. Perhaps weed researchers should better understand weedy taxa and moderate their views regarding the objects they are dealing with. This will help many researchers not start every article saying that all weeds should be controlled at all costs and that weeds are among the greatest threats to the Planet’s biological diversity.

Only cross-disciplinary research, integrating weed research with other disciplines, including *Social Science* and *Ethnobotany*, will allow weed scientists to better appreciate the values of weedy taxa. Weed scientists must realize that they are also responsible for forming hypotheses regarding the potential uses of colonizing taxa that can be carefully tested. Presenting a convincing research agenda is the only way to attract funding from governments or civil societies and change the discourses to favour these resourceful taxa.

The prevailing *minority view* that weeds are not the enemy of humans, not liabilities, but are valuable resources – for now and for the future, is not a radical idea. Nor is it a misleading notion. Although the message is somewhat muted in the discourses, most people, farmers, biologists, and even politicians who care for the environment will have to agree.

Colonizing taxa have clearly staked claims on disturbed habitats over large landscapes, which are increasing around human habitations. This is inevitable as the vast human population disturbs the Planet’s natural ecosystems. Hardly any areas on the Planet now exist untouched by human hands.

The sheer abundance and persistence of many weedy taxa get our attention. They meet our wrath because they will not yield to control easily. These experiences often cloud our judgements, and in this confusion, it is easy to overlook the redeeming values of colonizing species. They provide vegetative cover over barren areas, stabilizing soil, anchoring nutrient cycles, producing food for animals and humans, and pollen and nectar for bees. They enrich Nature by

adding variety, richness, abundance and biological diversity to any landscape.

Let’s listen carefully and also observe carefully. We will hear the silent story that weedy, pioneering species tell us – *of their resilience in the face of adversity and capacity to adapt* – profound lessons humans can and should learn. The species also spotlight a spectrum of human follies in damaging the environments we should preserve.

### Learning from nature

Instead of demonizing species, we must learn from each other, Nature, and pioneering plants and animals. Our ancestors, *pioneers themselves*, did so admirably. Our existence today is a testament to our pioneer ancestors’ adaptability and survival skills. Unfortunately, survival is now precarious for many human cultures and societies across the globe. As climate change poses the greatest threat to humankind’s survival, our future existence as a species depends on how well we integrate with Nature’s wonders and the challenges the natural world throws at us. Humility, combined with a fundamental understanding that we are merely a species passing through a specific period in the Planet’s life, would be a definite advantage as we continue our struggles to survive on Earth.

We must also do our best to mitigate human impacts on the environment. Some of the most destructive human activities include the excessive use of fossil fuels (related to global warming), over-exploitation of natural resources (such as caused by mining for oil, gas and minerals), habitat destruction, large-scale deforestation, expanding animal farming, monocultures and other forms of unsustainable agriculture. One must add soil, air, and water pollution, damages caused by the globally rampant wildlife trade and poaching, and pollution caused by human waste created by a burgeoning population.

An emerging idea – of *Nature’s Contributions to People* (NCP) – was recently highlighted by Pascual and co-workers (2017). It is a conceptual framework that fits the world of colonizing taxa and how we may strive to create a sustainable future for the present and future generations. As the authors explain:

“...Nature’s contributions to a good quality of life are often perceived and valued by people in starkly different and often conflicting ways. People perceive and judge reality, truth, and knowledge in ways that may differ from the mainstream scientific lens...”

“...Hence, it is critical to acknowledge that the diversity of values of nature and its contributions to people’s good quality of life are associated with

different cultural and institutional contexts and are hard to compare on the same yardstick...”.

The NCP concept is a pluralistic approach, applicable to knowledge-based policy initiatives. The NCP platform recognizes the benefits of embracing diversity and power relationships across stakeholder groups with different values regarding human-nature relationships. Resonating with the term *Ecosystem Services*, the NCP concept includes all of the positive benefits and occasionally negative contributions, losses, or detriments that people obtain from Nature (*anthropocentric values*). It also captures a *non-anthropocentric* value centred on something other than human beings. These values can be *non-instrumental* (e.g. a value ascribed to the existence of a specific species for their own sake) or *instrumental* to non-human ends (for example, the instrumental value a particular habitat type may have for a species that is well-adapted to it).

Other knowledge systems, such as ‘*Nature’s Gifts*’, prevalent in many indigenous and traditional cultures, are recognized within the NCP concept. In a sympathetic worldview, colonizing taxa, which are accused of causing adverse effects on biodiversity and people, fall within the milieu of NCP and are most certainly ‘*Nature’s Gifts*’. *A flexible mind will allow us to seek clarification on this viewpoint.*

### Conservation of biodiversity

I sometimes wonder how many people actually appreciate that the most unique feature of the Earth is its biological life, and the most amazing feature of life on Earth is its biological diversity. Innovative messaging and a greater emphasis on ‘*ecological literacy*’ are required in discourses to hammer this message to some sections of society.

*Approximately nine million types of plants, animals, protists and fungi inhabit the Earth. So, too, do more than eight billion people.* Human actions have been continually dismantling the Earth’s ecosystems, eliminating genes and biological traits of these species at an alarming rate (Hooper *et al.* 2012, Cardinale *et al.* 2012). Most people push global biodiversity losses and their link to human activities to the margins of their consciousness because they cannot comprehend the complexities of understanding ‘causes and effects’. Some people (such as climate change denialists) refute the linkages altogether, mainly for their own benefit.

There is still a great deal of money to be made by continuing destructive activities, such as large-scale logging of the tropical forests in Borneo or the Amazon and relentless extraction of oil and gas in the fossil fuel industry. Despite the overwhelming

evidence (IPCC 2022), it is too risky for many parties to accept that climate change is occurring. *And the poor will suffer most from inaction by the rich.*

Nevertheless, a clear message emerging from ecological studies is that increased biodiversity often leads to more significant and less variable levels of ecosystem functioning. That means that the richer the biodiversity, the lesser the threat of the extinction of plant and animal species.

Cardinale *et al.* (2012) and Hooper *et al.* (2012) argued that diversity-driven increases in function can boost rates at which nutrients, energy and organic matter flow through an ecosystem and increase their overall multi-functionality and stability. Therefore, in the conservation efforts of global species and ecosystems, maintaining high levels of overall biodiversity across landscapes is necessary to even reduce the extinction risks of specific species.

As critical components of biodiversity in any bio-geographical area, assemblages of pioneer taxa would collectively exploit the resources of particular environments to maximize the cycling of energy and nutrients through those ecosystems. Along with all other life forms of plants, pioneer species will fill various ecosystem roles. Of their very unique Nature, they will withstand disturbances and bounce back, responding to environmental changes. Although frugal in how they consume resources, these highly adaptive species will share them.

### Concluding comments

It has been argued in this paper that *Weed Science* will continue to under-perform if our discipline does not consider that weeds may, in many situations, provide positive ecosystem services for the Planet and societal benefits, not just disservices (Marshall *et al.* 2003, Jordan and Vátovec 2004, Altieri *et al.* 2015, Chandrasena 2019). Therefore, weeds are not plants that should *necessarily* be killed all the time with herbicides or any other method. This point has emerged strongly in recent discourses on ecosystem services and disservices (Vaz *et al.* 2018; Tebboth *et al.* 2020, Guo *et al.* 2022).

Therefore, we should encourage weed scientists in India and elsewhere to look beyond the paddock in researching weedy taxa for their values and usefulness in future societies. Those who are in cropping systems research and agriculture must look for opportunities to live with weedy species and focus on *nature-friendly farming*, *conservation farming* and *regenerative agriculture* systems. As Altieri *et al.* (2015) showed, the pollination benefits alone of maintaining weedy taxa in agricultural landscapes is enormous. Besides, weedy taxa and

their genes enrich the biological diversity of landscapes which they occupy. Can people ever imagine a world without colonizing species?

At all times, we must use IWM approaches to tackle and manage those problematic species in the field and be aware that this might take more than a few seasons. None of the above ideas is new. Many countries have adopted ways by which they could use weedy taxa and the bioresources they provide to the maximum. However, in our Asian-Pacific region, weed biodiversity and utilization are topics that are yet to become front and centre of weed discourses.

Hill and Hadly (2017) recently wrote: ‘*As the world stumbles deeper into the Anthropocene, the novel biogeographic dynamics (globalization, mass disturbance, and climate change) will progressively warp habitats*’. Under such disturbances, colonizing taxa will thrive and change their habitats. However, I must emphasize that *weedy species are no more alien or villainous than we humans have been*. With or without humans on the Planet, colonizing species will play vital roles in stabilizing the Earth’s ecosystems. *They will also survive future catastrophes on Earth. We may not.*

Countering mis-information about weedy taxa requires the following: (1) recognition of the seriousness of the problem and (2) refuting the claims that weeds are bad news all the news with evidence-based scientific findings. Science helps us approach the ‘*world of weeds*’ with wonder and humility. Scientific ethics call for us to have an honest dialogue with Nature. Science will also help us fight fake news and mis-information, navigate the troubled waters, and find a more resilient and reasonable position concerning weedy taxa. We must all strive to ‘*re-think Nature*’ (Hill and Hadly 2018) and attempt to find the ‘*middle ground*’ in the discourses (Shackelford *et al.* 2013) instead of blaming colonizing taxa for human follies.

Sometimes, science, as a human enterprise, moves too slowly, as Thomas Kuhn (1962) said. Science is also largely conservative in the sense that changes in ideas and directions occur only after the cumulative accumulation of sufficiently robust evidence, which might take a long period. Science also suffers from prejudices, sentiments and conventions, as it is a human endeavour.

Concerning the broad aspect of *utilization of the powers and strengths of weedy taxa*, I believe that we have reached a point that the evidence cannot be ignored any more. We are all aware that scientists

spend too much time taking long periods and small steps towards working out solutions to a problem. Weed researchers are no exception to this. Introspection and profound reflections on the subject matter are critical to formulate new hypotheses and test their validity. However, when there is a large volume of evidence to support changing a paradigm, scientists should not hesitate for too long.

We believe colonizing taxa, labelled intruders in human-modified landscapes, have suffered enough. This “fixed” pessimistic worldview of colonizing species has led us to a crisis point of relentless warfare against them. This unsustainable, negative attitude must change to a new paradigm of ‘living with weeds’, which is not radical. Positive appreciation of weeds has also existed around human-plant interactions for millennia.

With their remarkable botanical and ecological attributes (Baker 1965), weedy taxa generate ‘threshold’ situations for us – moments when the factors that cause environmental degradation are, for a time, reversed. We can take advantage of these moments. Weeds can turn the plant world and enhance the biodiversity of landscapes around them and make a genuine dialogue with all that is ‘still wild’ possible. This suggestion (claim) can be scientifically investigated, which will help understand their critical ecological roles better. We encourage weed researchers all over the world to urgently re-focus attention on understanding the ecology and biology of weeds a great deal more. Weed scientists should also redouble their efforts to combat misinformation about weeds and seek a collaborative co-existence.

Egocentric humans might argue that humans can devise ways to survive without the natural world and that we need not depend on it for our existence. But is that world we want to live in? People will find no joy in a world without the rich diversity of flora and fauna, including colonizing species that share the Planet with us. Weed Science, in my view, should also be taught at various levels, to foster a deeper appreciation of our natural world and the critical role weedy species play in it. A change in attitude towards misunderstood weedy taxa can be expedited by focusing on their utilization and economic values and *what they can offer to our Planet mother, who is presently in distress*. In that sense, what I have sought to highlight in this essay is not necessarily a need for a ‘paradigm shift’ in Weed Science (in the sense of Thomas Kuhn 1962) but simply an objective re-appraisal of weedy taxa that can assist both human societies and the distressed Planet.

## REFERENCES

- Altieri MA. *et al.* 2015. *Crops, Weeds and pollinators. Understanding ecological interaction for better management.* Food and Agriculture Organization (FAO). p 106 (<http://www.fao.org/3/a-i3821e.pdf>).
- Appleby AP. 2005. A history of weed control in the United States and Canada - a sequel. *Weed Science* **53**: 762–768.
- Baker HG. 1965. Characteristics and modes of origin of weeds. pp. 147–172: In: *The Genetics of Colonising Species*. H. G. Baker & G. L. Stebbins (Eds.) Academic Press, New York.
- Baker HG and Stebbins GL. (Eds.) 1965. *The Genetics of colonising species*, Academic Press, New York.
- Bunting AH. 1960. Some reflections on the Ecology of Weeds. Pp. 11-25. In: *The Biology of Weeds*. (Ed.) J.L. Harper, Blackwell Scientific, Oxford.
- Burnside OC. 1993. Weed Science – The Step Child. *Weed Technology* **7**: 515–518.
- Cardinale, B. J. *et al.* (2012). Biodiversity loss and its impact on humanity. *Nature* **486**: 59–67.
- CBD (1992). *United Nations convention on biological diversity* (<https://www.cbd.int/convention/text/>).
- Chandrasena NR. 200. Liabilities or Assets? Some Australian Perspectives on Weeds, Chapter 1 (pp. 9-56). In: *Utility of Weeds and Their Relatives as Resources*, (Eds. Kim, K. U. *et al.* Kyungpook National University, Daegu, Korea.
- Chandrasena N. 2014. Living with weeds: A new paradigm. *Indian Journal of Weed Science*, **46** (1): 96–110.
- Chandrasena N. 2019. Seeing ‘Weeds’ with new eyes. *Weeds* **1** (2): 1–12.
- Chandrasena RN. 2020. ‘Alien’ Species, ‘Pertinacious Weeds’ and the ‘Ideal Weed’ – Revisited. *Weeds* **2**(2): 1–16.
- Chandrasena NR. 2021. ‘Aliens’, ‘Natives’ and ‘Artificial Habitat’ -Revisiting the Legacies of H. C. Watson and S. T. Dunn. *Weeds* **3**(1): 1–19 ([http://apwss.org.in/Article.aspx?Article\\_id=23](http://apwss.org.in/Article.aspx?Article_id=23)).
- Chew MK. 2015. Ecologists, Environmentalists, Experts, and the Invasion of the ‘Second Greatest Threat’. *International Review of Environmental History* **1**: 17–40.
- Chew MK and Carroll SP. 2011. Opinion: The invasive ideology: Biologists and conservationists are too eager to demonize non-native species. *The Scientist* **7** September, (<https://www.the-scientist.com/news-opinion/opinion-the-invasive-ideology-41967>).
- Chew MK and Laubichler MD. 2003. ‘Natural enemies—Metaphor or misconception?’, *Science* **301**: 52–53
- Coley PD, Bryant JP and Chapin FS. 1985. Resource availability and plant anti-herbivore defence. *Science* **230**: 895–899.
- Daehler CC. 2001. Two ways to be an invader, but one is more suitable for ecology. *ESA Bulletin*, **82**(1): 101–102.
- Darlington W. 1859. *American weeds and useful plants: Being a second and illustrated edition of agricultural botany*. A.O. Moore & Co., p. 460. (Available at: <https://play.google.com/books/reader?id=YjBjAAAIAAJ&hl=en&pg=GBS.PR1>).
- Davis M. *et al.* 2011. Don’t Judge species on their origins. *Nature* **474**: 153–154.
- Davis MA. 2005. Invasion biology 1958-2004: The pursuit of science and conservation. Pp. 35–62. In: *Conceptual ecology and invasions biology: Reciprocal approaches to nature*. (Eds. Cadotte, M. W., *et al.* Chapter 2 ). Kluwer Publishers, London.
- Davis MA and Thompson K. 2000. Eight ways to be a colonizer; two ways to be an invader: a proposed nomenclature scheme for invasion ecology. *ESA Bulletin* **81**: 226–230.
- Davis MA and Thompson K. 2001. Invasion terminology: should ecologists define their terms differently than others? No, not if we want to be of any help. *ESA Bulletin* **82**: 206.
- Devine-Wright P. *et al.* 2022. Placing people at the heart of climate action. *PLOS Climate* **1**(5): e0000035
- Duke SO. 2005. Six decades of Weed Science since the Discovery of 2,4-D and Challenges for the 21<sup>st</sup> Century. Proceedings 20<sup>th</sup> APWSS Conference, 7-11 November 2005, Ho Chi Min City, Vietnam, 3-11.
- Duke JA. 1992. *Handbook of edible weeds*. Boca Raton, FL: CRC Press. 246 p.
- Dunn ST. 1905. *Alien flora of Britain*. London, West, Newman & Co. 236 p. (<https://archive.org/details/alienflorafbri00dunn/page/n5/mode/2up>).
- Dwyer J. 2011. Weed psychology and the war on weeds. *Plant Protection Quarterly* **26**(3): 82–86.
- Elton CS. 1958. *The ecology of invasions by animals and plants*. London: Methuen & Co. Ltd., 181 p.
- Emerson RW. 1879. In: ‘Fortune of the Republic’, a Lecture first given on 30 March 1878. (<https://archive.org/details/fortunerepublic00emergoog>).
- Evans C. 2002) *War on weeds in the Prairies West: An environmental history*. University of Calgary Press, Calgary, Alberta, 309 p.
- Falck ZJS. 2010. *Weeds: An Environmental history of metropolitan America*. University of Pittsburgh Press, Pittsburgh, 256 pp.
- Gray A. 1879. The Predominance and pertinacity of weeds. *American Journal of Science and Arts* **85**(2): 161–167 (Re-published by Sargent, C.S. (1889). *Scientific Essays of Asa Gray*. Vol II. Essays and Biographical Sketches, 1841-1886. Houghton Mifflin, NY, pp. 234–243).
- Guia<sup>o</sup> RC and Tindale CW. 2018. Logical fallacies and invasion biology. *Biology & Philosophy*, **33**: 34 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6133178>).
- Guo RZ, Song Y-B. and Dong M. 2022. Progress and prospects of ecosystem disservices: An updated literature review. *Sustainability* **14**: 10396 (<https://doi.org/10.3390/su141610396>).
- Harper JL. 1956. The evolution of weeds in relation to the resistance to herbicides. *Proceedings of the 3<sup>rd</sup> British Weed Control Conference*. 1: 179–188.
- Hall M. 2003. Editorial: The native, naturalized and exotic – plants and animals in human history. *Landscape Research* **28**(1): 5–9.
- Hill AP and Hadly EA. 2018) Re-thinking “Native” in the anthropocene. *Frontiers of Earth Science*, **6**: Article 96 (<https://www.researchgate.net/publication/326422387>).
- Heap IM. 2022. International Herbicide-Resistant Weed Database (<http://www.weedscience.org>).

- Hooper D. *et al.* 2012. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature* **486**, 105–108.
- IPCC. 2022. Intergovernmental Panel on Climate Change. 6<sup>th</sup> Assessment Report (28 February) (<https://www.ipcc.ch/assessment-report/ar6/>).
- Jordan NR and Davis AS. 2015. Middle-way strategies for sustainable intensification of agriculture. *BioScience* **65**: 513–519.
- Jordan N and Vatovec C. 2004. Agroecological Benefits of Weeds. Chapter 6, pp. 137–158. In: *Weed biology and management*. (Ed. Inderjit Kluwer Academic Publishers).
- Kim KU, Shin DH and Lee IJ. 2007. *Utility of weeds and their relatives as resources*, Kyungpook National University, Daegu, Korea. 222 p.
- Kuhn TS. 1962. *The Structure of scientific revolutions*. First Edition. University of Chicago Press, Chicago, USA.
- Larson BMH. 2005. The War of the roses: Demilitarizing invasion biology. *Frontiers in Ecology and the Environment* **3**(9): 495–500.
- Lowell JR. 1848. *A fable for critics* (Page 23). GP. Putnam, Broadway, NY, p. 80 (<http://quod.lib.umich.edu/m/moa/ax1065.0001.001/25?q1=weed&view=image&size=100>).
- Marsh GP. 1864. *Man and nature Or physical geography modified by human action*. Sampson Low, Son and Marston, London. p. 599 (Available at: [https://archive.org/details/bub\\_gb\\_4tKNdhQYypgC](https://archive.org/details/bub_gb_4tKNdhQYypgC)).
- Marshall EJP *et al.* 2003. The role of weeds in supporting biological diversity within crop fields. *Weed Research*, **43**: 77–89.
- MEA (2005). *Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. p. 156 (<https://www.researchgate.net/publication/297563785>).
- Mooney HA *et al.* (Eds.). 2005. *Invasive species in a changing world*. Island Press, Washington DC., p. xxx.
- Morita, H. (2007). Edible Wild Plants, including Weed Species, mainly used as Vegetables in Japan. Pp. 169–180. In: *Utility of Weeds and Their Relatives as Resources*, Kyungpook National University, Daegu, Korea (Eds. Kim KU, Shin DH and Lee IJ).
- Parker JD *et al.* 2013. Do invasive species perform better in their new ranges? *Ecology* **94**(5): 985–994.
- Pascual U *et al.* 2017. The value of Nature's contributions to people. *Current Opinion in Environmental Sustainability* **26**: 7–16 (<https://www.sciencedirect.com/science/article/pii/S1877343517300040?via%3Dihub>).
- Rejmánek M. *et al.* 2005. Ecology of invasive plants: State of the art. In: pp. 104–161. *Invasive alien species: A new synthesis*. (Eds. Mooney, H. *et al.*) Chapter 6. Island Press, Washington.
- Sagoff M. 2002. What's wrong with exotic species? P. 349. In: *Philosophical Dimensions of Public Policy* (Ed. Galston W). Routledge. NY, (Chapter 34).
- Shackelford N, Hobbs R Heller, Hallett NL and Seastedt T. 2013. Finding a middle-ground: The Native/Non-native debate. *Biological Conservation* **158**: 55–62.
- Star SL and Griesemer JR. 1989. Institutional ecology, 'Translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Social Studies of Science* **19** (3): 387–420.
- Stapp JR. 2004. The role of weeds as sources of pharmaceuticals. *Journal of Ethnopharmacology* **92**: 163–166.
- Stapp JR and Moerman DE. 2001. The importance of weeds in ethnopharmacology. *Journal of Ethnopharmacology* **75**: 25–31.
- Taylor GJ and Crowder AA. 1983. Uptake and accumulation of heavy metals by *Typha latifolia* L. in wetlands of the Sudbury, Ontario region. *Canadian Journal of Botany* **61**: 63–73.
- Timmons, F. L. (2005). A history of weed control in the United States and Canada. *Weed Science*, **53**: 748–761. [Originally published in *Weed Science* 1970 **18**(2): 294–307].
- Tebboth MGL, Fewa R, Assend M and Degefue M A. 2020. Valuing local perspectives on invasive species management: Moving beyond the ecosystem service-disservice dichotomy. *Ecosystem Services* **42**: 101068.
- Theodoropoulos DI. 2003. *Invasion biology: A critique of pseudoscience*. Avvar Books, California. 256 p.
- Thompson A. 2011. *The Virtue of Responsibility for the Global Climate*. Pp. 208–222. In: *Ethical Adaptation to climate change: Human virtues of the future*. (Eds. Thompson, A. and Bendik-Keymer, J. Chapter 10. MIT Press, Cambridge, MA. Thompson K. 2014. *Where do camels belong?* (pp. 47–48). In: *The story and science of invasive species*, London: Profile, 224 p.
- Tiwari S, Dixit S and Verma N. 2007. An effective means of biofiltration of heavy metal contaminated water bodies using aquatic weed *Eichhornia crassipes*. *Environmental Monitoring and Assessment* **129**: 253–256.
- UN. 2024. United Nations. *sustainable development goals: Transforming our world: the 2030 Agenda for Sustainable Development* (<https://sdgs.un.org/2030agenda>).
- Varshney JG and Sushilkumar. 2009. *Proceedings of National Consultation on Weed Utilization*. 20–21 October 2009, Directorate of Weed Science Research, Jabalpur (Madhya Pradesh), India. 59 p.
- Vaz AS. *et al.* 2017. Integrating ecosystem services and disservices: insights from plant invasions. *Ecosystem Services* **23**: 94–107 (<http://dx.doi.org/10.1016/j.ecoser.2016.11.017>).
- Voeks RA. 2004. Disturbance Pharmacopoeias: Medicine and Myth from the Humid Tropics, *Annals of the Association of American Geographers* **94**(4): 868–888.
- Watson HC. 1847. *Cybele Britannica [Or, British Plants and Their Geographical Relations]*. Vol. 1. London: Longman & Co. p. 472 (<https://www.biodiversitylibrary.org/item/104172>). [The definition 'Alien' is on p. 63].
- Watson HC. 1870. *A Compendium of the cybele ritannica or British plants in their geographical relations*. Longmans, London, 671 p.
- Wilson EO. 1992. *The diversity of life*. W. W. Norton, New York. 432 p. (<https://archive.org/details/diversityoflife0000wils>).
- Wilson EO. 1997. Foreword. Pp. 9–10. In: *Strangers in paradise: Impact and management of nonindigenous species in Florida*. (Eds. Simberloff, D., Schmitz, D. C. and Brown, T. C. Island Press, Washington, DC. 479. p.
- Wolverton BC and McDonald RC. 1976. Don't waste waterweeds. *New Scientist* **71**(1013): 318–320.
- Wolverton BC and McDonald RC. 1979. The water hyacinth: from prolific pest to potential provider. *Ambio*, **8**: 1–12.