International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 11 | 2019

Prediction and Management of Life History Traits of Introduced Species: A Trade Off between Reproduction and Survivorship

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Abstract: *Invasive alien species are the main agent of biodiversity loss in protected natural areas. Prevention is the most appropriate management tool for addressing this challenge, albeit, virtually all ongoing management efforts are focused on established populations. Prediction of species invasiveness and susceptibility of an area to invasion is essential as a measure to plan ahead of the prevention and control measures before any establishment. Nevertheless it requires a broad knowledge and understanding of how particular specie interacts with life history traits, genetic and environmental variables, such as temperature and nutrients to predict their invasiveness. Many of the introduced species assumes various stages before spread to other areas. The knowledge of these stages becomes important when thinking of devising controlling and preventing measures to the spread of invasive species in a particular area. This article reviews various literatures on the spread of invasive species and it aims at providing basic understanding to the reader specifically on the biological and environment attributes contributing to successful spread and invasion of introduced or invasive species. The review has drawn various examples worldwide to provide an insight about the interaction between biological attributes of invasive organisms and environments. Therefore the review focuses much on the life history traits of introduced species, predicting their chance of success in a novel environment and management.*

INTRODUCTION

Life history traits are attributes influencing individual life processes in reproduction and survival. It involves birth rate, mortality rate, growth rate, dispersion, size at birth, number of offspring, longevity and tolerance in response to environmental variables (Vandermeer & Goldberg, 2013; Seiter & Kingsolver, 2013). The impact of invasive alien species is a key component of global change and it is considered to be one of the main causes of biodiversity loss worldwide (Sala et al., 2000; Lövei & Lewinsohn, 2012; Simberloff et al., 2013; Alexander et al., 2014). Many protected natural areas contain alien species that are recognized as the main threat to their conservation objectives. Prediction indicates that their impact will increase in the future unless effective management measures are adopted (McKinney, 2002; Pyšek et al., 2002). To ensure persistence, a trade off exists between reproduction rate and survivorship where by individuals might either consume growth energy in reproduction or accumulate resources for survival (Vandermeer & Goldberg, 2013). Life history traits of invasive species usually changes due to changes in environments they inhabit (Allendorf & Lundquist, 2003). For instance studies have documented invasive insects to have high reproductive and dispersal rate, however they have higher mortality rate and short lived (Schowalter, 2006). This can be depicted from ants which are known to have high reproductive rates, forms super colonies with multiple or single queens and can easily spread through hitch hiking (Rabitsch, 2011; Simberloff, 2013). Such trade-off in life history traits had made most introduced species capable of invading new areas, to outcompetes and eliminates native species (Allendorf & Lundquist, 2003). In that manner, understanding of life history traits provides useful insights for appropriate anticipation of invasive species, ecosystem vulnerability to invasive species and spread (Allendorf & Lundquist, 2003). This will help in planning, policy formulation, and devising appropriate risk assessment measures of areas prone to invasive species.

STAGES OF INVASION

Invasion processes involve the successful overcoming of several challenges: a potential invader must survive transport from its place of origin, become established in the new site, persist and reproduce until a sustainable population is formed that eventually expands (Theoharides & Dukes 2007; Blackburn et al., 2011; Jeschke et al., 2013). The ability to successfully overcome these stages depends not only on the species' own characteristics, but also on the characteristics of the invaded habitat that determine its susceptibility to invasion, the number of propagules and introduction events, the establishment of effective relationships with local dispersal agents and other symbionts and the particular conditions at the time of the arrival of the propagules (Marco et al., 2002; Colautti et al., 2006; Dechoum et al., 2015; Amodeo & Zalba, 2017). The success of an invasive species depends on life history traits which in turn influence their stages of establishment (Sakai et al., 2001). Studies have found change in life history traits of the same non indigenous between new and native environments.

There are two primary phases in the development of species invasion. The first phase involves introduction, colonization and establishment. This is the time during which introduced species are new to the environment and includes arrival, surviving and species start to establish or attain a self-sustaining level (Allendorf & Lundquist, 2003). The second phase involves introduction, establishment, lag phase and spread (Sakai et al., 2001). After invasion the population has to adapt to the environment changes followed by genetic adaptive differentiation in response to selection pressure in local environment (Biere et al., 2012). Usually establishment is associated with lag time in which individuals undergoes exponential growth, the duration of which depends on the number of individual contributing to the exponential growth. The larger the initial population the rapid population growth and hence the short the time lag (Lockwood et al., 2013). Spread is considered to occur when invasive species have accumulated at maximum level and when individuals establish and disperse the population is said to persist (Davis, 2009). Sometimes introduced species may invest a lot in reproduction than in qualities which ensures long term survival. For instance studies have found that, an invasive tree plant the Chinese tallow tree (*Sapium sebiferum*) produces more seeds but with low quality leaves and invest little energy in defence (Allendorf & Lundquist, 2003).

Such traits in establishment stages are much useful in prediction as they lead into better prevention measures and control methods (Clout & Williams, 2009). For example in most plants, the bottleneck genetic variations occurs between introduction and establishment whereby individuals are reduced to low number (Prentis et al., 2008). Although the combination of species attributes and environments makes the use of attribute alone no enough to predict. Due to this variability in time, space and invasiveness, a systematic approach is essential in management of invasive species (Manaco & Sheley, 2012).

TRAITS AND PREDICTION OF INVASIVENESS

Life history trait determine successful establishment and distribution of invasive species (Monaco & Sheley, 2012) and are influenced by genetic evolution and environmental changes (Seiter & Kingsolver, 2013). Most of invasive plant have rapid growth rate, early sexual maturity, long flowering and fruiting period, higher sexual and assexual reproductive capacity, long seed dispersal, large propagule, high soil seed bank and long persistence to soil (Truscott et al., 2006). For instance researches on rapid growth and dispersal of two North American species of Elodea (*Elodea nuttallii* and *Elodea canadensis*) shows that, both species have similar range in Northern America, but following introdcution in Europe, *E. canadensis* seems to have high competitive and displaced *E. Nuttallii.* However, Both of them have high vegetative reproductive rate, regeneration and colonization capabilities which enabled them to establish and distribute widely than native species. This means high investment in reproduction, regeneration and growth and seasonal palatability to herbivores suggests trade off between reproduction and ant herbivore chemicals (Barrat-Segretain et al., 2002).

The next traits to invasive plant is a long fruiting period, For example an invasive species of coastal vegetation in Australia, Bitou bush *Chrysanthemoides monilifera* and Lantana – *Lantana camara* produces fruits throught the year with peak production in autumn to winter during which few native species produces fruits. The palatability of fruits with low fat contents has made *C. minilifera* attractive to frugivores and hence its dispersal (Gosper, 2004). So traits like long fruiting period and massive seed production or assexual reproduction makes the plant to produce and store a large soil seed bank while seed dormance ensures plant survival in unfavarouble conditions (Stork & Turton, 2008). The palatability and low fat contents increases dispersal rate of the seed spread as they become more visitied and taken by frugivores birds. These traits are very important in management effectiveness of invasion and helps in predicting future invasion of a particular species (Rejmanek, 2000).

Higher reproductive rate with short life span than in their native range (Vandermeer & Goldberg, 2013) affirms variations in life history between their novel and native ranges (Mooney & Cleland, 2001). Again such an understanding provide a frame work for predicting further invasion and spread in new area as well as their possible genetic evolution or changes (Richardson, 2010). An obvious example is of introduced Argentina ants (*Linepithema humile*) and red fire ants (*Solenopsis invicta*) showed high cohesion between colonies and polygyn in novel range, an attributes not shown in their native range. In their native range mates attack the outsider while in novel range the colonies are corporative and non-aggressive (Allendorf & Lundquist, 2003). Some traits are sensitive to environmental factors like temperature, humidity and light (Seiter & Kingsolver, 2013). Understanding phenotypic plasticity or physiological requirement of a particular specie would aid in predicting the success of invasion in area favourable to such traits (Lockwood et al., 2013). Take an example of the change in morphological trait in respond to the new environmental gradient of European wild rabbit when it was taken to a new area. The development of long ear and leaner bodies of the introduced European wild rabbit *Oryctolagus cuniculus* in Australia as an adaptation to thermal gradient in warmer regions (Lee, 2002). Invasive species can alters ecosyetem functions they invades like changing the nutrient cycling, altering fire regimes and intensive water use (Biere et al., 2012). For example in America southwest the mediteranian salt cedar can cause severe water loss by drawing a lot of water due to their deep root penetrating in the soil. Also the nitrification ability of American nitrogen fixing firebush replaced and dominated the native species adapted in a poor nutrient soil of the Hawaii volcanic Island. Knowing the potential capabilty of the America nitrogen fixing firebush in a poor nutirent soil probably we can predict future invasion of such species in other poor or nitrogen rich areas or doubt of other species to utilize the available nitrogen (Simberloff, 2013).

Prediction of complex impacts (meltdown invasion) resulting from chain interaction between invasive species or and native species may be aided by using life history traits (Simberloff et al., 2013). A noted incident is the Chines Banyan tree- *Ficus microcarpa* in Frolida which remained dormant for many years, but it turned into invasiveness after introduction of pollinating agents- the wasps *Parapristina verticillata* (Kauffman et al., 1991 as cited in Barker et al., 2013). The wasps of its natural range aided rapid pollination, reproduction and consequently spread of introduced ficus tree. Attractiveness of their seeds and fruits to frugivorous birds facilitated the spread of the seed of these non native ficus (Simberloff & Von Holle 1999). Therefore, highly coevolved plant-pollinator species may become a virtual time bomb which requires only the arrival of associated insect to set off an invasion (Simberloff & Von Holle 1999). In certain situation eradication of invasive species could results into complex and unforeseen consequences. A noted and striking example is that of introduced cat to control rats and mice. In 1878 Iberian rabbit were introduced in Australia as the source of food. But latter on the rabbit caused great impacts on crops and vegetation. Then in 1968 a rabbit myxoma viral was introduced which brought down the number of rabbits the consequence of which resulted into vegetation recovery. Due low number of rabbit, cats turned into preying on the ground nesting birds (Simberloff, 2013). Approaches to be taken and prediction of associated consequences in management of introduced species are essential when trying to eradicate or control invasive species. Otherwise attempt to eradication may worsen instead of solving the problem (Carroll, 2010).

Willems (2010) argued that, the relationship between life history traits and fire can increase our prediction power on fire resistance invasive species and their alteraltion in ecosystem function. An obvious example is the pepper back tree in America and Australian developed traits such as spongy, highly flammable leaves and litter, a trait which has displaced most native species not adapted to intensive fire (Simberloff, 2013). Next is the introduction of cheatgrass, the fast growing, early maturity and higher fire intensity due to big fuel load in summer. This resulted into decrease in dominance of low resistance sagegrass in sagebrush ecosystem in Western USA (Manaco & Sheley, 2012).

However, species multiple introduction results into allele blending and high genetic variation in introduced range (White et al., 2012). More introductions create more diverse population than the native range and cause more invasiveness and spread (Sakai et al., 2001). Nevertheless, it is difficult to predict the presence of propagule or soil seed bank and spread of invasive plants (Manaco & Sheley, 2012). In other cases interactions are easily predictable while others are complex. Non evolutionaly or non genetic traits like physiological changes can be easily predicted while it is difficult to predict evolutionary traits as they take long or sometimes an organism can respond differently (Davis, 2009).

MANAGEMENT OF INTRODUCED SPECIES

Life history traits such as the genetic and evolution changes is very useful in management aspect for designing appropriate control model and procedure (Allendorf & Lundquist, 2003). For example by knowing that most invasive ants are social, forms super colonies and are hitchhikers suggests early preventive measures or control before spread (Rabitsch, 2011). This can be achieved by supplying baits to ants super colonies as most ants shared the bait with the rest of the colonies (Abbott, 2006).

Also traits like mechanism of dispersal or spread agent of terrestrial or riparian vegetations would help in devicing appropraite time and procedure of controlling invasive species (Truscott et al., 2006). The relation between plants and vectors should increase our ability to manage and prevent spread and establishment of invasive species. For example a fruit bat tends to drops seed in a large roots opens an opportunities for monitoring invasion process by identifying new alien species of seeds in the bats guano dropped within the roots, while reducing fruits bats activities around the settlements would reduce their ability to disperse plant seed. In that case a vector based approach should be used in reducing invasion process (Richardson, 2010). Furtehrmore in controling seed dispersal and vegetative regeneration of introduced Mimulus species, a perennual riparian herb introduced in Great Britain from Northern America in 1812 should consider time between August and September, the down stream and up stream water bodies as it has been observed to release seed between August and September when water velocity is low to facilitate its long dispersal because seed beouyance is affected by turbulence of water (Truscott et al., 2006). For stowaways or invasive species through marine or cargo ships the best control is through ballast management and treatment (Rolim et al., 2008).

Life history traits studies and establishment steps in invasive species gives the choice of the most appropriate control procedure to apply in response to the stage reached (Manaco & Sheley, 2012). For example the rapid germination of perennial buffelgrass and crimson foundation grass (*Pennisetum setaceum*) occurs soon after rainfall of which their management and monitoring should best work during germination before seed maturation. By knowing the step at which invasive species are few in number and confined in certain place it is easy to eradicate them before they spread to unmanageable extent (Sakai et al., 2001).

Finally, a study in interaction between fire and traits such as fire avoidance by forming thickbark, seedbank and tubers would help to device an appropriate mechanism on how to control plants with such traits (Willems, 2010). Forexample non native species that survive under frequence and annual burning are perennual grasses and forbs such as *Pennisetum setaceum* sprought vigorously after fire. Invasive annual grassess like medusahead and ripgut brome (*Bromus diandrus*) diminish under frequent fire because their seed or buds are not protected (Willems, 2010).

CONCLUSION

Generally, life history traits, biology and spread are widely used in risk assessment of invasive species. For example, the development of Weed Risk Assessment (AWRA) would look on three aspects of an introduced species such as history, range and biology. So knowing the characteristic of invasive species such as reproductive rate, means of reproduction, growth cycle has an important implication in terms of invasiveness management. Monaco & Sheley, (2012) suggested that, the management approaches of an invasive species should target the most vulnerable or susceptible stage of the invasive species like germination and before fruiting or seedling in plants. Timing and techniques used are importance for successful management of invasive species.

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