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PhD Preliminary Examination

PhD Cognate Area 1

**A Summary of Plant-Animal Interactions in Ecology**

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**Insert 2 externals**

**Table 1:**  A summary table of modern themes and major hypotheses associated with plant-animal interactions. Theories and themes compiled from ? The Web of Science searches and most highly cited peer-reviewed publications? How did you select Li et al for top-down, google scholar check has this paper as most cited Top‐down cascade from a bitrophic predator in an old‐field community from 1996 or was that not the best paper? I think just in Table legend here explain how you selected the papers to be representative - development could also just be definitions too - your call

Put topic col first, then definition, then paper

|  |  |  |
| --- | --- | --- |
| **Representative paper** | **Topic** | **Definition** |
| *Modern Theories* | | |
| Gripenberg & Rosalin (2007) | Bottom-Up Effect | The influence of lower trophic levels on the community structure and composition of higher trophic levels through resource restriction. |
| Li et al. (2020) | Top-Down Effect | The influence of higher trophic levels on the community structure and composition of lower trophic levels through interactions such as predation and herbivory. |
| *Major Hypotheses in Direct Interactions* | | |
| Bronstein (1994) | Mutualism | The interaction between species where each species experiences a net benefit. |
| Ohgushi (2005) **again why this paper etc** | Herbivory | The interaction between a plant and animal species in which the plant species is consumed by the herbivorous animal species. |
| Bertness & Leonard (1997) | Facilitation | The beneficial interaction between a plant and animal species whereas one species positively benefits while the other is unaffected. |
| Jennings et al. (2010) | Competition | The interaction between two species in which **(in which a bit clunky can you find better phrasing for the table)** both are negatively affect, typically due to a competition of resources. |
| Xu et al. (2018) | Neutralism | The relationship between species in which the interaction results in a net neutral outcome. |
| Xi et al. (2013) | Amensalism | The relationship between 2 species in which one experiences an unintentional negative impact effect the other is unaffected. |
| *Major Hypotheses in Indirect Interactions* | | |
| Holt & Lawton (1993) | Apparent Competition | An antagonistic indirect interaction where one species **influences** another within the same trophic level, through a common consumer. |
| Schöb et al. (2013) | Indirect Facilitation | **A** beneficial indirect interaction occurring **when?** the positive effects of one species on the other occur through a common competitor. |
| Vesterlund et al. (2012) | Exploitative Competition | The positive or negative interaction between species which interact through resource consumption, typically through herbivory. |
| Mulder & Ruess (1998) | Associational Resistance | The positive interaction between individuals where a palatable individual is associated with an unpalatable species, resulting in a reduction in herbivory. |
| Schmitz et al. (1999) | Trophic Cascade | The positive or negative interaction between plants and herbivores as a result of alterations to their available resources. |
| Vandenberghe et al. (2009) | Shared Defense | The positive interaction between a palatable plant species when it is protected by a nearby unpalatable species. |

**Could Also have another column in stead of the rows that is ‘modern’, direct, or indirect**

**I. Introduction**

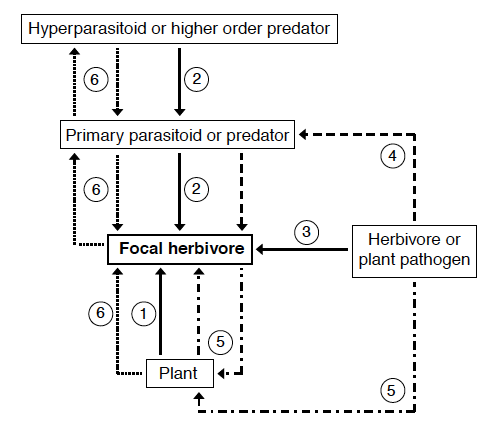
*Background*

The importance of species interactions has been a primary topic for ecologists for decades? Nearly 100 years>? More maybe. The central goal of community ecology and also evolution is to understand these community dynamics by simplifying species interactions into smaller, more manageable subsets, rather than focusing on the entirety of the community (Vandermeer 1969; Billick & Case 1994; Strauss & Irwinn 2004). This is not to say that analyzing the community as a whole does not provide excellent insight into an ecosystem, but it suggests that observing simplified interactions can show the net outcomes between species. Net outcomes are the… Through simplifying these interactions, ecologists are able to more readily observe the impacts organisms have on abundance, diversity, phenotypes, and richness (Strauss & Irwinn 2004; Agrawal et al. 2007). While literature on interactions between plant-plant and animal-animal individuals has taken center stage in many branches of ecology, the importance of plant-animal interactions has become the center of attention over the last several decades. These plant-animal interactions, including those resulting in a net positive (Schemske & Horvitz 1988; Brotolus et al. 2002; Schupp et al. 2017), or negative (Cumming & Cumming 2003; Jennings et al. 2010; Kaplan et al. 2011; Xi et al.2013; Bhattarai et al. 2017) outcome are common in all ecosystems globally. As a result, two larger categories of plant-animal interactions have been used in the literature, depending on the degree of the association between interacting species. These plant-animal interactions are commonly divided into direct interactions, where the direct impact of one organism on another is not mediated by another individual (Miller 1994), and indirect interactions, which occur when the impact of one species on another is mediated through a third individual (Strauss 1991; Bruno et al. 2003; Sotomayer & Lortie 2015). These plant-animal interactions can then further be subdivided into specific hypotheses depending on the overall impact on both the plant and animal species (**Table 1**). Then resolve.

I Love the organization but easy to get lost to TWO big categories - direct and indirect - then hypothesis in each?> is that it. Are there ever hypotheses that Bridge both direct and indirect. Did you also try a plot? Do the hypothesis within each category sometimes overlap too? Then end with why this topic is so important, just in one sentence - understanding interactions in subsets supports a deeper understanding of community assembly as a whole (citations) and also lets us understand how global change impacts different interactions separately (citations). GOOD?

*Terminology and Concepts: this section is not really that - it is more top-down versus bottmw-up*

There are a series of terminologies and concepts directly developed to support the topic of plant-animal interactions. When observing the interactions between plants and animals, it is crucial to analyze the impacts these interactions have on the local community composition and structure of an ecosystem. These effects are typically identified based on the direction of movement across trophic levels (citation). Bottom-up effects are when a lower trophic level in an ecological community affects the community structure of higher trophic levels through resource restrictions and various interactions (White 1978; Li et al. 2020). This effect typically focuses on the presence or alteration of a resource in an ecosystem, such as the overall availability of plant matter or production of fruit, and how these resources can act as a regulatory force on species composition, abundance, and interactions (Power 1992; Báez et al. 2006). In terms of plant-animal interactions, bottom-up effects are primarily influenced by the positive or negative interactions experienced between both species (Hairston et al. 1960; Smallwood 2001). Interactions, such as herbivory, are key drivers of these bottom-up effects as they can influence the overall availability of plant matter in an ecosystem, thus influencing the community composition of an ecosystem (Hairston et al. 1960; Chapin et al. 2002). In contrast, top-down interactions refer to the influence of higher trophic levels on the community structure and composition of lower trophic levels (Carpenter et al. 1985; Li et al. 2020). These top-effects are typically stronger at the top of food webs, while progressively weakening further down trophic levels, suggesting that these effects are stronger when there is a direct interaction between species (McQueen et al. 1986; Jeppesen et al. 2000; Li et al. 2020). Typically, key interactions, such as animal-animal predation, are commonly associated with these top-down interactions (Baum & Worm 2009; Valone & Balaban-Feld 2019), however these effects are also evident through plant-herbivore interactions (Carson & Root 1999; Schmitz et al. 1999). While both top-down and bottom-up effects have varying impacts on interacting species and on the corresponding trophic levels, these types of effects are not mutually exclusive. Many ecologists today believe top-down and bottom-up forces both contribute to the structure of communities and populations specifically in herbaceous insects (Hunter & Price 1992; Denno et al. 2005; Gripenberg & Rosalin 2007). In the past, these interactions were conceptualized only vertically and in one direction, but this view has been further expanded displaying complex horizontal interactions including indirect effects spanning several trophic levels (Fig 1; Harvey et al. 2003; Ohgushi 2005; Gripenberg & Rosalin 2007). Ah - so both can be direct and indirect right? Relate this typology to the initial setup you did as well More recently, these top-down and bottom-up impacts are also influenced by the interactions among species (Denno 2005; Vidal & Murphy 2018), through direct interactions such as predation, (Schoener & Spiller 1999) and insect herbivory (Denno & Finke 2005). The concepts of top-down and bottom-up effects are typically used in trophic interaction literature, specifically in plant-animal interactions, to explain their overall impacts on plant and animal species.



**Fig 1: U**nitrophic and multitrophic level interactions impacting herbivorous insects. 1) Direct bottom-up effects, 2) direct top-down effect, 3) direct competition, 4) apparent competition, 5) induced defense, 6) plant quality affecting natural enemies. Taken from Gripenberg & Rosalin 2007. What does it show - just one sentence

This last section is great - needs to tie into the intro a bit though I think

**II. Direct Interactions:**

*Background:*

One of the most prevalent and focused categories of interaction in plant-animal literature are those describing direct interactions. These typically occur when there is a direct impact of one organism on another, which is not mediated by another individual (Miller 1994). There is a vast variety of these interactions between plant-animal individuals that can result in an overall net positive or negative impact on either species depending on the extent and classification of the interaction (**Table 2**). These net effects on one interacting species becomes more complex when considering the net sum of all interactions (citation), and thus can determine the abundance of an individual species while also influencing community assembly (Miller 1994; Sargent & Ackerly 2008). Some of these interactions have been heavily studied in literature such as mutualism and herbivory while others such as amensalism is relatively less studied (citation to a review here). These less focused upon - clunky interactions typically display an overall net negative and/or neutral effect on the observed species (**Table 2**). For example, competition, while being a fundamental concept in ecology, is not typically seen unrelated taxa, but has been reported in some plant-animal interactions (Jennings et al. 2010) so?. The competition between *Sosippus floridanus* and *Drosera capillaris* for food, while displaying that this type of interaction being prevalent across nonrelated taxa, is one of very few examples of this type of plant-animal interaction (Jennings et al. 2010; Jennings et al. 2016). Interactions that show a net negative effect on plants while displaying a net neutral effect on the interacting animal species are also less commonly focused upon… same revise in plant-animal literature. This interaction, commonly known as amensalism, can be seen directly through the trampling of vegetation by cattle (Dunne et al. 2011) or through trampling by other larger herbivore species (Cumming & Cumming 2003; Xi et al. 2013). While these types of plant-animal interactions are observable in various ecological systems, here I will focus on the three more prevalent direct interactions; mutualism, herbivory, and commensalism. Got ya why you set up like this - good - however, work on flow in above paragraph.

**Table 2:** A list of possible direct plant-animal interactions throughout all fields of ecology. The overall positive, negative, or neutral net impact on the interacting plant and animal species is indicated.

|  |  |  |
| --- | --- | --- |
| ***Interaction*** | ***Effect on Plant***  ***Species*** | ***Effect on Animal Species*** |
| Mutualism | Positive (+) | Positive (+) |
| Herbivory | Negative (-) | Positive (+) |
| Commensalism/Facilitation | Positive/Neutral (+/0) | Positive/Neutral (+/0) |
| Competition | Negative (-) | Negative (-) |
| Neutralism | Neutral (0) | Neutral (0) |
| Amensalism | Negative (-) | Neutral (0) |

*Mutualism:*

Mutualistic interactions between plant and animal species is by far one of the most prevalent and well-studied niches of plant-animal interactions (Bronstein 1994). This type of interaction can be simplified as a positive interaction between 2 different organisms in which both species experience an overall benefit to their survival and fitness (**Table 2;** Boucher et al. 1982; Murray & Kinsman 2000; Bascompte & Jordano 2007). The concept of mutualism in itself can be further specified into varying specific plant-animal interactions including; plant-pollinator (Stout & Tiedeken 2016; Kaiser-Bunbury et al. 2017), plant-defender (Giusto et al. 2001; Yamawo 2021), and plant-disperser (Bas et al. 2006; Bascompte & Jordano 2007; Ramaswami et al. 2017). For example, several species of plants produce a larger abundance of nectaries to recruit various ant species (Oliveira 1997; Giusto et al. 2001; Grasso et al. 2015). This type of plant-defender interaction displays a mutualistic relationship between both the plant and the ant, as the plant species receives protection from herbivorous species by the ants, while the ants acquire a direct resource through the plant’s nectaries (Oliveira 1997; Grasso et al. 2015). During these mutualistic interactions, it is crucial to consider the net outcome of the interaction rather than just observing it as an overall benefit to both interacting species (Giusto et al. 2001) because.… Thus, quantifying the strength and observing the possible trade-offs of this interaction can influence the understanding of how these species interactions shape communities and ecosystems hmm bit repetitive of above stuff (Okuyama & Holland 2008; Vázquez et al. 2015). Studying and understanding these mutualistic interactions can play a pinnacle role both to achieve a basic understanding of various ecological systems and for their proper? conservation and management (Bronstein et al. 2006; Waser & Ollerton 2006; Vázquez et al 2009). Can you find a better punchline or research insight here - need to measure these interactions and measure conservation outcomes at the same time - need to review for sure in cognates but also have punchlines too.

*Herbivory:*

Herbivory is well studied (citation to a recent review). This interaction set in plant-animals provides a significantly different outcome? to both the plant and animal species. This interaction typically results in a net negative effect on a plant species while the corresponding herbivorous animal species experiences a net positive effect (**Table 2**; Smallwood 2001; Ohgushi 2005). For instance, species such as *Epherdra torreyana* in shrub dominated communities, is continually browsed by herbivores, resulting in the surviving individuals having fewer leaves at a significantly reduced size (Whiteford 2002; Whiteford & Steinberger 2020). This interaction displays - cut word displays throughout and find a better one if you can please the net negative impact these herbaceous species have on the survival and fitness of local plant communities. However, this interaction does not necessarily result in the complete death of a plant or a significant decrease in plant abundance (Hairston et al. 1960; Mulder & Ruess 1998). Depending on the severity of the damage experienced cause by the animal species, plant species can survive (citation to compensation literature). Studies observing the effects of mechanical damage done to plant individuals, whether through animal grazing or other mechanisms, suggests that these plants can recover via resprouting, displaying the resilience of these plant individuals (Lortie et al. 2018; Filazzola et al. 2020) - replace with other citations I think - good reviews perhaps. The resilience of these plant species is what prevents ecosystems from becoming barren landscapes, and prevents an overall depletion of green plant species (Hairston et al. 1960) meh. Observations of herbivorous interactions can occur in several ways -revise - be more precise in writing - herbivore in measure in the following three ways. The most common being through direct visual observation (citation), however the use of enclosures to identify the extent of these interactions acts as a quantitative means of observing the extent of these herbaceous effects (Manson et al. 2001; Sullivan & Howe 2009). This method can detect if plant-animal herbivory is present in an ecosystem, while also being able to display the strength this interaction has on local community composition. So one way? Or are there two - direct observation and exclosures? Not super novel here - can you jazz up this section - future again -

define, state what we know, perhaps what we do not (gaps), then next steps - ie like end of last section - consumer pressure and plant species diversity? Better ways to measure? Whatever you think the future directions are or if there are a few new papers suggesting this..

*Direct Facilitation/Commensalism:*

In recent years, there has been a large emphasis placed on facilitative interactions both in the study of community ecology as a whole (cite Vellend review perhaps), and specifically in plant-animal interactions (citation). Facilitation, also known as commensalism, results in a net positive effect on one of the interacting species while the other experiences a net neutral effect (Bertness & Leonard 1997; Molina-Montenegro et al. 2016; Zuliani et al. 2021). Understanding this type of plant-animal interaction has been proposed as an important tool to understanding community functionality, specifically in high-stress ecosystems, as the frequency of these types of interactions tends to increase (Lortie et al. 2016; Dangles et al. 2018). This category of plant-animal interactions can be further subdivided into 2 different types of facilitative interactions; 1) A positive effect on the animal species with a neutral effect on the plant species and 2) A positive effect on the plant species with a neutral effect on the animal species (citations). When an animal species experiences a positive effect while the associating plant species is unaffected, the animal is typically utilizing various characteristics of the plant to ameliorate various external stressors (Zuliani et al 2021). For instance, the lizard species, *Gambelia sila*, utilize the shrub cover produced by foundational shrub species in desert ecosystems to ameliorate harsh abiotic conditions and to aid in thermoregulation (Noble et al. 2016; Westphal et al. 2018; Ivey et al. 2020). This plant-animal facilitative interaction poses no negative nor positive effect on the plant species while providing a substantial benefit to the animal species. In contrast, facilitation where a plant species positively benefits while the animal species is unaffected is primarily seen through seed dispersal. While in some cases seed dispersal can be seen as a mutualistic interaction, through the consumption of fruit and dispersal of seeds via excrement (Ramaswami et al. 2017), this form of zoochory could also be achieved through the attachment and transportation of seeds on the exterior of an animal, also known as epizoochory (Schupp 1993; Herrera 2002). This interaction provides a positive benefit to the plant species, as it is able to disperse its seeds to establish viable offspring, while have a neutral effect on the animal species, which is unaware of the interaction (Sorensen 1986; Dovray et al. 2012). The presence of both varieties of plant-animal facilitative interactions allow for a positive effect on the beneficiary species, which in turn will have positive influence on the community composition and structure of these ecological systems (Lortie et al. 2016; Zuliani et al. 2021). Same as other sections - end with even a single wrap-up sentence that states ??? Implication, next step, big gap, the future..

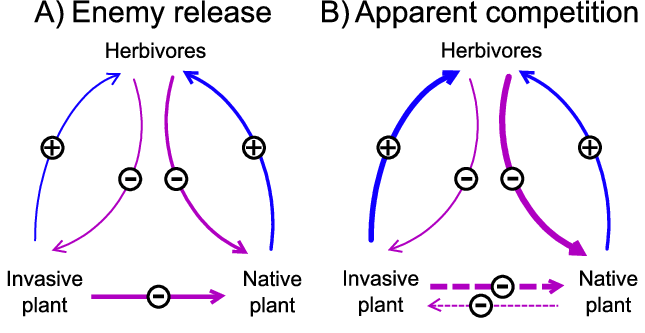
**III. Indirect Interactions:**

*Background:*

Indirect plant-animal interactions, when compared to direct interactions, have significantly fewer studies focusing on their overall effects (Sotomayer & Lortie 2015). How much fewer? Be specific This lack of focus?? Not focus just frequency - tighten up language a bit on this type of interactions are a result of increasing challenges posed by the complexity of analyzing three or more species?? Why (Callaway 2002; Brooker et al. 2007). Indirect interactions share the same classifications across plant-plant, plant-animal, and animal-animal interactions, where the strength and/or direction of two interacting species is altered in the presence of a third species so? This means what (Strauss 1991; Callaway 2007; Sotomayer & Lortie 2015). For instance, plant-plant interactions can be indirectly altered through the introduction of a herbivorous species, as seen in Vesterlund et al. (2012). These indirect interactions exist in all community multi-trophic assemblages, playing a crucial role in assemblage and coexistence hmm confusing (Miller 1994). This in turn, has the capacity to promote the abundance and diversity of these complex communities (Levine 1999; Sotomayer & Lortie 2015). There are several different hypotheses that are fundamental to the study of indirect plant-animal interactions including; apparent competition, indirect facilitation, exploitative competition, associational resistance, trophic cascade, and shared defense (Sotomayer & Lortie 2015). Of these indirect interactions, three are seen to be more prevalent in the literature; apparent competition, indirect facilitation, and exploitative competition. Indirect interactions are as important as direct because?? End same as usual with meaning to reader to keep reading :)

*Apparent Competition:*

One of the most commonly examined interactions, apparent competition, is an antagonistic interaction where one species affects another, within the same trophic level, through a common consumer (Holt & Lawton 1993; Sotomayer & Lortie 2015; Bhattarai et al. 2017). The most prevalent examples of these types of indirect interactions are observed through the direct herbivory of invasive plant species, resulting in a negative impact on native plant species (**Fig 1**; Orrock et al 2008). This is often conveyed through the increased abundance of a potential prey species resulting in an increased predator density (Recart et al. 2013). This increase in predator abundance will augment predatory interactions on the second species negatively impacting population growth and abundance (Orrock 2008; Recart 2013; Sotomayer & Lortie 2015). Thus, through this increase in herbivory, we can say that the direct interaction between plant and animal species will have an overall negative indirect plant-plant interaction. For instance, the introduction of invasive orchid species in Puerto Rico have impacted the native orchids through the overall associations formed with a local florivorous weevil species, *Stethobaris polita* (Barbosa et al. 2009; Recart et al. 2013). And — develop a bit more These direct interactions between invasive plant-herbivore and herbivore-native plant result will in turn result in an indirect competitive interaction between plant species, impacting the community composition in the ecosystem as the invasive plant species will typically out compete the native species (Recart et al. 2013; Sotomayer & Lortie 2015; Bhattarai et al. 2017). Same as other sections - you left me hanging :) end with punchline



**Fig 2:** Schematic diagram displaying the difference between enemy release and apparent competition. (A) Displays the impact invasive plant species have on natives when suffering low herbivory. (B) Invasive species indirectly negatively impact native plant species by increasing herbivore abundance. Figure taken from Bhattarai et al. (2017). Explain what figure means a bit too please.

*Indirect Facilitation:*

Through the last few decades, indirect facilitation has become as commonly examined as apparent competition (Citation —- or at least be more precise in writing). Indirect facilitation is the now one of the most commonly studied indirect interactions in the plant-animal research literature (citation to a review). Side note - how are you concluding this for each section>? Did you use Web of Science total counts?

Indirect facilitation is commonly defined as a positive interaction occurring when the positive effects of one plant species on the other occur through a common competitor (Schöb et al. 2013). These effects typically occur when the suppression of a competitor species is stronger than the direct competitive effects (Levine et al 1999). The most prevalent examples of indirect facilitation are seen through various pollinator interaction and through natural ecosystem engineering (citation - you mean by keystone or foundation species?). Most indirect facilitative interactions mediated by pollinators have focused on the “magnet species” that are individuals who attract significant numbers of pollinators, thus enhancing the pollination success of less attractive individuals (Braun & Lortie 2019; Debnam et al. 2021). This positive interaction between the attractive individual plants with various pollinating species indirectly enhance the ability for the associating less attractive species to experience pollination (citation). Ecosystem engineers can indirectly influence the germination, growth and survival of various plant species through indirect facilitation. These biological engineers, such as ants, indirectly increase the abundance and richness of plant species through activities such as soil bioturbation (Sosa & Brazeiro 2010) or seed dispersal ? (citations). Species that transform living or non-living materials from one physical state to another are seen as allogenic engineers (Sosa & Brazeiro 2010; Walker et al. 2015). Allongenic means… that these engineers influence resource availability or environmental conditions needed for growth, germination, and survival can have substantial effects via indirect plant-animal interactions. Therefore, these complex indirect facilitative interactions are crucial in ecological systems, as the indirect benefits experience by interacting species potentially increase their overall survival, leading to changes in both community composition and abundance. Ok - good ending here next step maybe - need to identify these engineering species in more species to better support them?

*Exploitative Competition:*

Competition between animal individuals for common resource is typically seen as a direct interaction since the species directly interact with one another. However, in the case of exploitative competition, a plant species presence a resource such as seeds, fruit or flowers, to two interacting species (Vesterlund et al. 2012; Sotomayer & Lortie 2015). This indirect competition can result in either a net positive or negative effect on interacting species (Samson et al. 1992). For instance, moose can reduce the overall biomass of pine branches or other ground plant matter through herbivory which in turn reduces both branch availability for aphid species and other terrestrial plant matter for smaller vertebrates (Vesterlund et al. 2012; Pedersen & Pedersen 2021). With this indirect competitive interaction, we could expect to see a potential decrease in negatively affected herbivore populations as they are outcompeted in their ecosystem and have a reduction in their available resources. While the effects on the interacting animal species tend to be negative, an overall positive effect can be experienced by the host plant species (Preisser & Elkinton 2008). If the presence of this interaction leads to the decline of another herbivore species which causes more damage to the host plant than the other, then the interacting plant species will benefit (English-Loed & Karban 1988; Preisser & Elkinton 2008).

This outcome is significantly more likely to occur if the interacting herbivore species vary greatly both in size and overall impact on plant fitness. It is evident that the impacts experienced by both plant and animal species during exploitative competition impact the overall fitness of all associated species, while also contributing to the local community composition. Same - very descriptive - need some insights, next steps, gaps, the future.

**IV. Conclusions:**

The concept of plant-animal interactions in multiple ecological disciplines is a fundamental concept used applied to explain the dynamics of ecological communities and evolution. Through the simplification - is this the best word - perhaps subsetting instead of these plant-animal interactions, we are able to better measure and infer their net impacts on abundance, diversity, phenotypes, richness, and community composition (Strauss & Irwinn 2004; Agrawal et al. 2007). Meaning? The subsequent simplification - same of these plant-animal interactions has been divided into direct interactions between 2 species (Miller 1994; Schoener & Spiller 1999; Denno & Finke 2005), and indirect interactions mediated through a third individual (Strauss 1991; Bruno et al. 2003; Sotomayer & Lortie 2015). Direct plant-animal interactions vary in the overall effect on plant-animal individuals with positive effects observed in mutualism (Bascompte & Jordano 2007), and facilitation (Zuliani et al. 2021), or can result in net negative effects through competition (Jennings et al. 2016), herbivory (Ohgushi 2005), and amensalism (Cumming & Cumming 2003). Similar to direct interactions, indirect interactions share the same classifications across plant-animal interactions, where the strength and/or direction of two interacting species is altered in the presence of a third species (Callaway 2007; Sotomayer & Lortie 2015). Several of these interactions have the capacity to alter community composition and dynamics in their ecological systems. Several indirect interactions, such as apparent competition, can positively influence invasive plant species, reducing the abundance of native annuals and altering the community dynamic and various trophic interactions (Orrock et al 2008; Bhattarai et al. 2017). Through observing these various plant-animal interactions, ecologists can further understand their effects on community abundance, diversity, and richness (Strauss & Irwinn 2004; Agrawal et al. 2007). Considering plant-animal interactions in ecosystems can provide the necessary insight needed for the conservation of many endangered species at relatively small and large spatial scales while also acting as a means for ecological conservation (Hansen et al. 2007). Agreed but this section needs more editing ok - please revise for flow, logic, and add next steps summarized - once you do for each section I think a bigger theme will emerge - ie plant-animal interactions are studied in different ways depending on the specific interaction subset or hypothesis but??? What is the big picture?

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