1. **<u>Project Title</u>: Using an aggregation compound formulation to strategically focus *Diorhabda carinulata* (Desbrochers) on *Tamarix* spp.: Enhancing the impact of a defoliating herbivore while improving the operational efficiency of monitoring and diverting establishment and population expansion**

2. **<u>Principal Investigator</u>**:
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3. **<u>Cooperators, Collaborators, and Other Participating Institutions</u>**:
Tom Dudley, Marine Science Institute, University of California, Santa Barbara, CA
Justin Russak, Chemistry Department, University of California, Santa Barbara, CA
Dan Bean, Colorado Department of Agriculture – Palisade Insectary, Palisade, CO
Agenor Mafra-Neto, ISCA Technologies, Inc., Riverside, CA
Alexander Gaffke (graduate student) – LRES Department, MSU, Bozeman, MT
Sharlene Sing – USDA FS, RMRS, Bozeman, MT
Liz Hebertson (BCIP contact) – USDA FS, FHP, Ogden, UT

4. **<u>Amount Requested, Project Leveraging</u>:**
Annual request- $71,700; matching funds- $23,898 (25%)
Match: $14,340 - foregone 20% F&A (IDC) charges; $9,558 (Weaver) salary + benefits; This project leverages an additional $9,300 to Dudley's subcontract with another 10-15% anticipated from other land management agencies and landowners.

5. **<u>Project Goals and Supporting Objectives</u>**:

Our goal is to optimize the deployment of male-produced aggregation pheromone of the tamarisk leaf beetle, *Diorhabda carinulata* (Dc), introduced for the biological control of *Tamarix* spp., to better develop, implement and assess the biocontrol program in western North America. By doing this we hope to strategically <u>reduce</u> any impact on threatened or endangered species

The project directly addresses two of the Priorities for the 2015 FHP/FHTET Biological Control of Invasive Native and Non-Native Plants program, specifically to: 1. Develop improved **rearing, distribution and post-release monitoring techniques** for a biological control agent; and 2. **Develop and implement technologies for rapid quantitative assessment** of biological control impacts. It also indirectly addresses the final FHTET Priority, 3. Integrated weed management with a **biological control component that is part of a methods development approach to determine efficacy** and is not considered an operational treatment.

Elements of the project are again directed at enhancing the effectiveness of *Tamarix* biocontrol programs in FS Regions 1, 2, 4 and 6 where Dc has been historically released, and to continue to evaluate its dispersal and establishment in FS Regions 3 and 5, and specific areas of Region 4, where population expansion is occurring and federally listed wildlife populations are potentially at risk via defoliation of nesting habitat.

The project once again combines the efforts of two research programs into a unified theme of optimizing efficacy of biocontrol of *Tamarix* spp. by Dc and by readily monitoring its continued expansion and establishment. We are proposing an expanded area for targeted herbivory in the summer of 2015, using a strategic deployment protocol. We will also expand objectives to include using commercial pheromone formulations to direct DC population establish away from sensitive locations, particularly where Southwestern Willow Flycatcher (SWFL) has nesting sites. Finally, we will explore the use of Dc produced compounds in formulations targeting other *Diorhabda* spp. that have established in southern areas impacted by *Tamarix* spp. The core component of this is greater strategic use of commercially formulated aggregation pheromone (in SPLAT™). The following objectives are centered on this technology.

1. Produce the alcohol component of the aggregation pheromone, (2*E*, 4*Z*)-2,4-heptadien-1-ol ("pheromone") first reported in Cossé et al (2005) in large quantities (175 g) suitable for an expanded strategic focus and to develop methods for ramping up production of the aldehyde component of the Dc pheromone, (2*E*-4*Z*)-2,4-heptadienal (75g) that are highly suited for field longevity and storage;

2. Expand field trials exploring increased efficacy using pheromone formulations to:
   a) specifically target heavy defoliation of *Tamarix* spp. by Dc populations at four sites in WY, and at an array of sites within the Arkansas Basin, CO where Dc is beginning to establish westward from KS
   b) facilitate retention of northern Dc populations in areas experiencing heavy pheromone-mediated defoliation the previous year, and
   c) further assessing Dc establishment at historical <u>and</u> new release sites using pheromone-baited sentinel trees,
   d) determine whether passive Delta traps facilitate better assessment on sentinel trees or whether detection of adults and larvae can be accomplished using sweep nets and visual rating of damage;

3. Implement a pheromone-mediated procedure using sentinel trees for monitoring dispersal and establishment of Dc in the U.S. southwest to:
   a) yield an early detection tool for tracking population expansion into tributaries of the lower Colorado River to the Mexican border, including several adjacent drainages, and
   b) to work closely with local cooperators to establish sentinel tree stations using pheromone formulations for detection of new colonization into regional watersheds such as the Verde/Salt/Gila system, Mojave and Owens, or upper Rio Grande;
   c) use alcohol and aldehyde components in Dc pheromone that are also present in behaviorally active collections from the three other *Diorhabda* species present in North America - these are active when presented in different ratios than for Dc (Allard Cossé, unpublished data);

4. Evaluate use of pheromone formulations to direct attention of Dc away from sensitive locations where *Tamarix* defoliation may be undesirable, especially where protected wildlife species, specifically SWFL, are nesting.

5. Ultimately provide an enhanced operational framework for future application to other systems by land managers using a familiar technology for deployment while maintaining a low level of environmental risk to sensitive riparian areas.

6. Project Justification/Urgency

The invasion of western landscapes by non-native tamarisk or saltcedar, *Tamarix* spp., constitutes one of the most extensive and damaging changes to riparian and wetland ecosystems. Its biology and impacts are well-known and controversial (Busch and Smith 1995, Dudley et al. 2000, Shafroth et al. 2005), including displacement of native riparian vegetation and riparian-dependent wildlife species (Ellis 1995, Dudley and DeLoach 2004), alteration of flood and erosion dynamics (Graf 1978, Manners et al. 2013), depletion of groundwater resources (Shafroth et al. 2005), poor forage quality for livestock (Lesica and Miles 2001) and increased frequency and extent of wildfire (Drus et al. 2012).

In response, specialist agents to suppress *Tamarix* spp., including Dc, were approved for release in heavily-invaded riparian locations (DeLoach et al. 1996). At the same time the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) was designated an Endangered Species that was known to use tamarisk as breeding habitat (Sogge et al. 2008). While not unexpected given its dominance within structural elements of riparian woodlands, the risk of *Tamarix* spp. defoliation and subsequent nest exposure during breeding season raised concerns that biocontrol could result in deleterious outcomes for the threatened species (Dudley and Bean 2012). After federal consultation, Dc was permitted for release in sites beyond 200 miles from known nesting sites in *Tamarix* spp., and in 2001 it was open-released in seven states (Dudley et al. 2001).

Results from initial releases were mixed (DeLoach et al. 2004, Dudley et al. 2012). In some sites populations established and within two to four years defoliated several thousand hectares of tamarisk (Pattison et al. 2010, Meng et al. 2012). Groundwater savings (Pattison et al. 2010), improved wildlife food resources (Longland and Dudley 2008) and target mortality along with evidence of a recovery process (Hudgeons et al. 2007, Bean et al. 2012) were documented, but **establishment failed at most sites** (Bean et al. 2007, Dudley et al. 2012). These need to be re-evaluated for locations which have not been visited in nearly a decade. It is possible that low level survival of the species was not observed and then sites were no longer visited.

Reasons for failures included avoidance of some host taxa that were not sympatric in locations of origin (Dudley et al. 2012) and predation by ants and other generalist predators (Strudley and Dalin 2013). Developmental synchrony with climate and host plants was also a key factor in establishment success or failure of southern releases (Bean et al. 2007). Critical day length that triggered diapause before the overall metabolic capacity to survive the prolonged interval before new vegetation was available initially prevented adult survival at southern latitudes and populations could not establish (Dalin et al. 2010). This biological safeguard against overlapping with Southwestern Willow Flycatcher habitat has faltered due to selection for a shortened critical day length in Dc (Bean et al. 2012). This forces an immediate need to effectively and strategically monitor expansion of Dc populations over a larger area southward: with no reason to assume that the risk of Dc utilizing an even larger area of critical habitat is unreasonable if the critical day length requirements of Dc continue to become shorter (McLeod and Koronkiewicz 2009).

There remains serious concern by wildlife managers that *Tamarix* spp. defoliation could have negative impacts to the federally listed species (SWFL), which is known to nest in tamarisk-dominated vegetation in the Lower Colorado River and its tributaries, and to a lesser extent, the upper Rio Grande. The Bureau of Reclamation and other land management agencies are mandated to protect ‘<u>Critical</u> <u>Habitat</u>’ of this species, which is only at risk during the brief nesting period of early summer when temperatures are high and sudden canopy loss could result in detrimental thermal exposure nestling birds. Methods have been proposed to exclude Dc from nest sites by using insecticides, but would pose and additional threat to SWFL, whereas the capacity to divert herbivore activity from nest locations offer safer means of avoiding local defoliation. Thus, the pheromone, which should pose no chemical risk to wildlife, may offer a safe and effective method for temporarily delaying herbivore impacts during the nesting period. We require strategic capacity and protocols using pheromones for this.

Recent findings using controlled release formulations. In 2012, we began the practice of using sentinel plants (Britton et al. 2010) to better assess Dc establishment and more readily measure impact by using trees baited with lures releasing species-specific aggregation-stimulating compounds in *Tamarix* spp. stands in WY. In 2013, both pheromones and host plant attractants were deployed using a commercially available sustained-release formulation (SPLAT™). The results were very encouraging, but the aggregation pheromone worked better than the reported aggregation-facilitating plant compounds (Cossé et al. 2006), their combination or a control at a pair of fully replicated, randomized complete block sites. These sites were located along the Big Horn River southwest of Lovell, WY and received Dc from Fukang, China in 2001 that were initially successful until populations crashed due to heavy flooding in 2008. A 2012 marginal population of Dc created surrogate 'initial release' sites in 2013 and for follow up experiments in 2014.

Greater beetle capture in sweep nets and more rapid defoliation occurred quite rapidly on all pheromone treated trees again in 2014, while the enhanced longevity of formulations was also replicated. In the summer of 2014 we were able to assess die-back due to the 2013 treatments. Die-back for pheromone treated trees across sites was more than double (> 50%) that for control or plant compound treated trees (< 25%). In 2014, greater cumulative adult captures, greater larval feeding and earlier defoliation again occurred on pheromone treated trees relative to those treated with blank or plant compounds. Heavy feeding caused total defoliation on pheromone treated trees and again caused larvae to displace to the less successful treatments, which were defoliated to a lesser degree at the end of the feeding period. Once again, the numbers on the less successful treatments became inflated due to the success of the pheromone treatments! We believe that this carryover feeding may have been responsible for the lesser, but significant die-back we saw in these treatments in early summer of 2014.

Due to the longevity of the pheromone product in the SPLAT™ formulation, we strategically applied 4g "dollops" (from Lapointe et al. 2011) as were used for mass trapping of other species (Vargas 2009), but only at the time of overwintering adult Dc emergence, emergence of 1st generation Dc adults and when the 2nd generation Dc adults in reproductive diapause fed before winter dormancy. These new 'land manager friendly' treatments at two new sites showed much greater adult densities and feeding on treated trees for each Dc generation, essentially changing weekly application strategies to three per season in WY**. The concentrated feeding by overwintered and late season adults was not expected, because previous reports suggested no pheromone response would occur in these adults. This is an obvious benefit to a land manager, who can focus monitoring on several strategic target dates.**

Thus, deployment of these 4g formulations can be used to monitor and control subsequent dissemination and spread of biological control agents throughout a release location by targeting specific sentinel plants to measure spread or to focus herbivory. It has also become apparent that the use of this technology in monitoring is quite critical, especially when tracking of populations provides critical environmental benefit. This past summer these formulations of pheromone in SPLAT were adopted mid-season with the concomitant use of sticky traps in large area monitoring in southern populations. Pheromone baiting to focus herbivory was also begun in CO. Finally, the potential for monitoring of other established *Diorhabda* spp. is very fortuitous because of the recent discovery (Allard Cossé, unpublished) that these use different ratios of the same aldehyde and alcohol components. **We have also demonstrated that pheromone treated sentinel trees draw beetles in so that they can be captured in passive commercial delta traps hung near the treated tree, but we propose to evaluate this further for strategic monitoring by land managers.**

7. <u>Approach</u>:

I. Pheromone Synthesis – production of gram scale amounts. A challenge for this project is the amount of costly pheromone needed – driven by synthesis components and reaction rate. The published synthesis of (2*E*, 4*Z*)-2,4-heptadien-1-ol and (2*E*,4*Z*)-2,4-heptadienal (Petroski 2003) has been modified to be more than twice as efficient by changing reaction conditions, more rapid addition of a catalyst and increased mixing rate. This scale-up by the organic chemist will yield at least 175 g of (2*E*,4*Z*)-2,4-heptadien-1-ol and 75g of (2*E*-4*Z*)-2,4-heptadienal. This is a direct funding line in the budget.

II. Formulation. We will provide pheromone compounds to ISCA Technologies, Inc., Riverside, CA to produce a 2.5% formulation in a specifically designed matrix. This will require product formulation costs that are also a direct funding line in the budget. Development costs will be mitigated by our field and laboratory experiments, specifically with the aldehyde pheromone component.

III. Field studies, type one – Deploying Product to Focus Herbivory – "Land Manager Friendly". We will target two sites in the area near Lovell, WY (44°46'30", 108°11'8") and two near the Boysen Reservoir (43°17'12", 108°12'16") again. At each site, an existing array of trees will be divided into 3 blocks, each containing at least 20 trees. Tree positions within each block will be randomized and UTM coordinates of each tree will be logged using a GPS. Within these blocks, there will be three treatments with 5 trees for each treatment. Treatments will be 1) SPLAT with aggregation pheromone, 2) SPLAT as a blank formulation and 3) a random untreated tree. Temperature and weather data will be monitored on-site using 3 HOBO dataloggers per block. Categorical data will be taken at the time of first deployment of lures, as will pre-counts. We will take weekly sweep counts and measure defoliation, but SPLAT™ products will be deployed only at the time of emergence of 1) overwintering, 2) F1, and 3) reproductive diapause adults based on temperature records and development rates first reported by Herrera et al. (2005), but now modified using our current data. The experiments will be a CRD design with the three treatments. Analysis appropriate for comparing local abundance of insect numbers, density, life stage and damage will be used. A mixed-model MANOVA will be used to quantify overall effects. The data collected will be part of a Ph.D. student project and will be published in scientific journals and in FHP numbered publications, where appropriate. **This experimental design, with at least 4 replicate sites, will also be implemented strategically in the Arkansas Basin in 2015.**

IV. Field studies, type two – Monitoring and Dc Displacement.

Monitoring. The distribution of Dc in North America has numerous geographic inconsistencies; (http://www.tamariskcoalition.org/BeetleMonitoring), owing to ineffective survey methods for early detection when initial populations are small. **Proposed surveys using the pheromone formulation associated with delta traps are intended not simply to fill gaps, but to target systems south, west and east of the mapped area that are likely avenues of beetle dispersal**. In 2015, a strategic network of pheromone based sentinel trees established in 2014 will be used to track dynamics of colonizing insects. Because dispersal occurs following epidemic population increases at sites where high *Tamarix* biomass supports high population growth rates, we will be especially vigilant during such periods based on routine inspection of currently established monitoring locations such as dense growths near Big Bend State Park (NV).

With this sentinel monitoring system, particular attention will be directed to dispersal pathways toward, and locations inhabited by SWFL in the Gila/Verde/Colorado system as well as the Rio Grande, in response to concerns regarding potential risk to nesting birds (Sogge et al. 2008). We work closely colleague Matthew Johnson, who has previously been supported by FHP for *Tamarix* spp. biocontrol in relation to SWFL critical nesting habitat. Similarly, we will work closely with Bureau of Reclamation biologists charged with assessing impacts to SWFL populations in the Lower Colorado, including identification of locations where restoration efforts should be focused. This will be coordinated with our restoration efforts for SWFL habitat, supported by the Walton Family Foundation and Clark Co., NV (Dudley and Bean 2012).

Recent research by Allard Cossé (unpublished data), shows that the known alcohol and aldehyde components in Dc pheromone are also present in pheromone samples collected from the three other *Diorhabda* species found in North America, however at different proportions than for Dc. These species are primarily in Texas and adjacent areas. Limited volumes of species-specific proportions of these in SPLAT will be sent to long-established cooperators in these areas to evaluate effectiveness. At each site three replicates of formulations for Dc, *D. elongata*, *D. sublineata* and *D. carinata*, plus untreated SPLAT will be deployed using baited delta traps. Adult counts will be made after 2 weeks of field deployment. From this, we hope to be able to develop tools suitable for effective monitoring or, potentially, exploiting these species as per Dc.

Displacement. A series of sites outside SWFL Critical Habitat where Dc is well-established but has not caused major dieback of host plant foliage will be identified. Each site would consist of a patch of 10 *Tamarix* trees to simulate a SWFL nesting site intended for protection, while a series of SPLAT dollops would be placed in different configurations in *Tamarix* vegetation at 50 m distant from the 'nest' site. The experiment configurations, replicated by at least 3 times for each configuration, would include one array downwind of the proxy nest site; another array 50 m to either side of the protected site; and another with treatments in each cardinal direction will be used to determine the best approach to distracting Dc away from protected SWFL sites. This would occur in early summer when the birds would be nesting, and patches monitored frequently to count number of beetles and assess whether defoliation had occurred.

If successful, we would immediately coordinate with the Bureau of Reclamation, US Fish & Wildlife Service, State wildlife management agencies and others tasked with wildlife habitat protection to ensure that sufficient SPLAT pheromone product, and instructions on deployment of pheromone in known nesting locations within SWFL Critical Habitat potentially exposed to defoliation. From our prior work at other locations where SWFL are present within our study areas, the short duration period for implementing and monitoring near nesting sites are highly unlikely to disrupt SWFL behavior.

A Rapid Assessment approach (Dudley and Brooks 2011, Bateman et al. 2010) will also be applied to monitor condition of *Tamarix* plants in relation to insect herbivory, including multiple *Diorhabda* spp. (Dc, *D. elongata*, *D. sublineata*, *D. carinata*; Tracy & Robbins 2009). Data from this approach, already in use at sites in western states for several years, plus geographic information on plants and herbivores will be logged into a GIS base map to be maintained on a project website (http://RIVRLab.msi.ucsb.edu/). **Numerous managers and researchers have expressed need for formulated pheromone and a protocol for its use.** Incorporating this as part of a dedicated research program will allow us to maintain cohesion for recording results from our own work and those of other stakeholders across the western states.

8. <u>Expected Products and Outcomes</u>: (products and how they will be used)

Demonstration that controlled release technology is readily implementable for weed biological control applications using sentinel trees and semiochemicals. Specific products:

- **I.** Aggregation pheromone thoroughly tested in controlled release formulation for use by researchers, land managers and other stakeholders
- **II.** Strategy for deployment of formulations to: 1) direct, 2) retain, 3) monitor and 4) potentiate biocontrol agents in targeted locations or across large landscapes.
- **III.** Incorporation of facile monitoring and displacement of Dc expanding into critical habitat that builds on existing infrastructure available to disseminate information to stakeholders.
- **IV.** Strategic field demonstration using a model weed biocontrol system that could be developed for other target weed biological control systems.
- **V.** Future development of the commercial potential of the technology by seeking grants supporting small business development for this specific technology.

BUDGET

Salary - Graduate student (0.4 FTE) -	$13,600
Benefits @ 10% -	$1,260
Undergraduate student @ $10.50/hr x 300 hr	$3,150
Benefits @ 10%	$315
Pheromone synthesis- total 250 g @ $165/g	$23,750
Pheromone Formulation- 80 syringes with 60g @ 2.5%	$4,995
Subcontract – Dudley (Itemized below)	$11,632
Supplies - Field items -	$1,400
Supplies - Lab items -	$4,600
*Travel (CO)-	$2,000
**Travel (Project vehicle)-	$4,998
TOTAL REQUEST	**$71,700**

*Travel Details

Dan Bean, Manager, Palisade Insectary, Palisade, CO

CDOA vehicle use	$1,600
Palisade to Arkansas River Basin (La Junta, CO) *(4 trips @ 800 mi/trip = 3200 mi @ $.50/mi)*	
Per diem	$400
(1 person, 4 trips @ 3 d/trip = 12 person days @ $33.33/day)	
Sub-total	$2,000

***Travel Details*

Montana State University

Fuel – *(650 mi @ 13 mpg X $3.25 gal) - $162.50 (12 trips)*	$1,950
Lodging – *$90/night for 2 per room (12 trips)*	$1,080
Per diem (meals per day trip @ out-of-state rate) – *($41/person X 2 days X 2 people - $164 (12 trips)*	$1,968
Sub-total	$4,998

Subcontract Details - Dudley

o	Salary - Co-PI - (0.05 FTE)	$4,000
o	Benefits @ 28% -	$1,120
o	Technical assistant (0.25 FTE for 4 mo. @ $15/hr)	$2,400
o	Benefits @ 18%	$432
o	Supplies - Field items -	$500
o	Supplies - Lab items -	$300
o	*Travel (Private vehicle)-	$2,880
	TOTAL REQUEST	***$11,632***

*Travel Details

Vehicle – *(800 mi @ $0.44 per mile) - $352/trip (6 trips)*	$2,112
Lodging – (rental house or camping expense – Contributed)	$0
Per diem (meals per day trip @ out-of-state rate) – *($32/person X 24 days X 1 person – for 6 trips)*	$768
Sub-total	$2,880

TIMETABLE

April - November 2015:	Delivery of pheromone; formulation
May - September 2015:	Field trials on large-scale targeted herbivory in WY
May - September 2015:	Field trials on large-scale targeted herbivory in CO
April- September 2015:	Laboratory trials - longevity, release rates (new)
May - November 2015:	Field monitoring -large scale in the Southwest
June – August 2015:	Field assessment - longevity, release rates (new)
May – September 2015:	Field monitoring - formulations (other *Diorhabda*)
October 2015 - May 2016:	Analyze data, prepare reports and publications

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Publications (of >100)

D. Piesik, D. Pańka, M. Jeske, A. Wenda-Piesik, K. J. Delaney, and D. K. Weaver. 2013. Volatile induction of infected (*Fusarium* spp.) and neighboring uninfected barley and wheat may influence attraction/repellence of a cereal herbivore. Journal of Applied Entomology. 137: 296-309.

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Relevant Publications (of >90):

Dudley, T.L., C.J. DeLoach, J. Lovich and R.I. Carruthers. 2000. Saltcedar invasion of western riparian areas: Impacts and new prospects for control. Pp. 345-381. Trans. 65th No. Am. Wildlife & Nat. Res. Conf., Chicago.

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Recent Select Publications

Dudley TL, Bean DW, Pattison RR, Caires A (2012) Selectivity of a biological control agent, *Diorhabda carinulata* (Chrysomelidae) for host species within the genus *Tamarix*. Pan Pacific Entomologist (in press)

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Education

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Publications:

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Carillo, N., E.A. Davalos, J.A. Russak and J.W. Bode. 2006. Iterative, aqueous synthesis of β3-oligopeptides without coupling reagents. J. Am. Chem. Soc. 2006, 128, 1452-1453

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B. PUBLICATIONS (from 49)

1. Ye, L.; Wang, X.; Keogh, E. J.; Mafra-Neto, A. 2009. Autocannibalistic and Anyspace Indexing Algorithms with Application to Sensor Data Mining. In: Proceedings of the SIAM International Conference on Data Mining. April 30 - May 2, 2009. Sparks, NV SDM 2009: 85-96.
2. Lapointe, S. L.; Stelinski, L. L.; Evens, T. J.; Niedz, R. P.; Hall, D. G.; Mafra-Neto, A. 2009. Sensory Imbalance as Mechanism of Orientation Disruption in the Leafminer Phyllocnistis citrella: Elucidation by Multivariate Geometric Designs and Response Surface Models. J. Chem. Ecol. 35: 896-903.
3. Vargas, R. I.; Pinero, J. C.; Mau, R. F. L.; Stark, J. D.; Hertlein, M.; Mafra-Neto, A.; Coler, R.; Getchell, A. 2009. Attraction and Mortality of Oriental Fruit Flies to SPLAT-MAT-Methyl Eugenol with Spinosad. Entomol. Exp. Appl. 131: 286-293.
4. Vargas, R. I.; Pinero, J. C.; Jang, E. B.; Mau, R. F. L.; Stark, J. D.; Gomez, L.; Stoltman, L.; Mafra-Neto, A. 2010. Response of Melon Fly (Diptera: Tephritidae) to Weathered SPLAT-Spinosad-Cue-Lure. J. Econ. Entomol. 103 (5): 1594-1602.
5. El-Shafie, H. A. F.; Faleiro, J. R.; Al-Abbad, A. H.; Stoltman, L.; Mafra-Neto, A. 2011. Bait-Free Attract and Kill Technology (Hook RPW) to Suppress Red Palm Weevil, Rhynchophorus ferrugineus (Coleoptera: Curculionidae) in Date Palm. Florida Entomologist 94(4): 774-778.
6. Patt, J. M.; Meikle, W. G.; Mafra-Neto, A.; Sétamou, M.; Mangan, R.; Yang, C.; Malik, N.; Adamczyk, J.J. 2011. Multimodal cues drive host-plant assessment in Asian citrus psyllid (Diaphorina citri). Environmental entomology 40 (6), 1494-1502.
7. Batista, G. B.; Hao Y.; Keogh, E.; Mafra-Neto, A. 2011. Towards Automatic Classification on Flying Insects. 10th International Conference on Machine Learning and Applications Workshops. 364-369.
8. Suckling, D. M.; Sullivan, T. E. S.; Stringer, L. D.; Butler, R. C.; Campbell, D. M.; Twidle, A. M.; Allen, W. J.; Mafra-Neto, A.; El-Sayed, A. M. 2012. Communication Disruption of Light Brown Apple Moth (Epiphyas postvittana) using Four Component Sex Pheromone. Crop Protection. In Press.
9. Vargas, R. I.; Stark J. D.; Piñero, J. C.; Souder, S. K.; Gomez, L. E.; Spafford, H.; Stoltman, L. and Mafra-Neto, A. 2013. Weathering and Chemical Degradation of SPLAT MAT- Spinosad-ME and SPLAT MAT- Spinosad-C-L for Fruit Fly (Diptera: Tephritidae) Control Under California Weather Conditions. J. Econ. Entomol. In Press.
10. Vargas, R. I; Piñero, J. C.; Souder, S. K.; Gomez, L. E.; Spafford, H.; Stoltman, L. and Mafra-Neto, A. 2013. Field Trials of SPLAT MAT-Spinosad ME and SPLAT MAT-Spinosad ME/CL Mixtures for Fruit Fly (Diptera:Tephritidae) Suppression of Bactrocera dorsalis (Hendel) and Bactrocera cucurbitae (Coquillett) in Papaya Orchards. In Press.
11. Vargas, R. I; Piñero, J. C.; Souder, S. K.; Gomez, L. E.; Spafford, H.; Stoltman, L. and Mafra-Neto, A. 2013. Field Trials of SPLAT MAT-ME Against Bactrocera dorsalis, Bactrocera carmbolae, and Bactrocera zonata. Pest Management Science. In Press.

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- 01/2002 – 10/2005: Research Entomologist (Post-doc), USFS RMRS, Bozeman, MT

Selected publications

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