Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-401

Proposal Title: Pathogen-Driven Behavioral Changes in Deer Ticks

Project Manager Information

Name: Victor Lai

Organization: U of MN - Duluth

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Project Basic Information

Project Summary: This project develops an artificial feeding system to determine how Borrelia burgdorferi alters deer tick behavior, informing strategies to reduce Lyme disease risk and protect Minnesota's wildlife and natural resources.

ENRTF Funds Requested: $299,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Small Projects (G)

Secondary Category: Resiliency (A)

Project Location

What is the best scale for describing where your work will take place?

Region(s): NE

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Tick-borne diseases, particularly Lyme disease caused by Borrelia burgdorferi, are increasing across Minnesota. The deer tick (Ixodes scapularis) is now well established in Minnesota, where expanding tick populations—driven by climate trends, host abundance, and habitat changes—affect wildlife and human communities. Outdoor recreation and natural resource–based livelihoods are central to the region's economy and culture. Activities such as hunting, hiking, camping, fishing, and forestry work bring residents and visitors into frequent contact with tick habitat, increasing the risk of exposure to infected ticks.

Previous studies suggest that Borrelia burgdorferi infection may alter tick behavior in ways that enhance disease transmission. Infected ticks have been observed to quest higher on vegetation and remain in host-seeking positions for longer periods, increasing the likelihood of encountering human and wildlife hosts and transmitting the pathogen. However, existing studies rely on wild-collected ticks that often carry multiple pathogens and diverse microbial communities. This makes it difficult to determine whether observed behavioral changes are caused specifically by Borrelia burgdorferi. A controlled experimental system is therefore needed to isolate pathogen-specific effects and improve understanding of how infection influences tick behavior and Lyme disease risk in Minnesota ecosystems, and support science-based strategies to reduce transmission risk.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

We propose to develop and validate a controlled experimental system to determine how Borrelia burgdorferi infection influences the behavior of the deer tick. The project combines engineering approaches with vector biology to isolate pathogen-driven effects that cannot be clearly identified using wild-collected ticks.

First, we will optimize an artificial membrane feeding (AMF) system that allows laboratory-reared ticks to feed under controlled conditions and be experimentally exposed to Borrelia burgdorferi. Environmental factors such as temperature, humidity, and feeding orientation will be systematically evaluated to maximize feeding success and ensure consistent infection. Establishing a reliable AMF system will allow ticks to be infected in a controlled environment while minimizing confounding variables present in field-collected specimens.

Second, we will construct and utilize an environmentally controlled behavioral chamber to measure tick host-seeking (questing) activity under standardized environmental conditions. High-resolution imaging and environmental monitoring will be used to quantify questing frequency, duration, and height in infected and uninfected ticks.

Taken together, the system will enable investigation of how Borrelia infection and variation in tick gut microbial community composition influence survival, feeding success, and host-seeking behavior. Together, these experiments will provide controlled data on pathogen-driven behavioral changes that influence Lyme disease transmission risk.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

This project generates a validated methodology for isolating pathogen-driven behavioral changes in ticks, improving understanding of how Lyme disease spreads within Minnesota ecosystems. Outcomes include a reproducible artificial feeding protocol, quantified behavioral datasets, and guidance for future vector-pathogen research. We will establish a model system that can be extended to study the behavioral effects of other pathogens on ticks. These results support protection and enhancement of the state's natural resources by informing wildlife management, improving ecological disease modeling, and strengthening prevention strategies that reduce pathogen transmission among wildlife, domestic animals, and humans, enhancing Minnesota's capacity to address vector-borne disease challenges.

Activities and Milestones

Activity 1: Develop and Optimize an Artificial Membrane Feeding (AMF) System for Ticks

Activity Budget: $115,229

Activity Description:
Objective: Establish a reliable and reproducible artificial membrane feeding (AMF) platform that enables laboratory-reared Ixodes scapularis to feed under controlled conditions and be experimentally exposed to Borrelia burgdorferi.

Tasks:
• Fabricate modular AMF chambers compatible with the selected feeding membrane that maintain stable blood temperature and allow consistent tick attachment and feeding.
• Standardize blood preparation protocols and pathogen inoculation procedures for controlled exposure to Borrelia burgdorferi.
• Optimize environmental conditions known to influence feeding behavior, including temperature, humidity, and feeding orientation.
• Generate infected and pathogen-free ticks and confirm infection status using Polymerase Chain Reaction (PCR) based molecular assays.
• Quantify feeding success, engorgement mass, molting success, and infection rates across multiple trials to validate system reliability.

Outputs:
• Validated artificial membrane feeding protocol
• Quantitative dataset describing feeding success and infection efficiency
• Standard operating procedures (SOPs) enabling reproducible experimental infection

Impact:
This activity establishes a controlled experimental platform for studying tick–pathogen interactions within Minnesota. This AMF system enables manipulation of tick infection with specific pathogens, thereby eliminating confounding variables associated with field-collected ticks and provides essential research infrastructure for future studies of tick-borne pathogens.

Evaluation:
Quantitative metrics include feeding success rates, PCR-confirmed infection rates, engorgement weight distributions, and reproducibility of results across independent

Activity Milestones:

Description	Approximate Completion Date
AMF prototype constructed	December 31, 2027
Environmental optimization for feeding conditions completed	June 30, 2028
Infection validation (i.e., successful introduction of Borrelia via feeding) confirmed via PCR	December 31, 2028
Finalized SOP and technical documentation	February 28, 2029

Activity 2: Quantify Behavioral Changes in Infected vs. Uninfected Ticks

Activity Budget: $183,771

Activity Description:

Objective: Determine whether Borrelia burgdorferi infection alters host-seeking (questing) behavior and other transmission-relevant behaviors of deer ticks under controlled environmental conditions.

Tasks:

- Construct an environmentally controlled behavioral chamber designed to replicate environmental conditions typical of Minnesota forest ecosystems.
- Establish standardized temperature, humidity, and photoperiod cycles to simulate seasonal conditions encountered in tick habitats.
- Incorporate vegetation-mimicking substrates and vertical structures to replicate natural questing surfaces used by ticks in natural environments.
- Record tick activity using high-resolution imaging and time-lapse recording system.
- Quantify behavioral metrics including questing frequency, duration of host-seeking posture, vertical questing height, and movement patterns.
- Compare behavioral responses between infected and uninfected ticks using statistical analysis.

Outputs:

- Quantitative dataset describing infection-associated behavioral changes
- Statistical analysis of questing behavior differences
- Peer-reviewed manuscript and final technical report

Impact:

Understanding how pathogen infection alters tick behavior is critical for predicting disease transmission risk in natural systems. Findings will improve ecological models of Lyme disease spread and inform wildlife and land management strategies aimed at reducing pathogen transmission risk in Minnesota's forests and outdoor recreation areas.

Evaluation:

Project success will be assessed through statistical significance of behavioral differences between infected and uninfected ticks, reproducibility across trials, and dissemination of results through peer-reviewed publication.

Activity Milestones:

Description	Approximate Completion Date
Behavioral chamber constructed and operational; environmental conditions optimized	March 31, 2029
Data from behavioral trials (videos, images) analyzed and synthesized	March 31, 2029
Behavioral trials of infected and uninfected ticks completed	December 31, 2029
Final report and manuscript submission	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Benjamin Clarke	University of Minnesota	co-PI	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
Results from this project will be disseminated through multiple channels to ensure that findings are accessible to researchers, natural resource managers, public health professionals, and the broader public in Minnesota. Peer-reviewed manuscripts describing the artificial membrane feeding methodology and behavioral findings will be submitted to journals focused on vector biology, ecology, and infectious disease. In addition, project results will be presented at a national scientific conference (e.g., a vector-borne disease or entomology meeting) to engage the broader research community and facilitate collaboration with scientists working on tick ecology and pathogen transmission.
To ensure practical application of the research, findings will also be shared with state and regional partners involved in wildlife and disease monitoring, including natural resource and public health agencies that use ecological data to guide management decisions. Experimental protocols, datasets, and standard operating procedures generated through this work will be documented and maintained at the University of Minnesota Duluth to support future research on tick-borne pathogens affecting wildlife and outdoor communities.
Project outcomes will be communicated in accessible formats through public presentations, online summaries, and institutional outreach channels to increase awareness of tick-borne disease risks and prevention strategies. All publications, presentations, and outreach materials will acknowledge support from the Environment and Natural Resources Trust Fund and include required attribution language and logo usage consistent with ENRTF guidelines.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
Project results will be disseminated through peer-reviewed publications, conference presentations, and collaboration with state wildlife and public health partners. The artificial feeding and behavioral assessment systems developed here will remain in place at UMD for continued research on additional tick-borne pathogens. Future work will be supported through federal grants (e.g., NIH, NSF), state natural resource funding programs, and collaborative partnerships. By establishing a sustainable research infrastructure and methodology, this project creates long-term capacity within Minnesota to investigate and manage vector-borne disease threats affecting wildlife and natural systems.

Project Manager and Organization Qualifications

Project Manager Name: Victor Lai

Job Title: Associate Professor

Provide description of the project manager's qualifications to manage the proposed project.
Victor Lai, Ph.D., will serve as Project Manager for this project. He is an Associate Professor of Chemical Engineering at the University of Minnesota Duluth with over a decade of experience leading interdisciplinary research at the interface of engineering, biomaterials, and vector-borne disease systems. His expertise in experimental system design and pathogen-related research uniquely positions him to manage the technical, logistical, and collaborative components of

this work.
Dr. Lai has successfully developed artificial membrane feeding systems and laboratory-based behavioral platforms to study Borrelia burgdorferi interactions with Ixodes scapularis. Preliminary work from his laboratory includes a peer-reviewed undergraduate-led publication demonstrating carbon dioxide–mediated attraction of ticks in an artificial feeding system, as well as collaborative research examining tick motor responses under environmental stress conditions. These publications directly inform the feeding optimization and behavioral measurement methods in this proposal.
As Principal Investigator on externally funded awards, including a current grant from the National Science Foundation, Dr. Lai has demonstrated strong project oversight, budget management, regulatory compliance, and milestone tracking. He has graduated multiple Master's students and mentored more than 15 undergraduate researchers in recent years. Each Master's student under his supervision has produced a peer-reviewed publication, and several undergraduate researchers have served as first authors on journal articles related to tick behavior and artificial feeding systems. His mentoring approach emphasizes structured project planning, reproducible experimental design, quantitative data analysis, and clear scientific communication—ensuring that research trainees contribute meaningfully to defined project milestones while maintaining continuity and accountability throughout multi-year projects.

Organization: U of MN - Duluth

Organization Description:
The University of Minnesota Duluth (UMD) is a regional public research university located on the north shore of Lake Superior in northeastern Minnesota. UMD serves as a major hub for research, education, and workforce development in northern Minnesota and plays an important role in addressing regional challenges related to environmental systems, natural resources, and public health. The university enrolls approximately 10,000 undergraduate and graduate students and maintains strong partnerships with local communities, state agencies, and industry.

PI Victor Lai is based in the Swenson College of Science and Engineering (SCSE), which houses departments spanning engineering, physical sciences, and biological sciences. SCSE emphasizes interdisciplinary research and applied science, with faculty and students working on problems relevant to environmental sustainability, biotechnology, and health-related systems. The college provides laboratory infrastructure, research facilities, and undergraduate and graduate training programs that support experimental and computational research.

Co-I Benjamin Clarke is affiliated with the University of Minnesota Medical School Duluth Campus, which is co-located with UMD and maintains close collaborative ties with SCSE. This proximity facilitates interdisciplinary collaboration between engineering researchers and biomedical scientists, creating a strong environment for studies of vector-borne disease systems relevant to Minnesota's ecosystems and communities.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Dr. Victor Lai, PI		Dr. Victor Lai will serve as Principal Investigator and Project Manager for the project. He will oversee all project activities, including experimental design, development and optimization of the artificial membrane feeding system, and construction of the controlled behavioral testing environment. Dr. Lai will coordinate project timelines, supervise student researchers, and ensure that milestones and reporting requirements are met. His laboratory will lead the engineering and experimental components of the project, including system fabrication, environmental control integration, and behavioral data collection and analysis. Dr. Lai will also coordinate dissemination of results through technical reports, presentations, and peer-reviewed publications, ensuring that project findings contribute to broader research on tick-borne disease dynamics in natural systems.			26.8%	0.06		$8,502
Dr. Benjamin Clarke, Co-I		Dr. Benjamin Clarke will serve as Co–Principal Investigator and will provide expertise in tick biology, pathogen detection, and vector-borne disease systems. He will advise on experimental infection protocols, assist in confirming Borrelia burgdorferi infection status using molecular techniques, and support interpretation of behavioral and ecological results. Dr. Clarke will collaborate on study design to ensure that laboratory experiments reflect biologically relevant conditions for tick–pathogen interactions. He will also contribute to data analysis, manuscript preparation, and dissemination of findings. His expertise in vector ecology and tick-borne pathogens will ensure that the project's experimental framework and results are scientifically robust and relevant to understanding Lyme disease dynamics.			26.8%	0.24		$82,033

Postdoctoral associate		A postdoctoral researcher will be hired in Year 1 and will lead day-to-day research activities during Years 2–3 of the project. The postdoctoral researcher will be responsible for building and implementing the artificial membrane feeding system, conducting experimental infections with Borrelia burgdorferi through the artificial feeding system, and building the terrarium to perform behavioral experiments that quantify host-seeking (questing) activity in Ixodes scapularis under controlled environmental conditions. They will also assist in assessing microbial composition within ticks to evaluate how pathogen infection and associated microbiome variation influence tick survival and feeding behavior. The postdoctoral researcher will oversee data collection, perform statistical analysis of behavioral and microbiological datasets, and maintain detailed experimental protocols to ensure reproducibility. They will work closely with the PI Lai and Co-I Clarke to interpret results, track project milestones, and prepare project reports. In addition, the postdoctoral researcher will mentor undergraduate student researchers participating in the project and contribute to the preparation of manuscripts and conference presentations.			20.7%	2		$160,855
Undergraduate research associates		Two undergraduate researchers will participate in the project during the academic year and summer terms. During the academic year, two students will work approximately 5 hours per week assisting with laboratory preparation, equipment maintenance, and preliminary experimental tasks. During the summer, two undergraduate researchers will work full-time (40 hours per week for 10 weeks) to support intensive data collection and experimental activities. Undergraduate researchers will assist with the development of the artificial membrane feeding system and the setup of controlled environmental conditions for behavioral experiments. They will also support behavioral data collection by monitoring and recording tick questing activity and assisting with			0%	6		$36,144

		imaging and environmental monitoring. Students will help prepare samples for microbiological and molecular analyses and assist with organizing and documenting experimental datasets. Under the supervision of the postdoctoral researcher and PI/co-PI, undergraduate researchers will receive training in laboratory safety, experimental design, and data management. They will contribute to maintaining standardized protocols and ensuring consistent data collection throughout the project.						
							Sub Total	**$287,534**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	Live-stream HD video camera (quantity: 1)	This piece of equipment is necessary to capture real-time videos of the questing behavior of ticks in the environmental-controlled terrarium (Activity 2)	X				$4,199
	Tools and Supplies	Lab supplies specific to this project.	These are supplies and materials necessary for the various activities in this project - materials to build an artificial membrane feeding (AMF) system and an environmental-controlled terrarium to study tick behavior; PCR kits to confirm tick infection via feeding.					$5,319
							Sub Total	**$9,518**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	Conference attendance for 1 person in year 3.	For 1 person (likely the post-doc) to present results at a national conference in year 3. Out-of-state travel is requested as there are no similarly large-scale conferences of this type in Minnesota.	X				$1,948
							Sub Total	**$1,948**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$299,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Equipment, Tools, and Supplies		Live-stream HD video camera (quantity: 1)	This is considered a piece of audiovisual equipment, but is a critical component of observing tick behavior in the environmental-controlled terrarium.
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	Conference attendance for 1 person in year 3.	Out-of-state travel is requested as there are no similarly large-scale conferences of this type in Minnesota.The purpose is to participate in formal presentation of project findings.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
Cash	UMN unrecovered indirect costs are calculated at the UMN negotiated rate for research of 54% modified total direct costs.	Indirect costs are those costs incurred for common or joint objectives that cannot be readily identified with a specific sponsored program or institutional activity. Examples include utilities, building maintenance, clerical salaries, and general supplies.	Potential	$161,460
			Non State Sub Total	**$161,460**
			Funds Total	**$161,460**

Total Project Cost: $460,460

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 8ff321f3-c0a.pdf

Alternate Text for Visual Component

The Theory of Change framework illustrates how the two proposed research activities—controlled tick infection and behavioral monitoring in an environmental terrarium—produce experimental outputs that generate new knowledge about pathogen-driven tick behavior, ultimately informing improved prediction and management of Lyme disease risk in Minnesota ecosystems....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Authorization Letter	72586398-07a.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care,

treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Michael Jacob (University of Minnesota Duluth), Claudia Carranza (University of Minnesota Duluth)

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A