Leading Edge Species: Establishing an Early Detection & Rapid Response Program for Invasive Species on Galiano Island

Prepared for the Galiano Conservancy Association

ES 471/ER 412

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Territory Acknowledgement

We respectfully acknowledge that our time spent at the Millard Learning Centre is within the shared, asserted, unceded, and sovereign traditional territories of the Hul'qumi'num speaking First Nations Peoples. Coast Salish Peoples have lived, and cared for what is now called Galiano Island since time immemorial, and hold traditional rights, title, and responsibilities to the lands and waters we have the privilege of living and learning from.

Abstract

Invasive species are one of the greatest threats to species-at-risk, and are one of the leading causes of biodiversity loss globally. On Galiano Island, as well as many other places globally, much of invasive species management focuses on the removal and management of current problem species, rather than preventing the arrival of new species and deploying a rapid response program if they do arrive. Presently, the Galiano Conservancy Association (GCA) does not have a program in place to respond to new occurrences of invasive species. This report discusses two primary steps toward a leading edge species program. First an inventory of the thirteen priority invasive species on Galiano Island that are the most likely to be introduced in the near future and become invasive. Second is an iNaturalist project called 'Invasive Species Monitoring around Galiano Island' that collects all observations of the thirteen priority invasive species on the Northern and Southern Gulf Islands, Vancouver Island, the Sunshine Coast, and along the coast of Greater Vancouver, Northwest Washington, and the Olympic Peninsula. We hope these two components will provide the GCA with a better understanding of the movement and establishment of these species in other areas, making it possible for prevention and early detection to be at the forefront of management for these leading-edge species. We conclude with three key recommendations for the GCA and Galiano community members can act on moving forward:

1. We urge the GCA to explore the execution of a rapid risk assessment of the thirteen priority invasive species listed.
2. We recommend that the iNaturalist Project created be shared and used among the Galiano Island community.
3. Lastly, we suggest using data provided by the community through iNaturalist to monitor species-specific spread of invasive plants and animals to better support actionable plans that protects biodiversity on Galiano Island.

Introduction and Background

What are Invasive Species?

Invasive species by definition are non-native species that exist outside of their typical range and cause harm to local environments, people, and economy (Government of British Columbia, 2026) . Invasive species are one of the leading causes of biodiversity loss and species extinction across terrestrial, freshwater, and marine ecosystems on a global scale, and are recognized as one of the greatest threats to species-at-risk in Canada (Tamburello & Litt, 2023). As Canada's most biologically diverse province, British Columbia's threatened and endangered species are especially at risk. With at least half of all federally listed species-at-risk being found within BC, the management of invasive species is a crucial aspect of supporting the survival of species-at-risk. The direct impacts of these biological invasions often cause irreversible loss of species, which in turn results in a loss of genetic diversity as well (Mollot et al., 2017).

The ways in which invasive species impact species-at-risk are far reaching and ever changing, with some of the impacts involving behavioural changes (altered predator-prey dynamics), biofouling (accumulation of microorganisms on vessel hulls), disease (Whirlin disease in Rainbow Trout causes skeletal deformities), and genetic effects (interbreeding between introduced and native species) (Gharamah et al., 2025; Huxel et al., 1999; Mollot et al., 2017; Perry et al., 2025; Ruland & Jeschke, 2020). However, the primary mechanisms by which invasive species impact species-at-risk are through habitat alteration and degradation, competition, and predation. The impacts of competition and predation between native and non-native species can be understood through the way that biological invasions alter the structure of food webs.

It is also important to note that in this paper we use two terms 'introduced' and 'invasive' to describe species that are not native to a place. These two terms are sometimes used interchangeably. We want to clarify that throughout this paper, we use them as two separate terms. We refer to introduced species as a broader term for any non-native species, whereas we use the term 'invasive' to refer to introduced species that specifically pose a significant threat to native plant and animal species.

Ecology of Galiano Island

British Columbia is an ecologically diverse region, made up of fourteen distinct biogeoclimatic (BEC) zones that are each unique in climate and therefore vegetation (Apps, 2024). Galiano Island is located within the Coastal Douglas Fir biogeoclimatic zone. It is the smallest of the fourteen zones, making up only 0.3% of the province's land mass (Coastal Douglas Fir & Associated Ecosystems Conservation Partnership, 2022). This places a special interest in protecting diversity within the Coastal Douglas Fir Zone because it is restricted to a small range that is not seen anywhere else in British Columbia.

Additionally, Galiano is an island. That brings another layer to the diverse ecology of this place. Island masses provide a distinctive ecology. They are removed from larger land masses such as mainland Canada or Vancouver Island, causing the ecology on Galiano and other islands in the Gulf Islands and the Salish Sea to have developed differently than nearby areas. In these cases, island ecosystems lead to many different biologically diverse species that may not be exposed to the types of competition within their niche or specific habitat (Russell et al., 2017). The size of islands will also change the effects of inter and intraspecific competition between native island species and invasive species based on how large or small the island is. Furthermore, smaller islands have smaller populations that are distinct and therefore they are at greater risk of invasion and predisposed to being overtaken by invasive species (Losos & Ricklefs, 2009). One example of this on Galiano would be the Northern Alligator Lizard, which is a native lizard species on the Island. The Northern alligator lizard can be called a naive species, which refers to their lack of exposure to any sort of competition within their niche (Cox & Lima, 2006). This makes native species such as the Northern alligator lizard and others on Galiano Island vulnerable to invasive species introductions.

The Problem

At present, there are no protocols, monitoring programs, or frameworks in place to handle the issue or topic of leading edge species on Galiano Island to protect species such as the Northern alligator lizard. Provincial-level resources exist such as a list of priority species that can for the whole province. The list is produced as a part of the "Provincial Early Detection and

Rapid Response" program., and categorizes invasive species into management categories (prevent, contain, manage, etc.) on a provincial scale (BC Inter-Ministry Invasive Species Working Group, 2026). While it is a helpful guide to alert, observe, and act on new emerging species in the province, the list is quite exhaustive. Therefore, this list alone may be too broad for smaller scales – such as for an island – to use exclusively for building invasive species monitoring and prevention plans.

There are current and past projects facilitated by the GCA related to invasive species management, however they primarily include the management of already established species on the island, such as Scotch broom (Galiano Conservancy Association, 2021). There have also been student reports that evaluate the endangered status of native species on Galiano Island, and threats to those species often includes the presence of invasive species.

The GCA works tirelessly to conserve and restore biodiversity on the island; however, again there are no projects directly related to biosecurity, which is the stream of science that tackles the topic of invasive species. Biosecurity is a rigorous prevention tactic to manage invasive species, and has been implemented extensively in places such as New Zealand through national legislation that increases invasive species management such as rigorous border security (Hulme, 2020). A recent student report from last year focused on the ecology, threats, and conservation of the Northern Alligator Lizard – a native and naive species on Galiano Island – and the author does touch on the threats that early detection of introduced species is instrumental to preserving biodiversity and at risk species (Van Mierlo, 2025). The motivation of the work in Van Mirelo (2025) was to provide a comprehensive species summary and monitoring plan considering the incipient arrival of the invasive European wall lizard. This theme of invasive species arriving in nearby regions through deliberate or accidental introduction is becoming more and more apparent within and around Galiano Island.

Invasive Species Research and Management Strategies

Introduced species management and the ecological restoration of impacted ecosystems is a heavily researched topic, with a stream of new methods and ideas emerging as new challenges arise. The consensus on best practices for ecological restoration and management has changed through time and varies from place to place. However, much of introduced species' management and ecological restoration practices and ideas, particularly in North America, focus on the

management and regulation of existing invaders rather than proactively preventing and halting the emerging threat of new invasions (Colberg et al., 2024). This is unsurprising given that many of the top introduced species impacting focal species-at-risk in BC (Scotch broom, sweet vernal grass, largemouth Bass) were introduced over 100 years ago (Mollot et al., 2017). It is quite possible that we have yet to see the full potential of many of the more recently dispersed introduced species, especially as climate change influences the spread and establishment of invasive species (Colberg et al., 2024; Mollot et al., 2017). Considering these factors, there is a need for introduced species management to increase focus on preventing the arrival of new invasive species, or in other words, the leading-edge invasive species.

Australia's national biosecurity system poses as a great example of the effectiveness of prioritizing prevention, preparedness, early detection, and rapid response to protect the country from invasive species, pests, and diseases from overseas (AUSVEG, 2026). Part of what makes Australia's biosecurity system so effective is the coordination of the Department of Agriculture, Fisheries, and Forestry (DAFF) in preventing invasive species and pests from entering the country. Management activities begin overseas by assessing whether imported goods pose the risk of hosting exotic pests and diseases, and gathering intelligence on global pests. Activities that take place at Australia's border entail the inspection of goods, equipment, and vehicles entering the country, and if necessary they may be treated through fumigation, pressure washing, or temperature control. Incoming people and their luggage are also inspected. Within Australia, prevention and detection is considered the role of every Australian, where everyone holds the responsibility of reporting unusual pests and diseases. Management activities such as surveillance, movement restrictions on high risk plant material, and the preparation for a biosecurity emergency through education and planning are undertaken within Australia's border. When responding to an invasive species, pest, or disease biosecurity incident within the country, it is managed through a partnership agreement between the Australian government, state, territory government, national plant industry bodies, and Plant Health Australia. While biosecurity systems such as this require significant resources and planning to establish and maintain, it is cost-effective in the long term.

As outlined within the State of Victoria, Australia's "Invasive Plants and Animals Framework", prevention and preparedness are the most effective methods for managing high-risk

invasive species (Victoria Government, 2010). When an invasive species bypasses the biosecurity systems set in place, the next best invasive species management methods are listed within this framework., visualized by what is called the "invasion curve" (Figure 1). The first four levels are outlined as: (1) prevention & preparedness, (2) Eradication, (3) Containment, and (4) Asset-based protection (Victoria Government, 2010). The best management method for an invasive species is determined using risk management, first designating potential threats and then their relative risk is assessed to determine the most appropriate intervention method to maximize public benefit. As the invasive species position on the invasion curve steepens, the less likely it is to be eradicated. Once an invasive species has become widespread and abundant throughout its potential range, eradication is no longer considered a viable option, and (4) Asset-based protection becomes the most appropriate management method. At this stage, the next management method involves (5) Monitoring, Evaluation, and Reporting, which often involve science-based programs, then (6) Research and Development, where the knowledge that comes from R&D is intended to inform evidence-based management approaches.

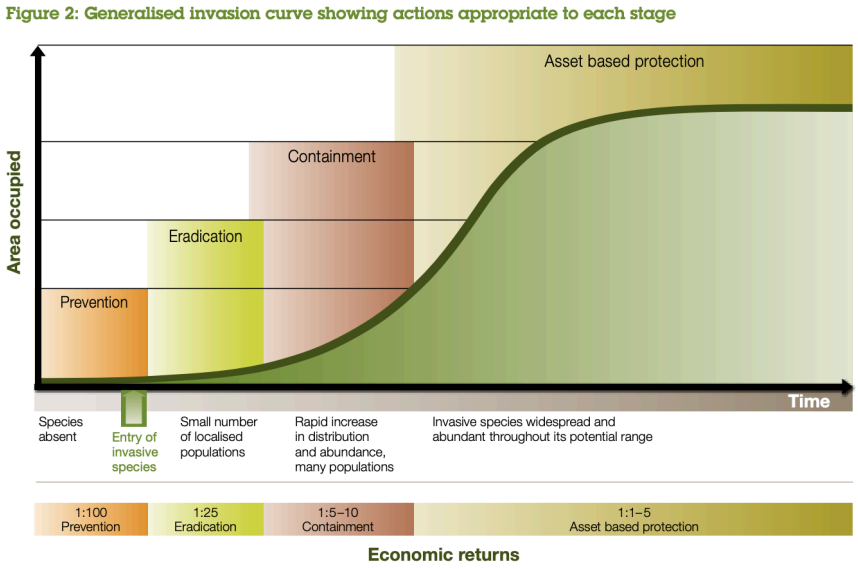

Figure 1: Model of the invasion curve from Australia's Invasive Plants and Animal Framework (Victoria Government, 2010). This figure shows how rapidly the 'area occupied' by invasive species increases over time, and therefore reduces the ability for invasive species to be eradicated.

There are numerous frameworks that are used to navigate complicated questions in conservation and restoration work that often lead to decision paralysis or delays in actionable items taking place. Some of these challenges that can impact decision paralysis in environmental

management include complicated governance structures, competing objectives, different value judgements, multiple stakeholders and rights holders, as well as many other challenges (Hemming et al., 2021).

These kinds of issues have led to research and publications that have produced different decision making frameworks for conservation and restoration science. This includes examples such as PrOACT (define the Problem, elicit Objectives, develop Alternatives, estimate Consequences, and evaluate Trade-offs) developed by Hammond et al. (2015), or the seven-phase process for undertaking ecological restoration, published in 'Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices' by Keenleyside et al. (2012) for the International Union for Conservation of Nature (IUCN). These two examples can be viewed further in Figures 2 and 3. These are two cases that use a structure to guide the design and implementation of ecological restoration at various scales. Publications such as this helped us produce our guiding principles for the project, and come up with solutions such as a 'Priority Invasive Species for Galiano Island Database'.

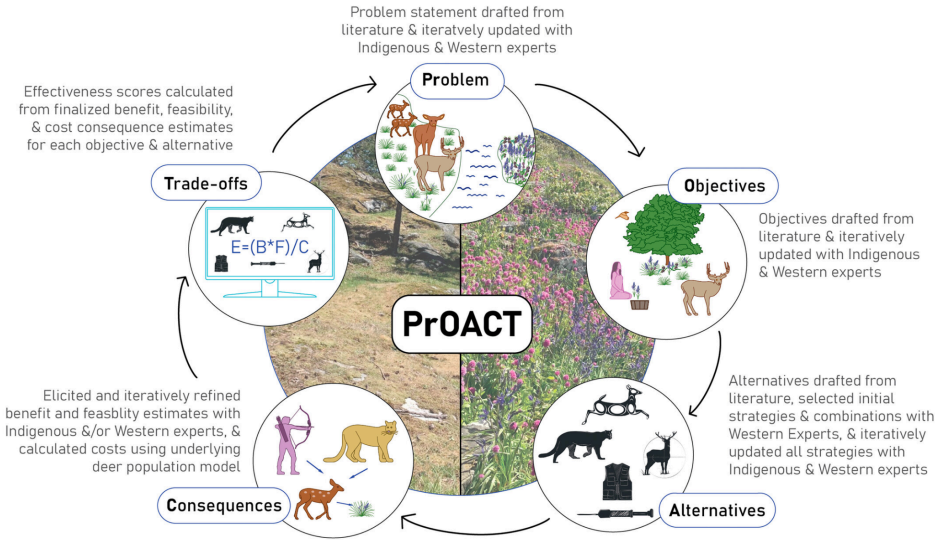

Figure 2: Implementation of structured decision making, using PrOACT in the decision analysis process that developed a management plan for hyperabundant deer in the Southern Gulf Islands using indigenous and scientific knowledges (McComb et al., 2025).

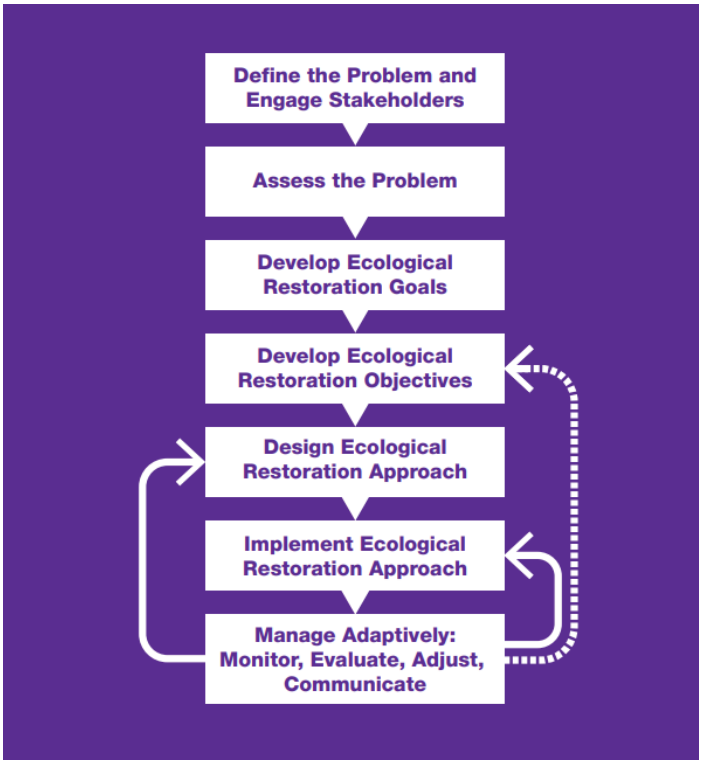

Figure 3: Seven-phase decision making process in Keenleyside et al. (2020) for undertaking ecological restoration in protected areas.

Additional guiding methods within invasive species management literature includes horizon scanning. It is a process in biosecurity that identifies unknown risks, emerging issues, and opportunities to inform policy, decision-making, and research prioritization (Lieurance et al., 2023). Results from horizon scanning guide the allocation of resources to invasive species research, prevention, and eradication. This is particularly important when resources for biosecurity are minimal or limited. Horizon scanning provides an evidence-based list of potential invaders, but can also include more information: pathways, type of impacts (socioeconomic, ecological, etc.), and mechanism. The steps to conduct horizon scanning are as follows, and were used as a guide in the development of our methods and results:

1. Assemble a panel of experts
2. Develop a candidate list of taxa for assessment
3. Complete rapid risk assessments and peer review
4. Build consensus among experts on final rankings
5. Collect additional data after consensus to further detail threats posed by ranked species.

iNaturalist

iNaturalist is a non-profit organization where citizen scientists can upload images of organisms as observations to be identified using the website's species identification tool, and then further verified by community experts (iNaturalist, 2023). Observations that are classified as 'Research Grade' are of the highest level of data quality. For an observation to be considered 'Research Grade', there must be evidence of the organism being present at a site, (image or recording), its identity (genus or species), location of recording (GPS coordinate), when it was recorded (date and time), and by whom (observer), as well as a two-thirds consensus on the identification of the taxon (Potgieter et al., 2024). As long as an observation contains all of the necessary information, historic imagery can be uploaded to the website. If an observation does meet one of these requirements, it is a 'Casual' observation, which differs from 'Casual' plants in the context of naturalisation, which refers to plants that have yet to form self-sustaining populations beyond captivity and cultivation. Observations classified as 'Needs ID' meet all 'Research Grade' requirements, and are waiting for confirmation by community experts to verify the species identity. Until there is a two-thirds consensus by all identifiers of the observation, its data quality classification remains as 'Needs ID'.

Data uploaded to iNaturalist is open source data, and is often used in biodiversity research, conservation, and education (iNaturalist, 2023). Within iNaturalist itself, there is the possibility to create a project within the website. iNaturalist projects can serve many purposes, such as creating a bioblitz, to track and display a set of observations within a certain location, and to communicate to project participants (iNaturalist, 2021).

Tansy Ragwort

One example of an invasive species that can be examined with the use of iNaturalist is Tansy ragwort. We highlight this species as we were informed by GCA staff, as well as local residents on Galiano Island, that Tansy ragwort populations have been increasing in recent years, and are being observed on a regular basis. In an effort to track the movement of Tansy ragwort within the Southern Gulf Islands, we created a map (Figure 6) that displays iNaturalist observations made between years 2007 and 2026. More on this will be revisited in the Results section.

Tansy ragwort is a member of the Asteraceae family and is native to Europe, northern Africa, and Temperate Asia, and has been introduced in North America, China, Australia, New Zealand, and beyond its native range in parts of Europe (CFIA, 2017). This widely introduced, toxic plant is a biennial to short-lived perennial that most often found growing in pasturelands and disturbed areas due it being an early successional species (Leiss, 2011). Tansy ragwort invasions are especially concerning due to its secondary plant compounds, particularly pyrrolizidine alkaloids (PAs), which help them defend against generalist herbivores. Consumption of this plant in any form by animals or humans can cause acute and chronic liver damage. Honey production is also threatened by Tansy ragwort, as honey produced from its flowers can have dangerous levels of PAs.

Goals and Objectives

The potential threats and impacts that introduced species could have and already pose on Galiano Island are concerning. Additionally, the fact that there are no guidelines on how to manage or act on the arrival of introduced species adds a level of uncertainty that limits the region's ability to prepare and plan for any form of action. Upon reflection of this research topic, the current measures in place on Galiano Island, and after a thorough literature review, we have come up with a few key objectives for our project. The main goal being to provide information and recommendations that aids the preparation and prevention of invasive species on the leading edge of invasion on Galiano Island as a means to protect biodiversity on Galiano Island and within the GCAs different properties. This goal is already being addressed through some of the GCAs existing programs for invasive species eradication and containment, but we have additional objectives to reinforce the preservation of biodiversity on Galiano Island. These objectives include the following:

1. Informing residents and landowners through implementing a priority invasive species inventory for Galiano Island into GCA programs such as the Nature Stewards Program
2. Engaging the community in invasive species management using citizen science platforms such as iNaturalist.

Methods

Priority Invasive Species for Galiano Island Inventory

We developed an inventory of high priority and likely leading edge invasive species based on personal conversations with GCA staff, and through research into different approaches to biosecurity, ecosystem restoration, and decision science. The methods used to develop this inventory used the steps described in the background for horizon scanning as a guide, but were not explicitly followed as they were beyond the scope of this report. Rather, we created this inventory of priority invasive species with the intention of it being a resource for the GCA to use should they choose to conduct the more advanced steps within horizon scanning such as risk assessment and threat rankings of invasive species.

This priority species inventory is a compilation of thirteen priority invasive species for Galiano Island. These are species that have not yet been recorded or have been recorded but not yet established (i.e., viable reproducing populations) on the Island, and pose a threat to native species and habitats. They are both literally and figuratively on the leading edge of invasive species introductions in the Southern Gulf Islands and other areas in the Salish Sea. In our inventory there is an assortment of information relevant for making management decisions to ensure the prevention of their arrival. We intend for this inventory to become a starting point for developing better information, resources, and biosecurity protocols on Galiano Island.

We initially conducted research into candidates for leading edge species, which involved conversations with GCA staff and ES 471 teaching team, Dr Eric Higgs, Alia Johnson, and Meghan Hamp. GCA staff consulted included Restoration Coordinator Adam Huggins and Conservation Coordinator Millie Kuyer. We also spoke with guest lecturers from the field school such as Dr Emily Gonzales and our peers in the course. All of whom helped shape this project's methods and results along with a thorough literature review.

Our inventory of key leading-edge species was drawn primarily from existing resources developed by the Galiano Conservancy Association and can be found on their website's page that lists introduced species on Galiano Island (Galiano Conservancy, 2026). Additional species such as the European green crab and nutria were added to this list though they are not listed on the GCA's website as a priority species. This was decided through discussions and literature review. We expect that this inventory will continue to grow and change in the future, as species dynamics

and range shifts change in response to emerging ecological novelty that is occurring here and around the globe.

Once a list of priority species specific to Galiano Island was created, additional information was researched and added to our inventory to better understand each species' type of impact on the island. This includes species characteristics, their type of threat (ecological, social, economic) (Government of Canada, 2017), whether there are any known threats upon their introduction, their preferred ecosystem, etc. Much of this information was sourced from resources such as the Invasive Species Council of BC, which is a great resource for information on new and introduced species by region in BC.

Some information such as land type classification was determined both descriptively under "Preferred Ecosystem" and more categorically as it relates to Galiano Island under "Simplified Ecosystem Classification". This was done at the request of the GCA to be compared to the GCAs Terrestrial Ecosystem Map, which can be explored on their Galiano Conservancy Island Explorer. The Galiano Conservancy Island Explorer is an interactive web mapping tool that provides ecological data for Galiano Island such as land classifications, sensitive ecosystems, wildlife areas, etc. to the public.

Our 'Simplified Ecosystem Classification' encompasses all of the different land classes that exist on the Terrestrial Ecosystem Map found within the Galiano Conservancy Island Explorer in a simplified format. This is defined further in the table below.

Table 1: Simplified classification of the GCA's Terrestrial Ecosystem Map classes, which are displayed in the 'Priority Invasive Species for Galiano Island Database'.

Simplified Ecosystem Classification	**Terrestrial Ecosystem Map Classes**
Forest	Douglas-fir - Salal, Douglas-fir - Shore Pine - Arbutus, Douglas-fir - Grand fir - Oregon grape, Western redcedar - Douglas-fir - Oregon beaked moss, Western redcedar - Grand fir - Foamflower, Western redcedar - Skunk cabbage
Meadow	Garry oak - Moss, Garry oak - Brome / Mixed Grasses, Garry oak - Oceanspray, Cladina - Wallace's Selaginella, Fescue - Camas

Wetland	Open Water, Pond, Pink spirea - Sitka sedge Swamp, Sitka sedge - Peat-moss fen, Sitka Willow - Pacific Willow - Skunk Cabbage Swamp, Cattail Marsh
Coastal	Dunegrass - Beach Pea, Beach, Cliff, Rock Outcrop
Other	Rural
Agriculture	Cultivated Field
Urban	Gravel Pit, Industrial

iNaturalist Project for Species Presence Monitoring

Once the thirteen priority invasive species that are of greatest concern on Galiano Island were identified, we created an iNaturalist project called 'Introduced Species Monitoring around Galiano Island' as a way to track their movement within surrounding areas. The project automatically includes observations made of the thirteen priority invasive species that are within the geographical range of the project, which includes all of the Northern and Southern Gulf Islands, Vancouver Island, the Sunshine Coast, and along the coast of Greater Vancouver, Northwest Washington, and the Olympic Peninsula. Polygons for each region were selected from those that are stored within iNaturalist's database. The range of the iNaturalist project was chosen to include all of the surrounding coasts and islands since transportation networks are a major pathway of invasive species spread, and since there are several key ferry routes connecting the regions mentioned above (Lieurance et al., 2023). Tracking the movement of the thirteen priority invasive species on surrounding coasts and islands will allow for the GCA to be better prepared when and if they do arrive on Galiano Island. As of August 10th, 2026, the iNaturalist project includes over 37,000 observations, including both 'Research Grade' and 'Needs ID' observations. The reasoning for including observations classified as 'Needs ID' within the project is because the only separation between the two data quality classifications is community agreement on the species identity. If one of the priority invasive species was observed on Galiano Island under the 'Needs ID' data quality classification, it could inform the GCA of its potential invasion even before it is verified as a 'Research Grade' observation. If the species identification

is contested by another community expert on iNaturalist, the observation would be removed from the project.

These species observations can be downloaded from iNaturalist as CSV files, and can be used to perform spatial analyses using GIS software. There is the potential to use these spatial data to map the overlaps in species observations, or modelled habitat between priority invasive species, and species-at-risk (Mollot et al., 2017). In this study, the iNaturalist project we created serves as a stepping stone towards more in-depth analyses. However, we did use iNaturalist data to map patterns of movement of two of the priority invasive species, being American bullfrog (*Lithobates catesbeianus*), a large generalist amphibian from eastern North America, and Tansy ragwort (*Jacobaea vulgaris),* a widely-established invasive flowering plant in BC. Both invasive species have demonstrated harm to native species and their habitats. Tansy ragwort is established on Galiano; the American bullfrog is not. Mapping the movement of American bullfrog in areas surrounding Galiano Island can provide some insights into appropriate preventative measures. Whereas, mapping Tansy ragwort, which is well established on Galiano Island and surrounding Southern Gulf Islands, provides some insight into the importance of early detection and rapid response, as the initial spread of an introduced species is often slow, and can go unnoticed.

Results

Priority Invasive Species for Galiano Island Inventory

The 'Priority Invasive Species for Galiano Island' inventory compiles key information on each of the thirteen invasive species that were identified as being on the leading edge within an accessible and condensed document. The information within the document is intended to be used as a tool for identifying ecosystem types which would be most vulnerable to the invasion of one of these species, as well as a way to identify the species itself. The general format of the document can be seen in Figure 4. The thirteen species that were chosen provide a diverse list of species that pose threats to multiple endangered habitats and species-at-risk on Galiano Island.

The thirteen priority invasive species are:

- Nutria (*Myocastor coypus*)
- Fallow deer (*Dama dama*)

- American bullfrog (*Lithobates catesbeianus*)
- European wall lizard (*Podarcis muralis*)
- Eastern grey squirrel (*Carcinus maenas*)
- Japanese knotweed (*Reynoutria japonica*)
- Himalayan balsam (*Impatiens glandulifera*)
- Poison Hemlock (*Conium maculatum*)
- Garlic mustard (*Alliaria petiolata*)
- Giant hogweed (*Heracleum mantegazzianum*)
- Milk thistle (*Silybum marianum*).

Key information categories:

1) Characteristics and identification: Describes physical and visual characteristics of the species. For animal species, characteristics such as detailed physical descriptions, expected size range, as well as specific characteristics that help differentiate from other species. For plant species, physical characteristics such as height, colour, descriptions of leaves, stems, flowers, growth patterns, and fruiting bodies are described.
2) Threat: Describes why this species is a threat, and to who. Potential threats include transmittable diseases, destructive behaviour towards important native habitats or native species directly, competition with native species, and toxicity.
3) Threat type: Categorized as (1) Ecological, (2) Social, (3) Economic (a species can have overlapping threat types).
4) Known sightings on Southern Gulf Islands and surrounding coasts (Vancouver and Washington): Determined using iNaturalist observations, lists the location(s) of observations, year observed, and the number of observations.
5) Pathway of introduction and spread: Describes how the species was initially introduced and describes the intention of introduction if applicable. Pathways of spread may be facilitated through human activity, animals (spread by birds or livestock) contaminated water or soil, and transportation (ferries, aircrafts, global shipping, vehicles, bottom of someones shoes or baggage).
6) Preferred ecosystem: Describes the key characteristics of the species preferred ecosystem(s), and whether the species is a generalist. Preferred ecosystems are described

as forest and woodlands (deciduous, evergreen, mixed forest), aquatic (wetland, river-side), grasslands, agricultural and cultivated land, wetlands, disturbed areas, and urban ecosystems. The preferred ecosystems of some species were described in greater detail, with some examples including preferred soil characteristics (fertile, moist, disturbed), preference for sandy beaches, salt marshes, sidewalks, derelict land, gardens, composts, etc.

7) Simplified ecosystem classification: Using the GCAs ecosystem classifications, each ecosystem type that the species is likely to invade is listed. This simplified list can be seen in Table 1.
8) Additional notes on the species: Includes information (if applicable) on any regional, provincial, federal, or global designations, such as ‘Regional Containment/Control’, ‘BC Provincial Priority Invasive Species List’, ‘Provincial Noxious Weed’, ‘Provincial Containment Species’, and ‘Top Ten Invasive Species by the IUCN. Details relating to toxic plant warnings by WorkSafeBC are also included.
9) Works cited: Includes links to sources of information.

Species	Characteristics & Identification	Threat	Threat Type	Known sightings on Southern Gulf Islands and surrounding coasts (Vancouver and Washington):	Pathway of introduction and spread:	Preferred Ecosystem	Simplified Ecosystem Classification	Additional notes on the species:	Works Cited
Nutria (*Myocastor coypus*)	Herbivorous, semiaquatic rodent from South America. Nutria can reach 60 cm long, not including their 30-45 cm long tail. They can be distinguished from Beavers or Muskrats by their tail and whiskers, as their tails are thin and round, unlike beavers. They have a white muzzle with long white whiskers, whereas beavers and muskrats have black whiskers. They can spread quickly since they can have up to 13 offspring per litter (average 4-5), and up to three litters per year.	Can transmit various diseases to humans and animals through water contamination.Destructive burrowing and feeding habits. They create burrows in soft soil, which damage native wetlands, which can also interfere with agriculture and human infrastructure such as dykes. They can destroy important habitats for native species of wetland animals. Native species at risk as a result: frogs, salamanders, turtles, aquatic insects, bird species.	Social, Ecological	Yes, one sighting on Galiano...on Saltspring Island, and there are numerous sightings within Washington and Oregon.	First introduced on the Lower Mainland and Vancouver Island by fur trade.	Prefers stagnant water and lots of aquatic vegetation. Ecosystem types: marshes, wetlands, slow-moving brackish water.	Wetland	Nutria are designated as a Prevent species by the BC Provincial Priority Invasive Species List.	Government of British Columbia. (n.d.). Invasive species alert! Nutria. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/alerts/nutria_alert.pdf Invasive Species Council of BC. (2023). Nutria. Invasive Species Council of British Columbia. https://bcinvasives.ca/invasives/nutria/

Figure 4: Image of the Priority Invasive Species for Galiano Island Inventory, showing all of the different key information categories. (see Appendices and Supplementary Info for the full document)

One example of the information that can be found on priority species listed within this inventory can be outlined with American bullfrogs. American bullfrogs are native to other areas in North America such as the east coast of North America; however, they are a prolific invasive species on the west coast. They are now the largest frog species in BC, and can grow to be 18-10cm long (Invasive Species Council of BC, 2023). They have profound negative impacts on native amphibian species. Their size and appetite often lead them to outcompete native species (Ficetola & Miaud, 2007). In the case of Galiano Island, this includes the blue-listed northern

red-legged frog (*Rana aurora*). This native frog species' population has been in decline (COSEWIC, 2015), and are also present at the Millard Learning Centre (Duncan et al., 2018).

American bullfrogs were introduced to BC to try and establish a frog farming industry in the province (Invasive Species Council of BC, 2023). They occupy wetland habitats, and once there eat nearly anything that they can fit in their mouth. Their spread across BC has been concerning, and are now established throughout the Lower Mainland, Vancouver Island, and are now being observed on some of the Southern Gulf Islands (Invasive Species Council of BC, 2023). This will be observed and discussed further in later sections using Figure 6, which collected observation data from the 'Invasive Species Monitoring Around Galiano Island' iNaturalist project.

Invasive Species Monitoring Around Galiano Island iNaturalist Project: Case Studies

Applications of iNaturalist to monitor spread of established and non-established invasive species in and around Galiano Islands are shown in these results using two different species as case studies: Tansy ragwort and American bullfrog. The data and information produced in Figures 6 and 7 were obtained as a result of our iNaturalist project. As seen in Figure 5, the use of iNaturalist provided over 37,000 total observations of the 13 priority species identified in our Priority Invasive Species for Galiano Island Inventory.

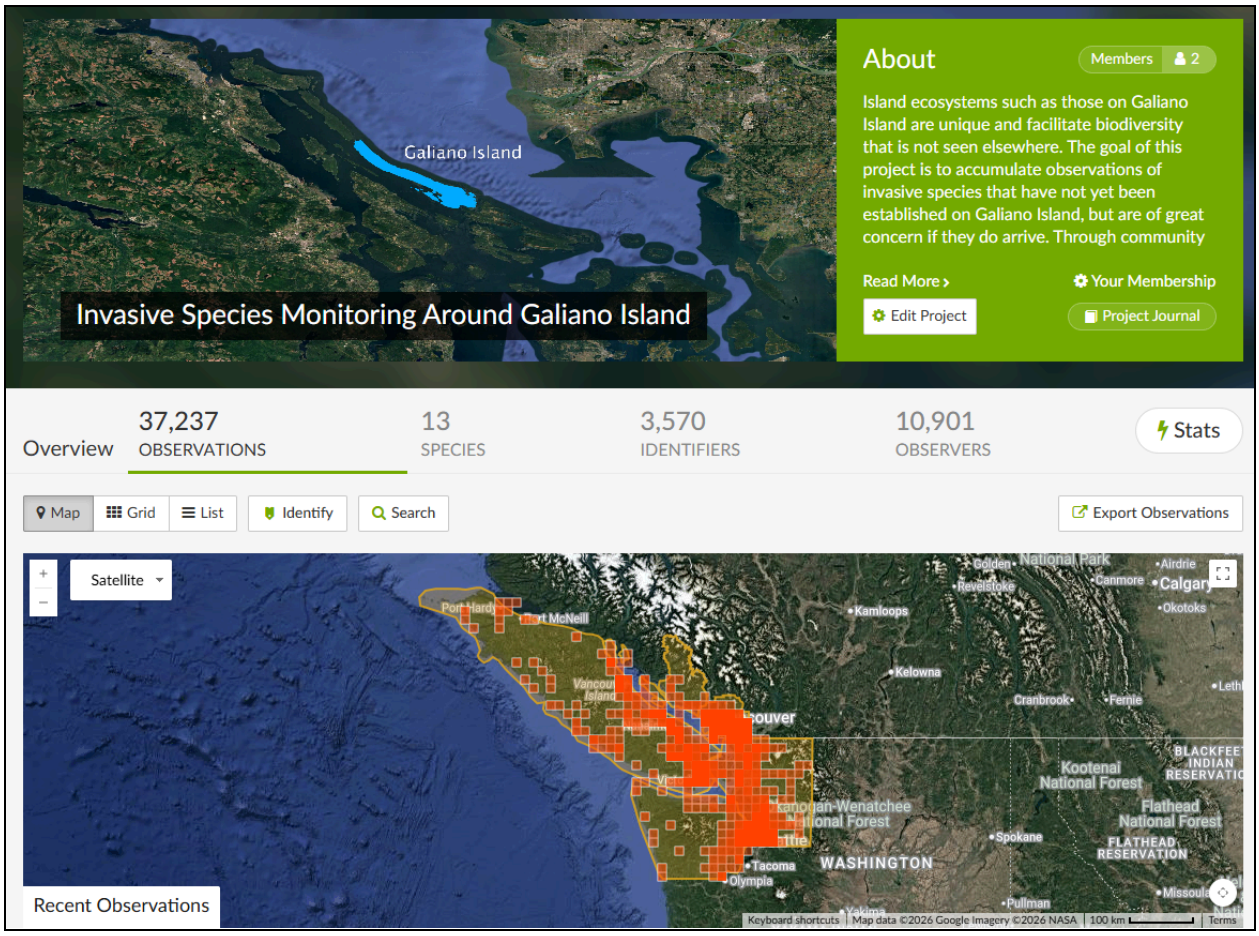

Figure 5: Home page of the Invasive Species Monitoring Around Galiano Island iNaturalist project. Figure shows a map of >37,000 observations of invasive species listed within our inventory that have been observed in regions throughout the Pacific Northwest.

The results discussed here use Tansy Ragwort (*Jacobaea vulgaris*) and American Bullfrog (*Lithobates catesbeianus*) as examples of species occurrence monitoring using the information in our "Introduced Species Monitoring Around Galiano Island" iNaturalist Project. These results could be replicated for the other eleven species listed in the database to track spread both within and around Galiano Island to assess and manage risks they may pose on local ecosystems. Access to both the "Priority Invasive Species for Galiano Island Inventory" and "Invasive Species Monitoring Around Galiano Island" iNaturalist project can be found in the Appendices and Supplementary Info.

The map in Figure 6 displays all iNaturalist observations of Tansy ragwort that have been recorded on the Southern Gulf Islands, dating back to August 2007 up to June of 2026. The panel on the left side of the map represents the twelve observations that were recorded between August

2007 and June 2018, and the panel on the right side represents all observations recorded between August 2007 and June 2026.

Throughout the eleven year period presented in the left panel, there were a total of sixteen observations recorded, all of which were located on Galiano Island, North Pender Island, and South Pender Island. However, there were some years in which zero observations were recorded. The first observation was recorded in August of 2007 on South Pender Island, which was then followed by a four year period in which zero observations were made, before the second observation was made on North Pender Island in August of 2011. After the second observation in 2011 was recorded, another four year period passed before the next two observations were recorded in August of 2015 on Galiano Island. From 2015 to 2018, all fourteen observations were recorded on Galiano Island except for a single observation on North Pender Island in 2017. The first observations on Saltspring Island and Mayne Island were made in 2019, and the first observation on Saturna Island was made in 2020. Thus, from 2020 onwards, Tansy ragwort observations were recorded on all five Southern Gulf Islands. By 2026, observations can be seen to be well dispersed across all Southern Gulf Islands.

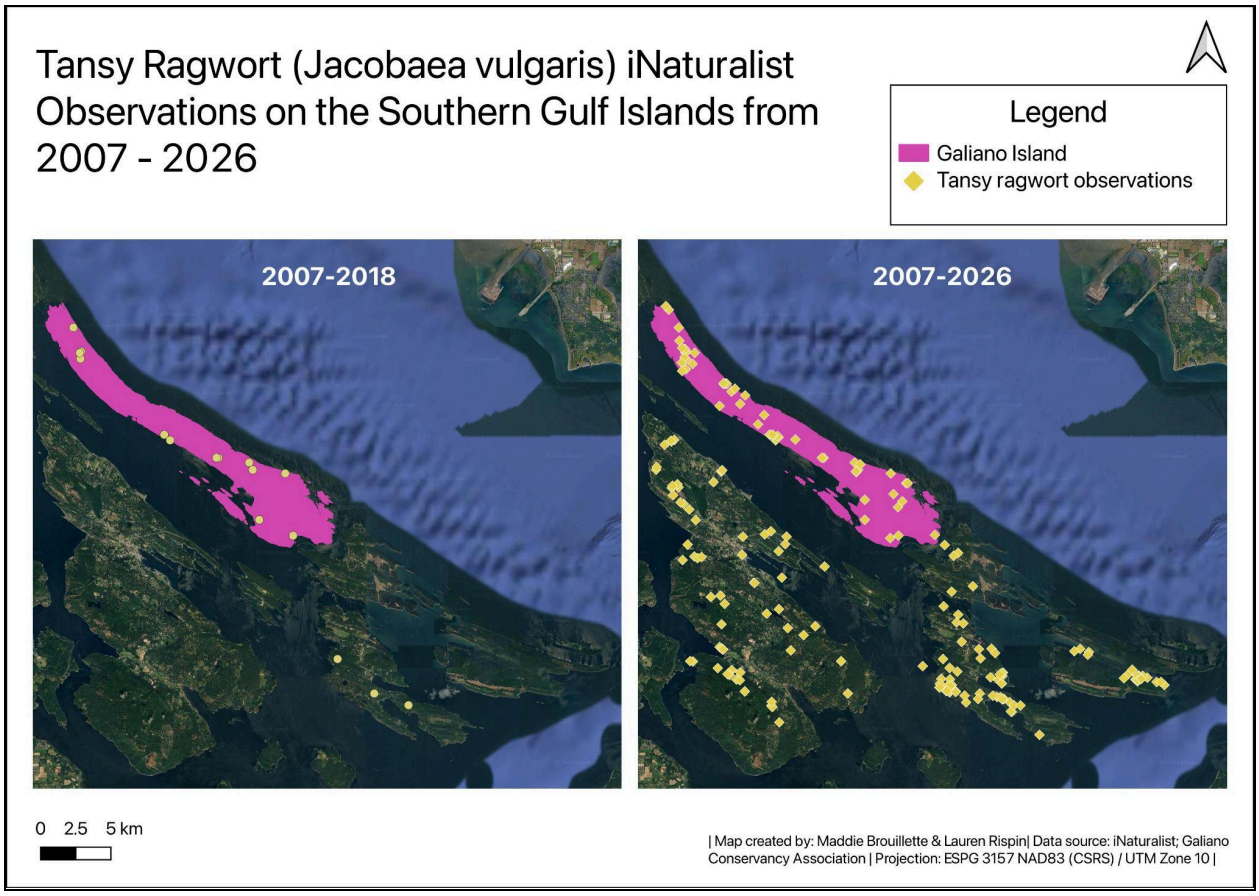

Figure 6: Map of Tansy ragwort observations within the Southern Gulf Islands. The panel on the left side represents observations made between the years 2007 and 2018, whereas the panel on the right represents all observations made from 2007 to 2026. Since Galiano Island is the primary focus of this study, it is represented by a pink polygon, and the Tansy ragwort observations are represented as yellow points. The Gulf Islands pictured here include Galiano Island, Saltspring Island, Saturna Island, Mayne Island, and Pender Island.

Figure 7 shows a map that outlines the progression and spread of American bullfrogs in areas surrounding Galiano Island. These observations were obtained from iNaturalist data in the Invasive Species Monitoring Around Galiano Island project that was created for this report. Data range from 2000-2026, and provide a number of different matters that are circled in green on Figure 7.

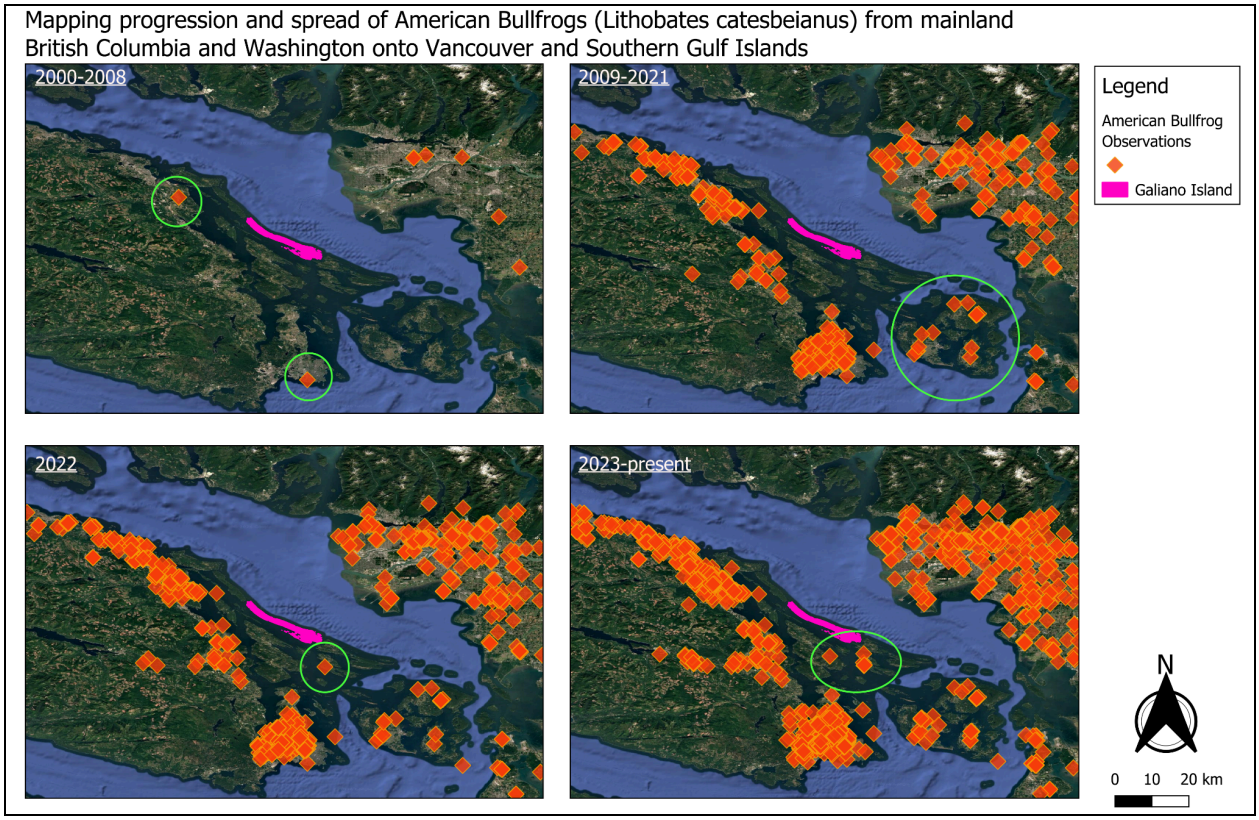

Figure 7: Map showing the spread of American bullfrogs across the Lower Mainland, Vancouver Island, and the San Juan and Southern Gulf Islands. Data are split to show different time periods and highlight different stages of the spread of Bullfrogs, which are circled in green.

Between 2000-2008, there are fewer than ten observations of American bullfrogs across the entire region that is mapped. In 2005 the first observation of American bullfrog was observed in Victoria, and a second was observed in 2008 near Nanaimo. 2009-2021 shows the continued spread of bullfrogs on Vancouver Island and the mainland. More importantly, observations were now being made on the San Juan Islands which are neighbouring the Southern Gulf Islands in the United States. By 2022, the first observation of bullfrogs encroaching on the Southern Gulf Islands will be collected on South Pender Island. Then in 2023 to present day, the map shows the continued rapid spread of this introduced species as well as the occurrence of bullfrogs on some of Galiano's neighbouring islands such as Salt Spring Island.

Discussion

The creation of the priority invasive Species for Galiano Island Inventory as a repository of knowledge to help inform management decisions in relation to the thirteen priority species

acts as a stepping stone towards introduced species management that is based on early detection and rapid response. As a spatial component, the iNaturalist project will allow for GCA staff to have a better understanding of the movement and establishment of these thirteen priority invasive species in areas surrounding Galiano Island. As an early detection and rapid response tool, this project could allow for GCA staff to target specific species that have been observed in specific areas. For example, there have been four observations made of the same Japanese knotweed plant on Galiano, with the first observation having been made in 2024, two observations in 2025, and one observation in 2026 (iNaturalist, n.d.). Implementing a rapid response by first consulting with the landowners, providing important information on why this invasive plant poses a risk to Galiano Island, and then removing the plant in its entirety could prevent the wider spread of this plant on Galiano Island. While this kind of action was not possible in the case of Tansy ragwort, it is not too late to implement an early detection and rapid response program for the priority species we have discussed here. It will be readily possible to expand this inventory to include new species of concern.

Speaking more broadly, the use of citizen science data through organizations like iNaturalist has become a widely used tool in the world of introduced species management. The platform allows for species identification, data aggregation, and community engagement, enabling real-time detection of invasive species through a community of users. While traditionally, the monitoring of invasive species utilized on-the-ground campaigns by trained professionals, making time and scope major limiters. The use of iNaturalist to collect invasive species data removes these limits, and allows for the identification of novel occurrences of invasive species (Fricke & Olden, 2023). Furthermore, making it possible to identify pathways of introduction, controlling and eradicating established invaders, and informed public opinion in invasive species management.

The tansy ragwort and American bullfrog maps in Figures 6 and 7, created for this report serve as visual representations of how the establishment of introduced species populations can proliferate if not actively monitored. However, further analysis in Figure 6 displays that there were few observations of Tansy ragwort on the Southern Gulf Islands between the years of 2007 and 2018, and increased consistently from 2019 onwards. This could be the result of the number of established populations increasing, and thus its ability to spread increased as well. As a plant that spreads by wind, water, people, and livestock, there are several potential pathways of spread

that could have facilitated its spread to the remaining Gulf Islands in 2019 (Leiss, 2010). Another factor that could be contributing to the increase in iNaturalist observations of Tansy ragwort on the Southern Gulf Islands since 2007 is an increase in users. Since iNaturalist platform first launched in 2008 as a masters student project at UC Berkeley, it was not until 2012 that the site grew in popularity (iNaturalist, 2023). Nonetheless, mapping the movement and patterns of introduced species as a tool for prevention can serve not only as a management tool, but also an educational tool. Visual representations such as those in Figures 6 and 7 are effective ways of conveying information to non-experts. As iNaturalist continues to increase in popularity, so will the number of observations, and thus our ability to monitor the movement of invasive species.

The ability to observe these shifts and spread of invasive species such as Tansy ragwort and American bullfrogs is crucial to being able to exercise appropriate preventative measures. These two case studies show one invasive species that has already been established on Galiano Island (Tansy ragwort) versus one that is not yet established but poses a significant threat to local biodiversity if or when it does arrive. As discussed in the literature, most invasive species management in BC has been focused on the containment of existing invasive species that pose the greatest threats to local biodiversity, as many of them were introduced over 100 years ago (Colberg et al., 2024; Mollot et al., 2017). Yet, some of the most effective invasive species management and protocols focus on the prevention of invasive species before they even arrive (AUSVEG, 2026; Victoria Government, 2010).

There is great value in creating plans and informing communities about how to contain and eradicate existing invasive species that are already here – such as Tansy ragwort. However, when it comes to leading edge species that have been introduced but not yet established in a specific place, there is potential to implement plans that are highly effective and lower cost as described with the invasion curve (Victoria Government, 2010). For Galiano Island, this starts with addressing the thirteen priority invasive species listed in our inventory and beginning to have discussions such as the ones in this paper to get ahead of the curve before it may be too late.

Limitations

The use of iNaturalist for introduced species management has its limitations, including error due to variation in observer experience/qualification, and sampling bias (Potgieter et al., 2024). An example of sampling bias is when the number of observations reflects the distribution

of observers more than the distribution of the species, such as in the Japanese knotweed observations on Galiano Island, mentioned previously. There could also be errors in identification and the allocation of records as cultivated or not. Furthermore, iNaturalist observations of a species can not act as a comprehensive record of all occurrences, but rather a representation of general patterns in distribution.

Recommendations

There are many challenges with biosecurity that lead to decision paralysis and uncertainty with how to implement early detection and rapid response initiatives. This often leads to delayed action until it is too late. There are many logistical, financial, and ethical challenges that impact the ability of a region to implement introduced species management. This is explained in the literature that has been investigated in this paper, with examples such as the invasion curve and rationales behind implementing decision making frameworks such as PrOACT (McComb, 2025; Victoria Government, 2010).

These frameworks helped define the goals and objectives of this project, which is to protect biodiversity on Galiano Island by creating resources and providing information that engages and informs residents, land owners, and other relevant parties about priority invasive species. We were able to then implement a plan following similar steps used in horizon scanning, a process used to inform the management of introduced species based on evidence-based lists. Our focus was to create an inventory that begins this process of horizon scanning, though due to the scope of our project the full application of this process – such as assessing the risk for each of the species in our database – are actions we did not have the time or resources to complete. Moving forward, we recommend three actionable items that could be taken by the GCA:

1. Explore the execution of a rapid risk assessment of this list of priority species.

    In Lieurance et al. (2023) this resulted in a score for each species from unlikely to occur with minimal impacts to very likely to occur with large impacts. These scores are based on three categories: likelihood of arrival in the next ten years, establishment, and negative impacts. This assessment requires a standardized scoring template, a peer reviewed period, and consensus to be reached among a panel (Lieurance et al., 2023).

2. We recommend that the iNaturalist Project we created be shared among the Galiano Island community.

    This could look like adding the iNaturalist project as a resource under the GCA's 'Introduced Species Explorer' page. Discussions with GCA staff were also suggesting the use of our work within the Nature Stewards Program, a voluntary land stewardship program run by the GCA that offers free stewardship consultations to Galiano land owners and residents. This program would be a great avenue to both engage and inform the Galiano Island community regarding this topic and actions they can take – such as reporting it on iNaturalist.

3. Lastly, we suggest the use of monitoring species-specific spread of invasive plants and animals to support and motivate actionable plans to protect the biodiversity that exists on Galiano Island.

    One example is observing the rapid spread and nearby occurrences of American bullfrogs. Being able to map and track this through citizen science can help raise red flags and implement species specific protection plans such as acoustic monitoring for bullfrogs on the island. These kinds of plans have been created in past student reports such as one done in 2018, which conducted a habitat assessment and monitoring protocol for bullfrog prevention to protect the native Northern Red-legged frog (Duncan et al., 2018).

These are some of the options that we strongly suggest be taken not only by the GCA, but also throughout the island community. Our goal to provide information and recommendations to aid the preparation for and prevention of leading edge invasive species is contingent on the engagement of community members who seek to better the wellbeing of local biodiversity. Our research found different frameworks that help facilitate the integration of different knowledges to come up with community driven solutions that address invasive species. These frameworks have initiated successful changes in places both locally and globally, but each of them begin with engaging, consulting, and informing communities about the issue at hand to come up with successful solutions. We strongly believe that the work that was produced for this report will aid in providing successful solutions for the prevention and management of leading edge species on Galiano Island.

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Appendices and Supplementary Material

Priority Invasive Species for Galiano Island Inventory

- Priority Invasive Species for Galiano Island Inventory (Final).xlsx
- Additionally a copy of this inventory has been downloaded as an excel file and shared separately for the GCA to continue to use long-term and edit as they see fit.

"Invasive Species Monitoring Around Galiano Island" iNaturalist project:

- https://www.inaturalist.org/projects/introduced-species-monitoring-around-galiano-island
- Alternatively go to inaturalist.org, under the tab "Community" click projects, and search up our iNaturalist project there (Invasive Species Monitoring Around Galiano Island).

Other invasive species reporting resources in BC

- Report to the BC Government online: https://forms.gov.bc.ca/industry/report-an-invasive-species/
- Or use their "Report Invasives BC" app on your mobile device

  For Apple Devices
  - Link: https://apps.apple.com/us/app/report-invasives-bc/id1004208197
  - QR Code:

    

  For Android Devices

- Link: https://play.google.com/store/apps/details?id=com.hipwood.invasivespecies&pcampaignid=web_share