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Great Salt Lake **Wetland Habitats**

A Needs Report Based on Interviews with the Managers

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For Snowy Plover, American Avocet, and White-faced Ibis (cover), the GSL ecosystem represents their species' largest breeding colonies or staging grounds (Paul and Manning 2002).

Introduction

Each year Utah's Great Salt Lake (GSL) and its wetlands (the GSL ecosystem) provide crucial habitat to an estimated 10 million migrating birds in the Pacific Flyway and allows 338 species to complete their annual life cycle (Sorensen et al. 2020). It is a critical stopover and staging area to fuel thousands of migration miles, provides cover and food to raise young, and is the refuge many species depend on to survive winter. These critical habitats have earned the GSL ecosystem many recognitions including a "site of hemispheric importance" from the Western Hemisphere Shorebird Reserve Network.

GSL itself provides resources for many birds, but it is the wetlands that supply some of the most critical bird habitats. There are over 351,000 acres of wetlands on GSL and they are incredibly diverse and dynamic (USFWS 2012; Downard et al. 2017). Depending on the proximity to GSL and freshwater inflows, the wetlands can be fresh, brackish, or highly saline. **A small change in the timing of freshwater flows or salinity can alter vegetation and completely change suitability for birds.** Different species and guilds of birds specialize in the different wetland types. For example, American wigeon (*Mareca americana*) forage on submergent plants in freshwater ponds and wetlands, and snowy plover (*Charadrius nivosus*) use highly saline playa wetlands for foraging on macroinvertebrates (mainly insects) and nesting.

The GSL ecosystem has been manipulated and managed by humans for over 10,000 years. Between the years AD 400 and 1,300, Fremont cultures farmed GSL wetlands and took advantage of the rich resources, including waterfowl (Simms and Stuart 2002). As early as 1884, waterfowl hunting clubs sprung up in GSL wetlands among settlers (Ray 2019). In 1928, the Bear River Migratory Bird Refuge was founded in response to the loss of wetland habitat and outbreaks of avian botulism that were impacting waterfowl populations. Many dikes and canals were developed on GSL wetlands to manage bird habitats in those early years. Water control infrastructure allowed for the manipulation of water depth and mitigation of high spring runoffs and flood damage.

Today, roughly 200,000 acres (or about 57 percent) of GSL wetlands are administered for the purpose of providing bird habitat. Management of GSL and its wetlands falls under the jurisdiction of many entities, each with their own specific objectives and mandates. State sovereign land below the GSL meander line (4,202-4,212 feet in elevation) is managed by the Utah Division of Forestry, Fire, and State Lands. The Utah Division of Wildlife Resources has jurisdiction over nine Waterfowl Management Areas on GSL: Farmington Bay, Harold Crane, Locomotive Springs, Ogden Bay, Public Shooting Grounds, Salt Creek, Howard Slough, Timpie Springs, and the newly-minted Willard Spur and two Wildlife Management Areas associated with GSL: Hat Island WMA and Gunnison Island WMA. The U.S. Fish and Wildlife Service manages GSL's largest wetland complex, the Bear River Migratory Bird Refuge. The Nature Conservancy, National Audubon, and Rio Tinto Kennecott all manage respective open lands as bird preserves. GSL is home to nearly 30 member-funded private duck clubs that manage wetlands for waterfowl hunting opportunities. Private landowners comprise the remainder.

Like many other saline lakes around the globe, the water level of GSL is shrinking at an alarming rate, primarily due to water diversions for agriculture and urban use (Wurtsbaugh et al. 2017). Once lake levels drop, there are few feasible options to reclaim the water and restore habitats. The loss of saline lakes like GSL not only impacts many bird populations, but hits economies hard. For example, water diversions to Los Angeles left California's Owens Lake dry and dusty. For over two decades and with no end in sight, Californians have spent over $2 billion dollars mitigating the dust and poor air pollution from it's dry lake bed (McNary 2020). Bird watching and waterfowl hunting on GSL alone is valued at $16.9 million to $52.4 million dollars annually (ECONorthwest and Martin & Nicholson 2019). Major multi-million dollar mineral extraction and brine shrimp industries rely on the maintenance of adequate water levels in GSL.

In order to sustain entire species of birds that rely on the GSL ecosystem, we need to commit water to the ecosystem and manage the water by the best means possible. While legal and policy actions are underway to secure water for GSL, we must be extremely resourceful with the existing water supply to maximize the full potential of the habitat for birds. **In order to realize best outcomes for the GSL ecosystem, we cannot neglect GSL's biggest champions and tireless advocates – our wetland managers.**

Just like today, GSL's first wetland and refuge managers were tasked with maintaining and creating bird habitat. In the early years, managing water levels to avoid outbreaks of avian botulism was a primary focus (Winsor 1933). While the job title and basic directive remains the same for GSL wetland managers, today the requirements of a wetland manager reflect the many challenges the GSL ecosystem is up against. Qualifications of a wetland manager are a bachelor's or advanced degree in natural resources (e.g., wildlife ecology, environmental science). Managers must be experts in wildlife science, wetland ecology, and habitat requirements. They must also possess experience working around contagious diseases and hazardous herbicides, pesticides, and other chemicals. The position requires developing and directing programs, budgets (allocation, collecting revenue, projecting budgets, and overseeing expenditures), and supervising personnel (including hiring, determining workload, delegating assignments, training). In addition, managers are required to write technical reports, articles, or related material based on research and coordinate and/or act as a liaison among their agency or work unit and other agencies.

The other necessary skills required of a GSL wetland manager, though rarely specified, include: writing and funding their own projects through grants, recreation management, water law and policy, agricultural irrigation, invasive species, environmental law and regulations (e.g., Clean Water Act, National

Environmental Policy Act), community outreach, security and trespass, heavy machinery mechanic and maintenance, government contracting, volunteer coordinator, and many others.

There are few academic programs or experiences that can prepare one for managing GSL wetlands. The unique ecology of GSL wetlands, coupled with complex management issues, such as water regulation and law, requires that managers develop their expertise over decades of service to their respective wetlands and cannot be replaced. If a manager is lost to another job, retirement, or a budget cut, the time it takes a new manager to effectively on-board is considerable. More importantly, the institutional knowledge of our career GSL wetland managers is irreplaceable.

The current class of GSL wetland managers are extremely dedicated to and passionate about the GSL ecosystem, seeing themselves as stewards of the lands they manage. However, we are at a pivotal time in the management of the GSL ecosystem. Managers are increasingly taxed by the continuing complexity and scope of the position. A significant contributor to this pressure is the lack of resources wetland managers are provided. Some of the more financially strained managers are with the Utah Department of Natural Resources, where managers are responsible for up to three different Waterfowl Management Areas each, totaling an estimated 31,000 acres of Waterfowl Management Area per manager (Table 1). For at least three decades, funding for wildlife and habitat has been in decline and not keeping pace with modern date needs (Echols et al. 2019). Private duck clubs tend to be more well-funded by membership dues and tend to have smaller wetland areas to manage. Low salaries for wetland managers are further complicated by the rising cost of living as the Wasatch Front urbanizes. Between 2010 and 2018, the median single-family home in Davis County increased from $235,000 to $400,000. As a result, only 42 percent of households can now afford a buy a home (Wood 2018).

Will tomorrow's wetland managers be willing to sacrifice their ability to own a home or retire in exchange for their part in conserving North America's greatest bird habitats? Without our managers and their expertise, the GSL ecosystem and the birds that rely on it will suffer. We see our managers, the on-the-ground experts, as key to conserving GSL for years to come. This Needs Report is based on interviews and conversations with GSL's wetland managers about their successes, challenges, and most pressing needs. We aim to support our managers by proposing where to provide critical resources and solutions to shared challenges.

Table 1. Acreage of Great Salt Lake areas managed for birds.

Area Name	Management Entity	Total Acres
Bear River Migratory Bird Refuge	U.S. Fish and Wildlife Service	77,102
GSL sovereign lands [1]	Utah Division of Forestry, Fire, and State Lands	27,000
Locomotive Springs WMA	Utah Division of Wildlife Resources	20,000
Ogden Bay WMA	Utah Division of Wildlife Resources	15,498
Willard Spur WMA	Utah Division of Wildlife Resources	14,154
Bear River Duck Club	Private	14,000
Public Shooting Grounds WMA	Utah Division of Wildlife Resources	12,442
Farmington Bay WMA	Utah Division of Wildlife Resources	11,208
Harold Crane WMA	Utah Division of Wildlife Resources	11,062
Salt Creek WMA	Utah Division of Wildlife Resources	5,290
The Shorelands Preserve	The Nature Conservancy	4,400
Inland Sea Shorebird Reserve	The Nature Conservancy [2]	4,089
New State Duck Club	Private	3,346
Ambassador Duck Club	Private	2,981
Gillmor Sanctuary	National Audubon	2,872
Howard Slough WMA	Utah Division of Wildlife Resources	2,286
Legacy Nature Preserve	The Nature Conservancy	2,072
Lakefront Duck Club	Private	2,002
Rudy Duck Club	Private	1,870
Northpoint Duck Club	Private	1,851
Timpie Springs WMA	Utah Division of Wildlife Resources	1,440
Harrison Duck Club	Private	1,320
Black Hawk Duck Club	Private	740
Burnham Duck Club	Private	622
Brown Duck Club	Private	220
Fowl Play Duck Club	Private	160
Cumming Duck Club	Private	120
Wasatch Duck Club	Private	120
Chesapeake Duck Club	Private	100
	Total Acres	***240,367***

[1] *Size varies depending on level of GSL.*

[2] *Managed under contract by The Nature Conservancy for Rio Tinto Kennecott*

Methods

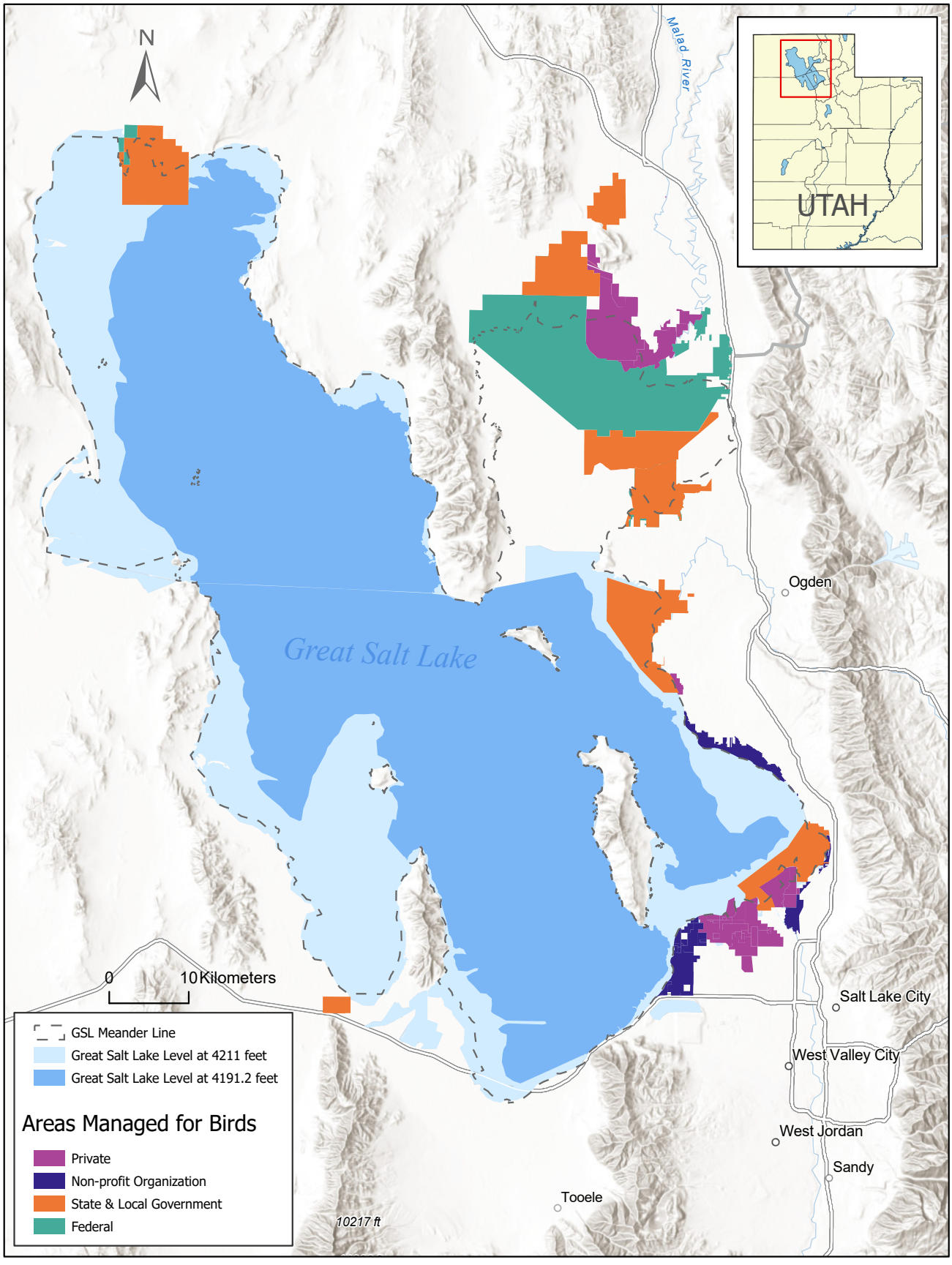
Between January and April 2020, we conducted a series of interviews with ten wetland managers that are responsible for providing waterbird habitat on GSL and one wetland water quality researcher. The interviewees represented a variety of entities: U.S. Fish and Wildlife Service; Utah Division of Wildlife Resources; Utah Division of Water Quality; Utah Division of Forestry, Fire and State Lands; The Nature Conservancy; National Audubon; and two private duck clubs (Figure 2). Over two to three interview sessions, managers were asked a standardized set of questions (Table 2). Conversation related to the questions, and discussion around other management topics was also encouraged.

Responses to interview questions were summarized. We identified priority challenges and opportunities that were common from the perspective of GSL wetland managers: phragmites (*Phragmites australis*) control, management goals and monitoring, water supply, and communication. Several research needs were identified.

Table 2. A subset of Great Salt Lake wetland manager interview questions.

What are you responsible for?
What do you think is working well or that you have a good grasp on?
Is there anything that you do now that you wish you had known when you started as a manager?
If you had more staff, what expertise would you want them to have?
What are the most significant outside forces (e.g., housing development, climate change, etc.) that impact the management of your wetlands?
Are there any regulations or requirements (legal, policy, institutional, etc.) that impact your work?
How much of your work is managing wetlands themselves versus managing “humans?”
Does your property have a Habitat Management Plan?
What metrics do you use to tell when a wetland is doing poorly or doing well?
How do you get information about new wetland management techniques or applications?
What do you want the community to know about the work you do?
Do you feel like you have the resources to develop a clear goal and objectives for management of your wetlands?
Are you part of any professional organizations that provide you with support for your work?
Do you manage your wetlands in collaboration with your neighbors or colleagues?
Is there a research question or topic you’d like to know more about?

Figure 2. Great Salt Lake wetlands managed as bird habitat.



Communications

During interviews, **wetland managers expressed an urgent desire for improved flow of knowledge among their peers and community.** Improved communication, new partnerships, and volunteer opportunities are already identified in many existing plans, yet these activities are largely absent. Most often, the responsibility to organize these communications falls on the managers themselves, who are already overwhelmed with land management tasks. With the lack of communication and the mosaic of management agencies and entities involved, many managers are missing opportunities to improve habitat management by sharing and learning with their peers.

Managers said they wanted more collaboration and detailed information on topics such as hydrology, weed control, and water rights. With substantial variations in habitat and wetland types across GSL's management areas, managers want to better understand unique and shared challenges and find opportunities for collaboration. However, they belong to or attend very few professional associations, working groups, or conferences and expressed several reasons the existing range of professional events were not meeting their needs. They felt professional events were often not providing the level of detail needed to inform their day-to-day work. Often times, the research and knowledge generated on wetland issues

is too theoretical and not realistic for on the ground management. This can lead to what scientists consider “a gap between theoretical and applied research”. It is also difficult for managers to prioritize attending meetings over work in the field, especially if meeting topics are perceived as too general. Events were often scheduled during busy times of the year, like phragmites treatment seasons or waterfowl hunts. At least one government entity restricts staff from joining or attending some professional events.

Managers stated that one of their most valued in-person meetings is the annual South Shore meeting, organized by the South Shore Wetlands and Wildlife Management, Inc., a cooperative of private duck clubs. The goal of the day-long meeting is largely to discuss routine topics like shared road maintenance, but it has become the best venue for some managers to meet face-to-face and network. Several managers also highlighted the value of a one-time Shorebird Symposium that was targeted specially to GSL’s wetland managers.

Several managers shared honest sentiments about isolated communication from their peers in the GSL ecosystem. Managers appreciate that the diversity of GSL’s wetlands requires a diversity of management techniques. However, in self-reflection, some said they made assumptions about other managers’ techniques. They recognized if they had opportunities to grow the personal relationships among their peers, it would increase knowledge sharing and understanding of techniques. Where professional relationships already exist between managers, we heard examples of sharing failures and successes with peers.

Managers identified community outreach as a challenge, as they are required to communicate with a growing public. Many of GSL’s wetlands have seen significant increases in visitation and from different constituents. In the past, GSL wetlands were often visited only by waterfowl hunters and occasional bird watchers. Today, more people explore GSL wetlands as open space for recreational activities such as wildlife watching, biking, and hiking. Managers also expressed increases in trespass and visitors engaging in prohibited activities (e.g., off-leash dog walking and drone flying).

Without the support of communications or administrative staff, managers find it challenging to develop appropriate communications content. Lack of communication with the public has led to negative perceptions about management of GSL wetlands. For example, draining water from a wetland may be required to repair infrastructure or control phragmites, a prolific non-native grass species. Yet, the public can interpret this as intentional degrading of bird habitat. These misconceptions and miscommunications lead to distrust in the resource agencies.

Managers understood the potential to use outreach and volunteers to support their work but largely do not for several reasons. Managers simply do not have the time to develop a volunteer program and manage volunteers. We heard anecdotes from some private duck clubs that they can no longer rely on their membership to volunteer on habitat projects. The members of private duck clubs are too busy to support and prefer habitat management be accomplished by staff. In addition, volunteers are not always appropriate to address priority management or information needs (e.g., research-grade avian surveys).

Volunteers have been used effectively through the Utah Division of Wildlife Resources' Dedicated Hunter program. The program is independently staffed to link projects with volunteers and takes administrative burden off of the managers.

Recommendations

Managers revealed that despite a lack of capacity, they strongly value information sharing between peers and are eager for opportunities to improve their communications with one another and the public. To improve communication among wetland managers, key recommendations are 1) identifying resources to organize professional events on behalf of managers; 2) developing events that are relevant to the day-to-day management of wetlands, and 3) providing opportunities for conversation and networking.

If each wetland manager is destined to learn from their peers and shared experiences, our wetlands and bird habitats benefit.

We propose an annual GSL wetland manager's workshop. The goal of the workshop will be to create the best management outcomes for GSL wetlands by encouraging information sharing and learning among GSL wetland managers. The target audience will be professionals and private landowners that manage GSL wetlands for birds. To ensure that this event stays connected to and addresses the most pressing management needs, it should be designed around surveys of managers' needs. Based on this Needs Report, phragmites management should play a central role in the workshop, with a potential working group and collaboration with university research departments, managers, and other relevant groups. For best attendance, the workshop will be held between January and March to avoid conflict with field schedules and waterfowl hunting seasons. The format of the workshop will include presentations for structured information sharing, site visits to demonstrate management practices, and space for unstructured conversation, such as a round table discussion. Opportunities for round-table discussions will allow managers to share highly relevant insights that their peers can benefit from. Venues for presentations include the Eccles Wildlife Education Center and Bear River Migratory Bird Refuge visitor center. The workshop will be most efficiently co-planned (e.g., venues, agenda, catering, budgets, registration) by a partnership between a non-profit organization and government agency. The cost of the event (i.e., planning staff salaries, travel allowances for presenters, food and beverage, printing materials) will be sponsored by grants and sponsorships. To assist in planning subsequent workshops, participants will be asked to provide feedback and inform content. The meeting is an appropriate venue to overlap with the Utah Phragmites Working Group meeting (see "Phragmites" section).

The consequences of ignoring public outreach can create negative perceptions about managers' work and worse yet, further the perception that these wetlands have no value. GSL is often characterized negatively by the community as the source of biting insects, dust, and odor, and these perceptions hurt conservation of GSL's wetlands (Trentelman 2020). Successful outreach with the public can be thought of in terms of avoiding conflict, but it is needed to support conservation of the entire GSL ecosystem. The public trusts the voice of resource managers (Bonnie et al. 2020) and are eager to hear from them. However, managers need support from experienced personnel to communicate with the public. Successful outreach requires expertise, especially in the era of social media. Some entities already have access to outreach specialists and have created channels that are tailored for their audiences. We recommend opportunities to improve outreach as an important topic at any GSL wetland manager's workshop.

Phragmites

A major threat to GSL wetlands is the non-native grass phragmites. In the 1990's, phragmites began a takeover of tens of thousands of acres of critical waterbird habitat and completely altered the GSL ecosystem. Expert opinion provides very grim insight on the impact of phragmites on the Pacific Flyway's birds. Wetlands invaded by phragmites simply do not support any waterfowl or shorebirds; an acre of phragmites equates to an acre of habitat loss. Entire populations of birds are likely impacted by phragmites: American avocet (*Recurvirostra americana*), Black-necked stilt (*Himantopus mexicanus*), Cinnamon teal (*Anas cyanoptera*), Green-winged teal (*Anas carolinensis*), Marbled godwit (*Limosa fedoa*), Northern Shoveler (*Spatula clypeata*), Redhead (*Aythya americana*), Snowy plover (*Charadrius nivosus*), and White-faced ibis (*Plegadis chihi*) (Kettering et al. 2020). Loss of habitat from phragmites remains one of the biggest threats to GSL's shorebird habitats (Sorensen et al. 2020). Not only is phragmites too dense for waterbirds to nest in, but it uses a significant amount of water to grow, which depletes water availability for native plants. Phragmites also often clogs important waterways that managers and recreationists use for access. Recent research on the flora of the region shows that almost 40 percent of plant species are non-native (Downard et al. 2017). Researchers also used high-resolution imagery to assess phragmites invasion and

estimated that phragmites occupied almost 23,000 acres of GSL wetlands (Long et al. 2017). While completely eradicating phragmites and other non-native plant species may be an impossible dream, managers apply a variety of strategic and pointed methods to control their growth.

Interestingly, almost all GSL wetland managers stated the control of phragmites was both their biggest success and their biggest challenge. One likely reason is that many GSL managers have been working in their wetlands for years honing their phragmites treatment skills and observing outcomes. This has allowed managers to learn how phragmites responds to different treatments and adapt their techniques accordingly. Managers stated their access to valuable resources provided by Utah State University was essential. For years, researchers at Utah State University have been working closely with managers, especially Utah's Waterfowl Management Areas, to identify and test the best methods to control phragmites. Managers have effectively paired different techniques to reduce infestations, such as mowing, cattle grazing, controlling water depth, and applying herbicides (Kettenring et al. 2020; Rohal et al. 2016). Controlled burning is highly effective, but concerns about air quality limit the reliable use of this method. In recent years, more GSL wetland properties have procured amphibious vehicles that mow down thick vegetation, and greatly increase managers' ability to manage phragmites.

Our interview results highlight the importance of teamwork as an extremely effective tool that GSL wetland managers are currently utilizing to help tackle large-scale phragmites projects. Managers from several entities have built informal and formal partnerships to eradicate phragmites. The managers work as a team to deploy their respective heavy machinery to treat large stands of phragmites across wetland

boundaries. These partnerships have also been very helpful to share administrative burdens from procuring contractors or renting equipment.

Unfortunately, even after decades of effort and use of the management techniques available, the overwhelming scale of the infestation consumes almost all of the managers' time and funding. Each year, thousands of acres of potential bird habitat remain choked by dense stands of phragmites. **The time and effort managers have poured into the work of controlling phragmites has resulted in a deficiency of monitoring and evaluation.**

In a given year, managers find it challenging to track and report the acres of phragmites that have been treated, which methods were used, and how effective the methods were. At its most basic, the lack of tracking or monitoring means managers cannot share the outcomes of their efforts. Evaluating the effectiveness of treatment methods and strategizing for future treatments is not being done. The phragmites invasion is devastating to our waterbird habitat and populations, but there is no means to define the impact.

Cost of phragmites treatments is another issue managers named as their biggest challenge. While some managers have a sufficient budget for employing phragmites control techniques, they do not have the personnel to get it done or anyway of hiring new personnel using their budget. On the other hand, some managers have the personnel but lack the budget. Managers are aware of state and federal sources that could fund larger-scale phragmites treatments; however, they stated it was a challenge to find the resources to prepare grant applications, coordinate project partnerships, identify matching dollars, or even administer the grants.

Recommendations

The interviews with wetland managers coupled with recent synthesis on the issue (Kettenring et al. 2020) highlight many positive actions to combat phragmites. However, our managers are facing a seemingly endless battle, and there are significant opportunities to improve phragmites management and restore bird habitat on GSL. We recommend improving communication and monitoring, developing partnerships, and supporting revegetation research.

Wetland managers have much to gain by communicating with their peers and experts about phragmites control and treatments (See also Communications). Utah State University remains the best source of information and facilitates feedback loops between managers and researchers. However, some managers are not receiving information or best management practices in a timely manner. The

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diversity and dynamic nature of GSL wetlands also creates challenging scenarios that require an open peer-to-peer communication system to address. A Utah Phragmites Working Group has been abandoned for several years because the existing managers do not have the capacity to facilitate the group. A Phragmites Working Group needs to be reinstated with dedicated staff to coordinate the group. The Working Group will allow managers to development more partnerships by creating a venue for communication. A Working Group also provides the best venue to coordinate large-scale control of phragmites and opportunities to fund the work.

Since phragmites began a takeover of GSL wetlands in the 1990's, there has not been an effective means to track the presence or absence of phragmites across the GSL ecosystem. With phragmites known to be one of the biggest causes of habitat loss for waterbirds, it is essential we fully invest in its management, which includes monitoring and evaluation. Phragmites tracking efforts are critical to measure outcomes (e.g., wetlands restored or success of treatment methods) and prioritize future work. The large scale of phragmites infestation is one of the biggest challenges to effective monitoring. Managers are also so overwhelmed by on-the-ground phragmites control that monitoring has historically been neglected. Although, there have been several large-scale phragmites mapping projects in the GSL region using multi-spectral imagery with 2011 LIDAR data (Long et al. 2017). These projects were able to give managers and researchers an estimate of phragmites infestation in GSL wetlands; however, this data is a snapshot of phragmites growth and managers need updated information on phragmites each year. Several dedicated staff with the Utah Department of Natural Resources began working with the University of Utah to develop remote sensing techniques to track phragmites. New methods of collecting aerial images (i.e., unmanned aircraft systems or "drones") have been used effectively in other regions of the United States to map and track phragmites (Vaz et al. 2018; Cohen and Lewis 2019; Abeysinghe et al. 2019; Samiappan et al. 2017). Studies are currently underway to test and refine methods. This promising monitoring method remains limited by the ability to collect aerial images throughout the GSL ecosystem, process images, ground-truth

results, and maintain a database of results. However, a trial run of this method on GSL wetlands is underway and the results show it is possible to track and monitor phragmites in conjunction with treatment actions. This project requires many participants, from GIS specialists, drone pilots, wetland data collectors and more and the flights and data need to be collected during a certain time window to capture before and after treatment data. It is crucial that these studies are supported and biologists are given the capacity to complete them because this information is extremely important for ensuring the future health of GSL wetlands. A GSL Phragmites Database needs to be fully developed and maintained. The goal of the database is to support restoration of waterbird habitats across the GSL ecosystem. This database will open up massive possibilities to improve decision making, prioritize treatments, reduce uncertainty, and target methods.

Controlling phragmites requires at least 3 years of intensive treatments, followed by restoration of native vegetation (Kettening et al. 2020). Revegetating areas where phragmites has been eradicated is of utmost importance to break the cycle of phragmites recruitment; however, this is a costly and time-consuming process. Utah State University is leading in developing best practice for re-establishing native plants following phragmites control. However, successful restoration of native plants requires on-going monitoring and maintenance. Just as managers struggle to monitor the treatment of phragmites, it remains a challenge to address revegetation. Utah State University continues to refine restoration methods that are essential to closing the loop in restoration of waterbird habitat and furthering their research is essential. Managers are participating in the research and eager to implement and share outcomes.

Management Goals & Monitoring

Across GSL wetlands, Habitat Management Plans are ubiquitous. Nearly all the wetland managers interviewed have a Habitat Management Plan (or similar) for their respective wetlands. Yet, with a few exceptions, most Habitat Management Plans were noted as being too general to inform meaningful management actions in the short-term (i.e., season or year). The Plans lack detailed objectives for the desired conditions and how to achieve them. Managers noted their Habitat Management Plans were more useful in cataloging history or existing conditions, such as land acquisitions, the locations of water control structures, or lists of bird species known to occur.

Despite a lack of detailed Habitat Management Plans, managers stated they have a clear idea of their management objectives and are given the resources to develop them. However, these objectives are largely not making it on the record. **A common anxiety among most wetland managers was that if they were to leave their position, there would be no documents to support transition to a new manager and the health of the wetlands would suffer.** Managers recognized they were not tracking management objectives and actions from year to year. As a result, there is no blueprint or game plan for how their respective wetlands need to be managed or the outcomes they are managing towards.

Monitoring outcomes provides key feedback into the Adaptive Management framework, which is the ideal approach for land/wildlife management agencies. Yet, monitoring outcomes of management actions on GSL wetlands was uncommon among wetland managers. Managers expressed they were overwhelmed by the scope of on-the-ground management responsibilities (i.e., "doing the work") and did not have time to monitor. It was also unclear which monitoring metrics and methods to use. Managers often rely on anecdotal visual observations (e.g., absence of phragmites, whether the wetland has water, presence of birds) to understand whether wetlands were healthy.

The potential positive outcomes for bird habitat as a result of good record keeping and monitoring was well understood by managers. Many explicitly stated they wanted support tracking and monitoring management to better evaluate the outcomes of their hard work and pave the way for future managers to be successful.

Recommendations

Comprehensive, ecosystem-level management of the GSL ecosystem has been ongoing by many entities since the mid-1970s. Since the inception of these plans, the management of birds has always been a priority (Smeath 1975; Jones et al. 1976). These first plans focused on acquiring land for preservation of habitat and understanding GSL ecosystem's role in the waterfowl food chain. Highly coordinated plans have been developed with many stakeholders (e.g., North American Waterfowl Management Plan [North American Waterfowl Management Plan Committee 2018], Pacific Americas Shorebird Conservation Strategy [Senner et al. 2016]). These plans are not meant to provide the detailed objectives for each of GSL wetlands, but are extremely relevant to site-specific Habitat Management Plans.

The resources invested in creating these larger, landscape-level plans is significant. But based on responses from managers, resources available for management planning at the site level is lacking. Wetland managers often make the choice to "do the work" (e.g., fight the phragmites infestations) instead of tracking their work because they often don't have the resources to do both well. We found only a few cases when a wetland had sufficient funding resources to hire the full suite of resource staff to plan the management, implement the work, oversee monitoring programs, update tracking documents, report results, and plan subsequent strategies.

Completing Habitat Management Plans with fully developed objectives and strategies is challenging. It requires contributions from many internal and external

stakeholders and can take years to finish. The funding and resources to hire staff or contractors to prepare Plans is often not readily available. For wetlands on public lands, Habitat Management planning invites public scoping, which requires expertise in coordinating and managing outreach and input.

The very nature of GSL wetlands also makes it difficult to develop specific objectives and track management. The GSL ecosystem is incredibly dynamic and best-laid plans are often upended. Seemingly small events such as a storm or one clogged irrigation canal require managers to regularly shift their priorities. The water supply to many of GSL wetlands hinges on the actions of many up-stream users and it is hard to predict the outcomes season to season or year to year. If managers are held accountable to objectives that are likely to change, it creates a culture of failure, instead of support. This may be more pronounced on government-managed wetlands, where public scrutiny into achieving objectives can be met with blame. The challenges in planning management goes hand in hand with a lack of recording management. The loss of institutional knowledge with staff turnover is a

serious issue, but not unique to wetland managers on GSL (La Peyre et al. 2001). Adaptive Management is a common element in natural resource planning, including in the GSL ecosystem. It uses an iterative process to adjust behavior, decisions, and actions based feedback (Stankey et al. 2005). In GSL wetlands, adaptive management is a necessity and its importance has been well documented (Downard et al. 2014). Despite the challenges working these dynamic wetlands, establishing clear objectives and strategies is critical. For example, in GSL wetlands, clear objective planning supports the habitat needs of birds and provides the

rationale for obtaining those needs (e.g., water supply).

It seems that no matter the level of detail included in a respective wetland's Habitat Management Plan, the need for detailed, actionable objectives and subsequent tracking is common among GSL wetlands. We heard from a subset of managers that Annual Work Plans were effective in providing the objectives that support larger goals identified in their respective Habitat Management Plans. Annual work plans are not only an effective way to break down goals into tasks that are manageable on a seasonal or yearly basis, but they can serve as a means to document management history through time, including when plans changed. If updated and referenced, Annual Plans can provide a venue for identifying when adaptive management was enacted, not when failures occurred. The U.S. Fish and Wildlife Service (2002)has been using this technique for years to manage habitat on the Wildlife Refuge System and at least one non-federal manager was also using them as a tool to track annual activities.

It is important to note that the lack of tracking not only impacts the success of future wetland managers but the researchers who support habitat management. Without even a basic history of management actions, it has been difficult for researchers to design studies on GSL wetlands or correlate observations with environmental conditions.

A monitoring program is key to evaluating if management methods and strategies are working, and how to adapt as needed. The lack of detailed management objectives, coupled with a lack of staff to support, it is of no surprise there is very little habitat monitoring occurs on GSL wetlands. Until detailed objectives can be crafted, priority metrics to monitor cannot be identified. It is easy to be overwhelmed by metrics to monitor and there is no one monitoring program can tell us what is going on across the entire GSL ecosystem. There is also no guarantee that local management actions on a wetland will lead to an increase in bird use. However, without collecting even basic monitoring data, we have nothing to inform local or regional observations.

Identifying objectives and then monitor metrics provides an opportunity to contract the program to third party or even garner support from volunteers. Involving volunteers, or community scientists, in monitoring is important because it can provide capacity to wetland managers and involve the community in conserving GSL. Many community scientist programs have been effectively designed around monitoring environmental conditions. Conservation of GSL is a goal shared by many organizations, and partnerships can provide the means to build capacity. Partners can provide capacity to support monitoring of GSL wetlands, including managing volunteers and data.

Water Supply

GSL is a shallow lake with an average depth of 15 feet. As a result, the surface area changes drastically, depending on water delivery from GSL's major inflows: the Bear, Weber, and Jordan rivers. Water consumption (e.g., agricultural irrigations, culinary use, etc.) from these rivers has reduced GSL's surface elevation by 11 feet. This seemingly minor elevation change has had consequences; GSL has lost half of its volume which has exposed 550 square miles of lakebed (Null and Wurtsbaugh 2020; Wurtsbaugh 2016). As GSL elevation drops, the implications for its adjacent wetlands are huge. Newly exposed mudflats are often invaded by phragmites, altered water salinity impacts plants and macroinvertebrates (i.e., waterbird food), and wetlands become more disconnected.

Managers pointed to water availability as a main concern for the future of their wetlands. Many managers had questions about how much water their wetlands needed throughout the year in order to sustain waterbird populations and healthy habitat. Water rights on GSL wetlands are highly complex, and managers lamented their desire to better understand water law and rights, especially early in their career. Managers regretted missing past opportunities to have bought and secured water for their wetlands.

Our interviews revealed that many managers along GSL have created unique

relationships with other water users in their area in order to increase their adaptive capability in regards to creating ideal waterbird habitat conditions during certain times of the year. Many managers have simple oral agreements with upstream water users that allow them to store water until they need it, which provides temporary solutions but no means of certainty. These agreements are essential for wetland health, but they are not legally binding and may be lost with staff turnover. They may also be insufficient in the future as development alters water sources and availability (Downard et al. 2014).

Not only is less water entering GSL wetlands, but also managers are grappling with how to address the rapid change in their source(s) of water. For decades, GSL habitat management has been aligned with return-flows from agricultural irrigation canals. In the spring, the irrigation canals provide ample water supply from snow melt run-off to support the habitat birds need during spring migration. In some areas, excess spring run-off can also be stored in wetland impoundments. During the summer months, agricultural irrigation is at its peak and water supply to GSL wetland diminishes. Managers will often use this time of drought to manage phragmites or water and soil salinity. Once the irrigation season ends in the fall, GSL wetlands again receive unused agricultural water, which supports the habitats birds need during fall migration.

However, as the Wasatch front continues to change from agriculturally dominated landscapes to urban, this harmonious relationship with agricultural return-flows is

proving inadequate. In sites closest to urban populations (e.g., Farmington Bay, New State Duck Club, GSL Shorelands Preserve), managers have already experienced changes in their water delivery; irrigation canals are no longer provided flow to wetlands, while other canals are overwhelmed by urban stormwater runoff. The dramatic increases in peak flow rates can cause erosion and channelization in the wetlands and decrease the overall water quality. These events are difficult to manage, because they are often unpredictable and typically do not line up with the natural hydrologic cycle that our managers prefer to follow.

Some managers have had success by staying cognizant of development near their wetland properties. Managers stressed the importance of forming a good relationship with city planners, attending planning meetings, and staying in-the-know on development around their wetland areas. For example, a manager was able to work out an agreement with a developer to require a settling pond and a cleaning culvert so stormwater entering wetlands was less polluted. While these strategies are successful, they take away precious time that wetland managers already lack. How will our wetland managers keep up with Utah's urban growth? What will happen to their wetland if they miss a development or planning meeting?

Recommendations

Although some GSL wetlands have priority foundational water rights, there are still many that have no guarantee of water supply or rights (Frank et al. 2019). The need to conserve water, create beneficial use and water rights, and develop water markets are essential to maintaining water flow to GSL's wetlands (SWCA Environmental Consultants 2017). However, our wetland managers need more detailed information on water supply to inform work on their respective wetlands.

The results of our interviews suggest a strong desire for a Water Needs Report or similar for GSL's wetlands. Recent legal analysis and review of strategies aimed at supplying GSL with water in the future emphasized the need to establish a legal right to water that has been conserved (ClydeSnow Jacobs 2020). According to Utah water law, the measure of a water right is the amount of water physically consumed or depleted by

the use (i.e., plants consume water through transpiration) (ClydeSnow Jacobs 2020). Therefore, it is imperative that we begin to understand the water needs of our wetlands.

For example, at the Bear River Migratory Bird Refuge, wetland water needs, water rights acquisition and water management are dictated by migratory bird use (Downard et al. 2014). This strategy is backed by water needs models built by the U.S. Fish and Wildlife Service and the Utah Division of Water Rights. The water needs models have informed managers of the volume of water required to meet the needs of waterfowl production, and they include information like habitat requirements, monthly bird use, daily evapotranspiration rates and canal seepage losses, water depth requirements for multiple habitat types, and water for flushing wetlands (Downard et al. 2014). Because of these models, the State of Utah granted Bear River Migratory Bird Refuge wetlands a higher “duty of water”, meaning that when water is available refuge managers can apply more water per area to their wetlands than can agricultural irrigators.

A similar study was completed in the Yellow River delta, an area of wetlands in China that have also been impacted by human development. The results highlighted the importance of allocating and using water resources rationally. A key issue is taking the water requirements of a wetland into account as to resolve the water resources conflict between supply and requirement (Cui et al. 2009).

Currently, most GSL wetland managers lack the data to support the need for more water. A Water Needs Report for each wetland would not only allow managers to justify the need for more water in the future (as needed), but also this knowledge will support development of more strategic management plans. Understanding water needs will also provide rationale for watershed-level water policies.

The hydrology of a wetland is considered one of the most important factors in establishing and maintaining specific types of wetlands and wetland processes (Mitsch and Gosselink 2000). For this reason, issues with stormwater runoff on our more urban GSL wetlands is concerning, especially as Utah's population is expected to double over the next 50 years (Perlich et al. 2017). Considering urban runoff quantity and quality are significantly affected by watershed development (Environmental Protection Agency 1993), the quality of the water that managers receive is likely to worsen in the future.

The delivery of extra water during a storm event may seem beneficial; however, without infrastructure or tools to manage the water, it often creates far from ideal conditions. For example, managers may have to move water to an area that was planned to dry out, stimulating the growth of phragmites. In addition, wetland inlets can become clogged with trash which requires many hours of laborious work to clean out. Managers explained how the need to respond after a stormwater event diverts them from other important projects. Further, stormwater is often contaminated by heavy metals and hydrocarbons that are detrimental to the fish and wildlife in wetlands.

Wetland managers around GSL are so overloaded with duties that it's difficult to imagine how they will keep up with issues like stormwater runoff. Managers

stressed that although stormwater does create a multitude of issues, they nevertheless would rather get that water than not receive it at all. With that being said, it is important that we aid managers, so that they can receive stormwater runoff in a viable and sustainable way. We recommend that Water Needs Reports and/or models include scenarios of increased stormwater run-off so that managers can adapt their techniques and prepare accordingly. Managers will likely also need increased support and capacity to stay up-to-date on current developments around their respective wetland areas.

Research Needs

Macroinvertebrates

The GSL ecosystem is especially important to birds because it's supplied with high-quality bird food, particularly aquatic insects and other small animal life, known as macroinvertebrates (Utah Division of Water Quality 2018). Birds rely on macroinvertebrates because they contain high energy and protein to fuel migration and reproduction. When asked about knowledge gaps, wetland managers most often had questions about how their management actions impacted the macroinvertebrates – the bird food – in their wetlands. Managers shared anecdotes of birds flocking to feed in wetlands after phragmites was mowed down or mudflats were flooded. Managers wanted to specifically identify the conditions that created the most macroinvertebrates for birds. Managers also often wanted to know more about the impact to macroinvertebrates of the management of two other species: common carp (*Cyprinus carpio*) and mosquitos.

The life cycles of macroinvertebrates, especially those adapted to ephemeral environments like wetlands, are incredibly complex. Coupling the production and emergence of macroinvertebrates with changes in the environment or management actions is a challenge. Likely because of this complexity, there are little to no GSL management plans that seek to further the understanding or monitoring of this critical issue. Some research has been

conducted on macroinvertebrates, but compared to the importance of the resource, we have much to learn in order to inform habitat management for birds (Cavitt 2006; Cox and Kadlec 1995; Gray 2005, 2009, 2010, 2011, 2012; Huener and Kadlec 1992; Leonard 2020; Miller et al. 2012; Sorensen et al. 2020; Richards 2014, 2018; Vest and Conover 2011; Vinson and Bushman 2005; Wilson 2010). Understanding macroinvertebrates is especially essential for shorebirds, as the availability of these food sources is what makes the GSL ecosystem a habitat of hemispheric importance (Sorensen et al. 2020).

Additionally, recent work by GSL expert entomologist David Richards (2018) suggested that the resistance and resilience of macroinvertebrate populations may be at an ecosystem tipping point. He stressed that future research needs to focus on macroinvertebrate ecology, life histories, and metapopulation dynamics. Other researchers on GSL wetlands stressed that it is critical to understand how to accurately sample macroinvertebrates in GSL wetlands. They pointed out that GSL wetlands are harsh environments that can change from wet to bone dry or fresh to saline and that there is a need to understand the relationship between the environment and biodiversity of GSL wetlands. Are the macroinvertebrates in GSL wetlands there because they are the only ones that can survive or are the wetlands impaired? Investing in the long-term viability of macroinvertebrates is essential to GSL waterbird conservation. Based on interviews, two specific research needs (mosquito abatement and carp control) tied to wetland management are proposed below.

Mosquito Abatement

Mosquito abatement districts have managed mosquito populations up and down the shores of GSL for decades (Rees and Andersen 1966). These districts use biological and chemical controls to abate mosquito-borne diseases like West Nile virus and in general reduce the population of mosquitoes. Birds can be impacted by mosquito abatement programs, as the pesticides reduce non-target insect populations that birds rely on (Poulin et al. 2010). Yet, this topic has received very little attention, not just in Utah, but across the globe (Poulin 2012). Richards (2018) noted that on GSL wetlands, mosquito abatement programs are using pesticides that are likely lethal to midges, important sources of food for birds.

Mosquito abatement districts have legal consent to access and treat mosquitos on all properties, and therefore, managers cannot simply opt out of pesticide applications. As urban development continues to encroach on GSL wetlands, the public will continue to demand mosquitoes be eradicated with increasingly intensive measures. If the existing mosquito abatement programs are impacting our bird populations, it is imperative that we understand why so that we can inform future management decisions. Protecting human health and bird populations are not exclusive of each other. Considering the timing, amount, and type of pesticides may mitigate some of the negative impacts to non-target insects (Richards 2018). Work in other regions has identified management alternatives to mitigate impacts to birds, while also reducing mosquito populations to publicly acceptable levels (Poulin et al. 2017; Bruhl et al. 2020).

Carp Control with Rotenone

Common carp are one of the most serious invasive species in the GSL ecosystem and across North American wetlands (Parkos et al. 2003). Common carp are attributed to major aquatic habitat degradation, including increasing phosphorus and turbidity and reducing aquatic plants and macroinvertebrate abundance (Miller and Crowl 2006; Huener and Kadlec 1992). Controlling the common carp is notoriously difficult, time consuming, and may not even be attainable (Pearson et al. 2019). Most managers interviewed actively control common carp by draining wetlands or using a naturally derived pesticide called rotenone in conjunction with waterlevel drawdowns.

While the habitat destruction carp inflict are known to reduce aquatic macroinvertebrates, managers also question how impactful carp treatment methods are on the macroinvertebrates they are trying to protect. Rotenone is known to cause mortality in some species of macroinvertebrates (Mangum and Madrigal 1999; Hamilton et al. 2009). The alternative to rotenone is to drain wetlands (also used to control phragmites), which similarly negatively impacts aquatic macroinvertebrates (Richards 2018; Huener and Kadlec 1992).

In the Bear River Migratory Bird Refuge, one study documented that controlling common carp with rotenone resulted in a greater abundance of macroinvertebrates, compared to wetlands with carp (Huener and Kadlec 1992). Entomologists recommend that rotenone treatments be spaced to allow macroinvertebrate communities to rebound (Richards 2018). Yet these management recommendations, and the many questions managers have, remain largely untested.

Predator Control

Many wetland managers expend a considerable effort reducing wildlife species that prey on nesting waterbirds, specifically raccoons (*Procyon lotor*), red fox (*Vulpes vulpes*), and striped skunk (*Mephitis mephitis*). Predator species that prey on GSL waterbirds have benefited as habitats are increasingly urbanized (Rodewald et al. 2011). In many waterfowl species, nest survival and nest predation are important metrics that influence species populations (Hoekman et al. 2002; Sargeant et al. 1992; Cowardin et al. 1985; Greenwood et al. 1995).

The relationship between predators and prey is incredibly complex. Predators also compete amongst themselves and other predator species for similar food sources (i.e., birds and bird eggs). For example, during interviews, several managers expressed anecdotal observations that coyotes, once targets for removal, were controlling the red fox and raccoon populations, which prey more heavily on nesting birds. In other ecosystems, this observation has been backed by data, as coyotes are indeed associated with greater waterfowl nest survival (Pieron and Rohwer 2010; Sovada et al. 1995).

Understanding the local predator dynamics is important to managers, because if species of predators are not actually impacting waterbird populations, the efforts to

control them equate to wasted time and resources (Blythe and Boyce 2020; Ellis et al. 2019). Existing literature on predator control programs may be biased, because if predator control programs are ineffective, the results are often not published or shared (Blythe and Boyce 2020). More recent work suggests that habitat improvement projects are more beneficial to increasing waterbird nest survival than predator control programs (Blythe and Boyce 2020; Ellis et al. 2019).

Within GSL wetlands, there are several studies of predator-prey relationships for managers to draw conclusions from (West 2002; West et al. 2007; Frey and Conover 2006, 2007, 2010). Efforts to control mammalian predators at Bear River Migratory Bird Refuge increased waterfowl nest success. These same studies also identify complex ecosystems, including how common carp are likely a main attribute to supporting the high numbers of predators (Frey and Conover 2010). Recent study on GSL found that avian predators (California gulls [*Larus californicus*] and common ravens [*Corvus corax*]), not mammalian predators, were the primary source of additive mortality (meaning they caused a decrease in survival of the population) on snowy plover nests (Ellis et al. 2019).

Predator control is rarely addressed in existing Habitat Management Plans for GSL wetlands, yet it remains a central activity for many managers. Based on the complexity of predator-prey dynamics and the time investment required of managers, this topic deserves more attention.

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