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REVIEW

Translocation and reintroduction of native fishes: a review of bull trout *Salvelinus confluentus* with applications for future reintroductions

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ABSTRACT: Declines in freshwater biodiversity resulting from anthropogenic landscape and climate changes are occurring throughout North America. Reintroduction techniques including translocation, captive rearing, and artificial propagation are often used to create new populations, repatriate extirpated populations, or supplement declining populations. Bull trout *Salvelinus confluentus*, a salmonid endemic to the northwestern USA and southwestern Canada, experienced significant reductions in abundance and distribution throughout the 20th century, leading to its listing in the US as 'threatened' under the Endangered Species Act (ESA) in 1999. A variety of projects involving reintroduction or stocking of *S. confluentus* have occurred across the western USA and southwestern Canada. In this review, we summarize case studies involving the reintroduction of *S. confluentus* and use these case studies to develop recommendations and guidelines for future *S. confluentus* reintroductions. We recommend that the threats leading to the initial decline of *S. confluentus* must be adequately addressed prior to reintroduction. Further, translocation and reintroduction project documentation is essential for informing future projects.

KEY WORDS: *Salvelinus confluentus* · Bull trout · Reintroduction · Translocation · Captive rearing · Artificial propagation

INTRODUCTION

While freshwater covers less than 1% of the earth's surface, freshwater habitats support more than 10% of all known species and about 33% of vertebrate species (Strayer & Dudgeon 2010). Freshwater habitats in North America are considered to support the greatest biodiversity and are also some of the most threatened aquatic ecosystems worldwide due to anthropogenic influences (Allan & Flecker 1993, Ricciardi & Rasmussen 1999, Abell et al. 2000). Anthropogenic threats to freshwater ecosystems include habitat degradation or destruction, water pollution, and flow modification (Dudgeon et al. 2006). The introduction of non-native species has also had significant negative and far-reaching impacts on freshwater ecosystems (Ricciardi & MacIsaac 2011).

The overexploitation and degradation of freshwater habitats in North America has led to declines in range and abundance of many freshwater organisms, including fish species (Jelks et al. 2008). An estimated 39% of all described fish species in North America were considered imperiled in 2008 and between 1989 and 2008, there was a 92% increase in the number of imperiled freshwater and diadromous ichthyofauna in North America (Jelks et al. 2008, Strayer 2008). Many conservation projects have been undertaken to restore freshwater habitats and conserve or recover the species that depend on them; however, significant action is still needed to avoid further declines in freshwater biodiversity (Strayer & Dudgeon 2010).

In an effort to recover imperiled freshwater species, the practice of propagating fish has been adapted for use as a restoration tool. While the majority of conser-

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vation projects involving captive propagation have focused on terrestrial mammals and birds, some projects have focused on aquatic species, including fish, frogs, and mussels (Morell 2008, Strayer & Dudgeon 2010). While reintroductions require considerable planning and follow through and may not be appropriate in all circumstances, they can be an important tool in the recovery of imperiled freshwater aquatic species.

BACKGROUND INFORMATION ON *SALVELINUS CONFLUENTUS*

Bull trout *S. confluentus*, members of the Salmonidae family and char subgroup, are native to western North America (USFWS 2015a). *S. confluentus* inhabit lakes and rivers, and may express either a resident or migratory life history strategy (USFWS 2015a). Within the migratory life history strategy, individuals may express fluvial, adfluvial, or amphidromous/anadromous tendencies. Fluvial individuals primarily reside in rivers while spawning and rearing in tributary streams. Adfluvial individuals primarily reside in lakes while spawning and rearing in streams. Amphidromous/anadromous individuals migrate between fresh and salt water (Cavender 1978, Fraley & Shepard 1989, Rieman & McIntyre 1993, McPhail & Baxter 1996, WDFW et al. 1997, Goetz et al. 2004, Brenkman & Corbett 2005, Downs et al. 2006, Jeanes & Morello 2006, Brenkman et al. 2007). Resident and migratory forms often occur in sympatry and produce offspring that may express either life history strategy (Rieman & McIntyre 1993, Brenkman et al. 2007, Homel et al. 2008). *S. confluentus* generally live at least 10 yr, and sometimes 20 yr or more, reaching sexual maturity in 4 to 7 yr (McPhail & Baxter 1996, Johnston et al. 2007, Al-Chokhachy & Budy 2008). *S. confluentus* are iteroparous, meaning that they spawn multiple times throughout their lifetime, and may express either consecutive or alternate year spawning (Leathe & Graham 1982, Fraley & Shepard 1989, Pratt 1992, Rieman & McIntyre 1996). Size, age at maturity, and life expectancy vary depending on habitat and life history strategy (USFWS 2015a).

S. confluentus have some of the most specific habitat requirements of any native salmonids in the northwestern USA (USFWS 2015a). Habitat requirements are encompassed by the '4 Cs': cold, clean, complex, and connected habitat (USFWS 2015a). *S. confluentus* require water with temperatures generally below 15°C, between 7 and 8°C for juvenile rearing, and between 2 and 4°C for egg incubation. *S. confluentus* also require low levels of suspended sediment and habitat with deep pools, overhanging banks, and large woody debris. In addition to habitat characteristics, there should be connectivity between spawning, rearing, foraging, migrating, and overwintering habitat (USFWS 2015a).

S. confluentus are widely distributed across the western coterminous USA, with populations in the Columbia and Snake River basins in Washington, Oregon, Montana, Idaho, and Nevada, the Puget Sound and Olympic Peninsula watersheds in Washington, the Saint Mary basin in Montana, and the Klamath River basin in south-central Oregon (Fig. 1) (USFWS 2015a). *S. confluentus* are also found in Canada and southeast Alaska and were historically present in the Sacramento River basin in northern California (USFWS 2015a)

S. confluentus abundance and distribution declined significantly throughout the 20th century, leading to the species' listing in 1999 as 'threatened' under the US Endangered Species Act (ESA) of 1973 (USFWS 2015a). Of the 4 *S. confluentus* populations in Canada, 2 are listed as being of 'special concern,' 1 is listed as 'threatened,' and 1 is listed as 'not at risk' by the Committee on the Status of Endangered Wildlife in Canada (Government of Canada 2016). At the time of

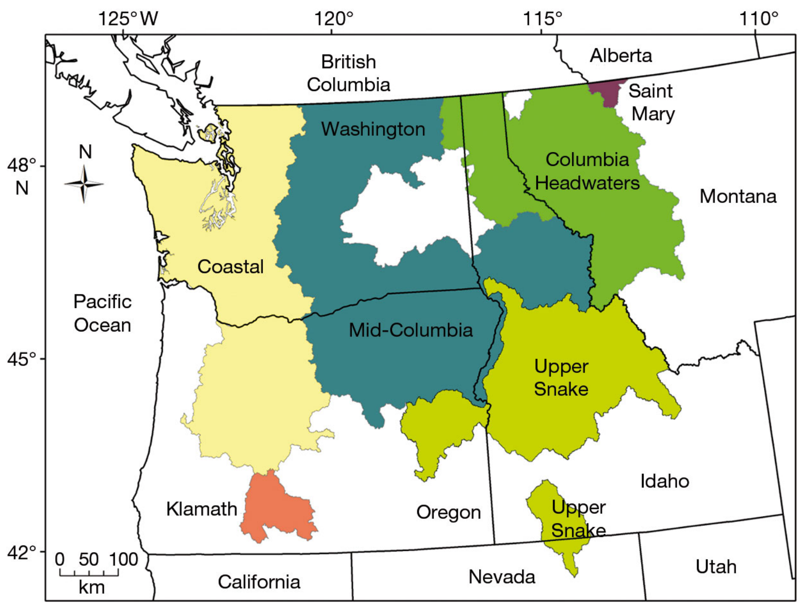

Fig. 1. Bull trout *Salvelinus confluentus* recovery units in the northwestern USA

listing under the ESA in 1999, *S. confluentus* had been extirpated from an estimated 60% of their historic range, leaving populations localized and fragmented (Quigley & Arbelbide 1997, USFWS 2015a). Conservation actions have been implemented in many areas, and *S. confluentus* are currently considered generally stable range-wide, with some populations increasing, some decreasing, and some remaining static, but with essentially no known change in general distribution (USFWS 2015a). The most recent short form status review completed in 2015, as well as a more thorough review in 2008, indicate that the threatened status is still appropriate (USFWS 2015a,b).

Declines in *S. confluentus* numbers and distribution are due to threat factors that vary significantly based on location (USFWS 2015a). Threats to *S. confluentus* include habitat loss and fragmentation, competition and hybridization with non-native fish species, and barriers to migration (USFWS 2015a,c). While anthropogenic climate change was not considered a threat when *S. confluentus* were listed in 1999, it has become clear that climate change impacts *S. confluentus* habitat and is an important conservation consideration (USFWS 2015a).

The US Fish and Wildlife Service's (USFWS) Recovery Plan for the Coterminous United States Population of Bull Trout (hereafter referred to simply as the 'Recovery Plan') establishes a strategic plan for the recovery of this ecologically important species (USFWS 2015a). The overall goal of the Recovery Plan is to restore *S. confluentus* populations through management of threat factors so the species no longer needs protection under the ESA (USFWS 2015a).

TRANSLOCATION AND REINTRODUCTION OF *SALVELINUS CONFLUENTUS*

Recovery of imperiled species often involves introduction, reintroduction, or supplementation. An introduction involves placing individuals in an area where that species was not historically distributed, whereas a reintroduction involves placing individuals in an area where that species was historically distributed but has been extirpated. Supplementation refers to the addition of individuals to extant populations. In the broader context of conservation, reintroductions are a method for restoring ecosystem function and species diversity to areas where extirpations have taken place (Ripple et al. 2014). The majority ofrecovery plans for threatened and endangered fish in the US call for introduction or reintroduction (Williams et al. 1988).

Introductions and reintroductions may involve translocation, captive rearing, or artificial propagation. Translocation involves capturing wild fish in the form of fertilized eggs, fry, juveniles, sub-adults, or adults and transporting them directly to a release site (Shively et al. 2007). In captive rearing, fertilized eggs, fry, or juveniles are captured in the wild and reared in a controlled facility prior to release (Shively et al. 2007). Artificial propagation differs from captive rearing in that the wild donor stock is held in a controlled facility and used to establish a captive broodstock program in which the progeny of the collected fish are released in the wild (Shively et al. 2007). For the purposes of this review, a successful project is defined as a project in which the overall trend in *S. confluentus* abundance is positive and a self-sustaining population seems to have been established according to the most recent data. An unsuccessful project is one in which the overall trend is negative and the establishment of a self-sustaining population seems unlikely. A project with mixed or unknown success is one in which either a small, but not self-sustaining, population has been established, or the outcome of the project is unknown.

The reintroduction of bull trout *S. confluentus* using translocation, captive rearing, artificial propagation, or some combination of these strategies will likely be required to restore *S. confluentus* populations in areas impaired by migratory barriers and lack of habitat connectivity (USFWS 2015a). The Recovery Plan states that reintroduction may be required to reestablish extirpated or supplement imperiled extant *S. confluentus* populations (USFWS 2015a,c). While the Recovery Plan specifies the use of genetically appropriate, pathogen-free individuals in reintroductions, instructions on the age, size, and condition of fish used and timing and techniques implemented are not provided (USFWS 2015a). Prior to future reintroductions of *S. confluentus*, it is essential to understand past reintroduction attempts and analyze their successes or failures. This review serves as a summary of past, current, and future attempts to reintroduce *S. confluentus* (collated in Tables 1–4), and considers the methods used and outcomes achieved in the context of future reintroductions.

CASE STUDIES

The following section provides an overview of *Salvelinus confluentus* translocation and reintroduction case studies, which are organized by projects that were successful, had mixed or unknown success, or

Table 1. General overview of case studies involving bull trout *Salvelinus confluentus* reintroductions. Regulatory compliance refers to compliance under the relevant sections of the US Endangered Species Act. T: translocation; CR: captive rearing; AP: artificial propagation; RR: removed from and returned to the same body of water; na: not applicable

Location	Years	Regulatory compliance	Methods used	Objectives	Outcomes	References
Past projects: successful						
Clackamas River	2011–2016	10(j) and Section 7	T	Create a naturally reproducing population of 300 to 500 adult *S. confluentus* by 2030	Increasing trend in recipient population	USFWS (2002a, 2009, 2011), Shively et al. (2007), Barrows et al. (2016)
Middle Fork Willamette River	1997–2013	Section 6	T and CR	Reestablish a naturally reproducing population of *S. confluentus*	Increasing trend in recipient population	Goetz (1994), Buchanan et al. (1997), ODFW & USDA Forest Service/Rigdon Ranger District (1998), Tranquilli et al. (2005), Shively et al. (2007), UWBTWG (2007, 2010), Zymonas (2011), Zymonas & Tranquilli (2012)
McKenzie River (Olallie and Sweet-water Creeks)	1993–1999	Section 6	T	Reestablish a naturally reproducing population of *S. confluentus*	Increasing trend in recipient population	Buchanan et al. (1997), Taylor (2000), UWBTWG (2007), Zymonas (2011), Zymonas & Tranquilli (2012)
Elwha River	2011–2014	Unknown	RR	Rescue and removal of *S. confluentus* during the removal of 2 dams in order to establish a core population of 500 to 1000 individuals	Increasing trend in recipient population, but there are still issues with habitat fragmentation	Adams et al. (1995), Brenkman et al. (2008), Ward et al. (2008), Littell et al. (2014), USFWS (2015d)
South Fork Skykomish River	1958–Present	Unknown	RR	Establish passage over 3 dams using a trap and haul facility	Increasing trend in recipient population, but likely reliant on continued operation of the trap and haul facility	Washington Department of Fisheries (1975), WDFW (2004, 2016), Herrera Environmental Consultants Inc. (2013), USFWS (2015d)
Crater Lake National Park (Sun Creek)	1992–2005	Section 7	RR	Increase *S. confluentus* abundance and eradicate *S. fontalis*	Significant increases in *S. confluentus* abundance and range; successful eradication of *S. fontinalis*	Wallis (1948), Dambacher et al. (1992), Buktenica et al. (2013)

Table 1. (continued)

Location	Years	Regulatory compliance	Methods used	Objectives	Outcomes	References
Past projects: mixed or unknown success						
Wallowa River	1968–1997	Unknown	T	Unknown	Out-of-basin translocation failed to establish any lasting population, and the translocation from within the larger basin resulted in a small population with low genetic diversity	Buchanan et al. (1997), Shively et al. (2007), Whitesel et al. (2015a,b)
Lake Pend Oreille, Flathead Lake, and the Clark Fork and Kootenai River systems	1944–1976	Unknown	T, CR, and AP	Unknown	Populations appear to be reproducing to some extent, but total range and abundance are unknown	Evermann (1893), Gilbert & Evermann (1894), IDFG (1952), Klavano (1960), Heimer (1965), Patterson (1992), Pratt & Huston (1993), Snider & Thompson (1993), Conley (1994, 1996), Clancy et al. (1995), Fredenberg et al. (1995), Janssen et al. (1997), Fredenberg (1998), Dunham et al. (2014), USFWS (2015a,e)
Hill Creek Hatchery	1990–2000	Unknown	AP	Mitigate loss of *S. confluentus* due to dam construction and conduct rearing and release experiments	Unknown	Clancy et al. (1995), Fredenberg et al. (1995), BC Environment (1996)
McCloud River	1989–1990	None	CR	Reestablish a naturally reproducing population of *S. confluentus*	Unsuccessful	Rode (1990), Buchanan et al. (1997), Rode & Dean (2004), Shively et al. (2007)
Deadwood Reservoir	1979	Unknown	T	Unknown	Unknown	Unknown
Future projects						
North Fork Santiam River	Future	Unknown	T	Reestablish a naturally reproducing population of *S. confluentus*	na	Goetz (1989, 1994), James et al. (1998), Spruell et al. (1999), Hvenegaard & Thera (2001), USFWS (2002b, 2015a), Goodson et al. (2005)
Yakima River	Future	Unknown	T	Expand the abundance and range of *S. confluentus* in the Yakima River	na	Ardren et al. (2011), Reiss et al. (2012), US Department of the Interior Bureau of Reclamation & State of Washington Department of Ecology (2014), USFWS (2015a)
White Salmon River	Future	Unknown	T and/or CR	Reestablish *S. confluentus* populations in currently isolated areas	na	Byrne et al. (2001), Thiesfeld et al. (2001), Northwest Power and Conservation Council (2004), Silver et al. (2009a,b, 2010, 2011), Allen et al. (2016)
Glacier National Park	2014–ongoing	Section 10	T	Reestablish a naturally reproducing population of *S. confluentus*	Unknown, too early to assess	GNP et al. (2003), Galloway (2014, 2016), Downs et al. (2015)

Table 2. Known reasons for declines in bull trout *Salvelinus confluentus* abundance and distribution, and restoration completed and in progress at case study locations. Reasons for decline include impacts from DD: dams and diversion; NF: non-native fishes; OH: overharvest; FOM: forest management; AP: agricultural practices; and RDU: residential development and urbanization. Restoration activities include: FP: improved fish passage over dams, culverts, etc.; LWD: placement of large woody debris; AR: more restrictive angling regulations; DR: dam removal; NR: non-native fish removal; GA: gravel augmentation; PB: enhancement/reestablishment of prey base; DS: diversion screening; GR: general habitat restoration and enhancement; AU: some restoration completed, but actions unknown

Location	Reasons for declines	Completed restoration	Restoration in progress
Past projects: successful			
Clackamas River	DD, OH, FOM, AP, RDU	FP	Unknown
Middle Fork Willamette River	DD, NF, OH, FOM, AP, RDU	LWD, GA, AR, FP	Unknown
McKenzie River (Olallie and Sweetwater Creeks)	DD, OH, FOM	AR, FP, GR	Unknown
Elwha River	DD	DR	AU
South Fork Skykomish River	DD, NF present but not considered a threat	Unknown	Unknown
Crater Lake National Park (Sun Creek)	NF	NR, DS	FP
Past projects: mixed or unknown success			
Wallowa River	NF, OH, FOM	None	None
Lake Pend Oreille, etc.	DD, NF, FOM, AP, RDU	None	None
Hill Creek Hatchery	DD	None	None
McCloud River	DD, NF, OH, FOM	AU	None
Deadwood Reservoir	Unknown	Unknown	Unknown
Future projects			
North Fork Santiam River	DD, FOM, RDU	None	FP
Yakima River	DD, NF, OH	None	FP, NR, PB, GR, DS
White Salmon River	DD	DR	None
Glacier National Park	NF	DR, GR	NR

are planned for the future (Table 2). Case study headings reference the USFWS recovery unit where projects occurred, are underway, or will occur (Fig. 1). A case study reference of Other indicates the project occurred in Canada or is not included in a USFWS recovery unit. *S. confluentus* recovery units are the major units for managing recovery efforts by the USFWS.

Clackamas River (Coastal Recovery Unit)

While bull trout *Salvelinus confluentus* were once prevalent in the Clackamas River system, by 1963 they were essentially extirpated due to a variety of factors including the construction of dams and diversion, overharvest, forest management, agricultural practices, and residential development and urbanization (Shively et al. 2007). A reintroduction effort using translocated *S. confluentus* from the Metolius River, in a nearby basin, took place from 2011 through 2016 (USFWS 2009). The goal of the project was to create a naturally reproducing population of 300 to 500 adults by 2030 (Shively et al. 2007). Planning for the translocations involved the development of a feasibility assessment of *S. confluentus* reintroduction to the Clackamas River system that determined that the factors leading to *S. confluentus* decline had been adequately addressed and reintroduction was feasible (Shively et al. 2007). In order to identify habitat appropriate for *S. confluentus* reintroduction within the Clackamas River system, a habitat suitability analysis was also conducted (Shively et al. 2007). The reintroduction effort involved translocation of *S. confluentus* and appears to have resulted in an increased number of *S. confluentus* present and increased spawning in the Clackamas River that may lead to the project's goal of 300 to 500 spawning adults by 2030 (Barrows et al. 2016). Monitoring of reintroduced *S. confluentus* in the Clackamas River sub-basin will continue for a minimum of 15 yr and will hopefully continue to show high rates of survival and successful spawning (Barrows et al. 2016).

Middle Fork Willamette River (Coastal Recovery Unit)

The Middle Fork Willamette River in western Oregon historically supported a native population of

Table 3. Habitat considerations, donor stock considerations incorporated in project planning, and methods and monitoring applied during project implementation of case studies involving reintroductions of bull trout *Salvelinus confluentus*. C: considered; NC: not considered; PL: planned; na: not applicable; P: present; U: unknown; OB: out of basin; IB: in basin, ILB: in larger basin; Y: yes; N: no

Location	Habitat considerations			Donor stock considerations				
	Water temperature	Stream size	Stream characteristics (large woody debris, pool habitat, gradient, substrate etc.)	Climate change impacts	Presence of non-native fish	Donor status	Genetic analysis completed	Disease/ parasite screening
Past projects: successful								
Clackamas River	C, ≤15°C	C, watersheds <1742 acres (~705 ha) and streams with a summer low-flow width of <2 m	C	C	P	OB	Y	Y
Middle Fork Willamette River	C	C	C	NC	P	ILB	N	C
McKenzie River (Olallie and Sweetwater Creeks)	U	U	U	U	P	IB	N	U
Elwha River	U	na	C, incl. sediment released following dam removal	NC	P	IB	Y	N
South Fork Skykomish River	na	na	na	na	na	IB	N	N
Crater Lake National Park (Sun Creek)	na	na	na	na	P	OB	N	N
Past projects: mixed or unknown success								
Wallowa River	U	U	U	U	U	OB, ILB	Y	N
Lake pend Oreille, etc.	U	U	U	U	U	IB, OB	N	U
Hill Creek Hatchery	U	U	U	U	U	ILB	N	Y
McCloud River	U	U	U	U	U	OB	N	N
Deadwood Reservoir	U	U	U	U	U	U	U	U
Future projects								
North Fork Santiam River	PL	PL	PL	PL	P	U	na	na
Yakima River	C	C	C	C	P	U	na	na
White Salmon River	C	C	C, incl. potential barrier to migration caused by multiple falls	C	P	U	na	na
Glacier National Park	C	C	C	C	P	IB	Y	Y

Table 4. Methods and monitoring used during project implementation of case studies involving reintroductions of bull trout *Salvelinus confluentus*. PL: planned; U: unknown; Y: yes; N: no; J: juvenile; SA: subadult; A: adult; M: minimal; ×: times; AN: annual; CO: continual; na: not applicable

Location	Methods			Monitoring	
	Number	Age/size	Frequency	Donor population	Recipient population
Past projects: successful					
Clackamas River	2140	J, SA, A	AN	Y	Y
Middle Fork Willamette River	10408	J, SA	9×	Y	Y
McKenzie River (Olallie and Sweetwater creeks)	7047	J	≥7×	Y	Y
Elwha River	U	J, SA, A	1×	Y	Y
South Fork Skykomish River	U	J, SA, A	CO	M	M
Crater Lake National Park (Sun Creek)	480	SA, A	1×	Y	Y
Past projects: mixed or unknown success					
Wallowa River	>600	SA, A	≥2×	N	M
Lake Pend Oreille, etc.	>200000	J	≥15×	U	U
Hill Creek Hatchery	>395299	J	~11×	U	M
McCloud River	270	J	1×	N	Y
Deadwood Reservoir	11000	J, SA	1×	U	U
Future projects					
North Fork Santiam River	U	U	U	na	na
Yakima River	U	U	U	na	PL
White Salmon River	U	U	U	na	PL
Glacier National Park	111	J	AN	U	Y

S. confluentus. *S. confluentus* populations in this fork of the river declined through the 20th century, and the last reliable observation of a *S. confluentus* in the Middle Fork Willamette River occurred in 1990 (Buchanan et al. 1997, Zymonas 2011). In an effort to reestablish a sustainable population of *S. confluentus* in the Middle Fork Willamette River, the Oregon Department of Fish and Wildlife (ODFW), the Willamette National Forest, the US Army Corps of Engineers, the Eugene Water and Electric Board, the USFWS, and other organizations came together to form the Upper Willamette Bull Trout Working Group (UWBTWG 2007). The UWBTWG conducted a project between 1997 and 2013 to restore habitat and reintroduce *S. confluentus* to the Middle Fork Willamette River (Zymonas & Tranquilli 2012). This project involved annual translocations of *S. confluentus* between 1997 and 2005 from Anderson Creek, located in the nearby McKenzie River basin, to the Middle Fork Willamette River (Tranquilli et al. 2005, Zymonas 2011). Between 2007 and 2013, the UWBTWG altered its previous methods by implementing a captive rearing program in an attempt to increase survival of released *S. confluentus* (Zymonas & Tranquilli 2012). Monitoring efforts are ongoing and indicate a positive trend in the recipient population and stable numbers in the donor population (Shively et al. 2007, Zymonas 2011). The UWBTWG is also considering *S. confluentus* reintroductions in the North Fork Middle Fork Willamette River and Salmon and Salt Creeks downstream to Hills Creek Dam (Zymonas & Tranquilli 2012).

McKenzie River (Olallie and Sweetwater Creeks; Coastal Recovery Unit)

The McKenzie River, a tributary to the Willamette River, is considered to be part of the same study area as the Middle Fork Willamette River. Buchanan et al. (1997) considered the *S. confluentus* populations in the mainstem McKenzie River and in 2 of its tributaries, Olallie and Sweetwater Creeks, to be of 'special concern,' while *S. confluentus* in the South Fork McKenzie River were considered 'high risk' by the UWBTWG (2007). Between 1993 and 1999, the UWBTWG transferred fry from Anderson Creek to Olallie and Sweetwater Creeks, all within the same basin, as part of the same project conducted on the Middle Fork Willamette River (UWBTWG 2007). Monitoring since translocations began in 1993 suggests that *S. confluentus* populations have been successfully reestablished in Olallie and Sweetwater Creeks (Zymonas & Tranquilli 2012).

Elwha River (Coastal Recovery Unit)

The Elwha River, a river flowing from the mountains of the Olympic Peninsula in Washington State west to the Pacific Ocean, historically supported a self-sustaining population of *S. confluentus*. Two dams were constructed within the mainstem of the Elwha River, i.e. the Elwha Dam in 1912, followed by the Glines Canyon Dam in 1927. While these dams created fish passage barriers resulting in isolated populations of *S. confluentus* within the mainstem of the Elwha River, in 2008, *S. confluentus* were still relatively prevalent in the upper watershed (Ward et al. 2008). Below the Elwha Dam, *S. confluentus* were much more restricted and the subpopulation was classified as 'depressed' by the USFWS (Ward et al. 2008). Between 2011 and 2014, the Elwha and Glines Canyon dams were removed and a rescue and removal plan was implemented to maintain *S. confluentus* populations in the Elwha River (Ward et al. 2008). No *S. confluentus* supplementation programs were established during this project. *S. confluentus* reestablishment relied on natural recolonization by rescued and removed fish and fish that remained in the river during dam removal (Ward et al. 2008). While dam removal is expected to have an overall positive impact on *S. confluentus* abundance and distribution, there are still threats facing *S. confluentus* in the Elwha River, including fish passage issues associated with dam removal sites, low instream flows from removal of water for municipal uses leading to seasonal lack of connectivity, and increased exposure to non-native fishes (USFWS 2015d). To reestablish self-sustaining populations of *S. confluentus*, additional habitat restoration will be completed to support recolonization (Ward et al. 2008). It is estimated to take between 3 and 5 generations (15 to 25 yr) or longer to establish a stable or increasing population (Ward et al. 2008).

South Fork Skykomish River (Coastal Recovery Unit)

Self-sustaining populations of *S. confluentus* and Dolly Varden *S. malma* (a species that was not distinguished from *S. confluentus* until the late 1970s) exist in the Upper Skykomish River basin of Washington State (WDFW 2004). In the South Fork Skykomish River, the Sunset, Canyon, and Eagle Falls create upstream fish passage barriers (WDFW 2004). In 1958, the Washington State Department of Fisheries, now the Washington Department of Fish and Wildlife (WDFW), constructed a trap and haul facility on the South Fork Skykomish River at Sunset Falls (WDFW 2004). The facility is co-managed by the WDFW and the Tulalip Tribes (WDFW 2016). This facility operates from July through December and moves fish from below the falls to release sites upstream of Sunset, Canyon, and Eagle Falls (Herrera Environmental Consultants Inc. 2013). This translocation over previously impassible obstacles allowed *S. confluentus* and *S. malma* to colonize ~87 km (54 miles) of previously uninhabited river (Washington Department of Fisheries 1975, WDFW 2004). A recent proposal has been made to relocate the release sites to improve the habitat available to fish recovering from translocation (WDFW 2016). Few details are available on monitoring following the construction of the Sunset Falls trap and haul facility; however, in 2004, *S. confluentus* stock were considered to be healthy throughout the Skykomish River basin (WDFW 2004). Persistence of this population may be reliant upon continued operation of the trap and haul facility located at Sunset Falls (USFWS 2015d).

Crater Lake National Park (Sun Creek; Klamath Recovery Unit)

Until the mid-20th century, a healthy population of *S. confluentus* occupied lower Annie Creek and a portion of Sun Creek, 2 tributaries to the Wood River and Upper Klamath Lake (Wallis 1948). A 1989 survey of Sun Creek found that brook trout *S. fontinalis* occupied the entire creek, *S. confluentus* range had significantly contracted, and non-viable hybrids between *S. fontinalis* and *S. confluentus* were present (Dambacher et al. 1992). A project run by the National Park Service (NPS) to eradicate non-native *S. fontinalis* and increase numbers of native *S. confluentus* took place between 1992 and 2005. The Sun Creek project was not a reintroduction, but rather a re-establishment of *S. confluentus* and eradication of *S. fontinalis*. *S. confluentus* were removed from Sun Creek and held in a nearby fish-less stream or reared at a hatchery until large enough to conclusively identify, *S. fontinalis* were eradicated using manual and chemical methods, and *S. confluentus* were returned to the creek (Buktenica et al. 2013). Between 1989 and 2010, *S. confluentus* abundance in Sun Creek has increased from approximately 200 individuals to 2000 individuals, and *S. confluentus* distribution has increased from 1.9 to 11.2 km of stream (Buktenica et al. 2013). The successful reestablishment of *S. conflu-*

entus in Sun Creek suggests that *S. confluentus* were limited by inter-specific competition with *S. fontinalis* (Buktenica et al. 2013). There are plans to continue this effort further downstream on Sun Creek while working to reconnect Sun Creek to the Wood River. Reintroductions of *S. confluentus* are also being considered in other creeks in the Klamath Recovery Unit (USFWS 2015a,c).

Wallowa River (Mid-Columbia Recovery Unit)

The Wallowa River, a river in northeastern Oregon that flows from the Wallowa Mountains into Wallowa Lake, supported a self-sustaining population of *S. confluentus* until they became extirpated in the 1950s (Buchanan et al. 1997, Whitesel et al. 2015a). This extirpation was likely due primarily to competition with non-native lake trout *S. namaycush* and redd superimposition by kokanee (sockeye) salmon *Oncorhynchus nerka*, a species that is also a prey source for *S. confluentus* (Shively et al. 2007). A variety of translocations took place between 1968 and 1997 that may be responsible for a small extant population of *S. confluentus* in the Wallowa River (Whitesel et al. 2015a, T. Whitesel pers. comm.). From 1968 through 1978, *S. confluentus* or *S. malma* were translocated from Alaska into the Wallowa River (Shively et al. 2007). In 1997, additional *S. confluentus* were translocated from the nearby Imnaha River to the Wallowa River (Shively et al. 2007). Monitoring between 1980 and 2013 indicated mixed success of these translocation projects (Buchanan et al. 1997, Whitesel et al. 2015b). The translocation of *S. confluentus* and/or *S. malma* between 1968 and 1978 was determined to be a failure (Buchanan et al. 1997). No monitoring followed the 1997 translocation of *S. confluentus* from the Imnaha River basin to the Wallowa River due to a lack of funding (Shively et al. 2007). Since 1997, there have been sporadic reports of *S. confluentus* observed and caught in the Wallowa River (Shively et al. 2007). Additional monitoring occurring between 2010 and 2013 involved the capture and genetic analysis of char in the Wallowa River (Whitesel et al. 2015b). These genetic results suggest that the 1997 translocation of *S. confluentus* from the Imhana River to the Wallowa River resulted in successful spawning and a small population with low genetic diversity (Whitesel et al. 2015b). While monitoring of *S. confluentus* will continue, there are currently no plans for future translocations of *S. confluentus* in the Wallowa River (T. Whitesel pers. comm.).

Lake Pend Oreille, Flathead Lake, and other Montana and Idaho projects (Columbia Headwaters Recovery Unit)

Lake Pend Oreille, Flathead Lake, and the Clark Fork and Kootenai River systems, part of the larger boundary system, historically supported populations of native *S. confluentus* (Pratt & Huston 1993, Dunham et al. 2014). Development in the form of timber harvesting, grazing, mining, dam construction, and settlement as well as the introduction of non-native fish species have negatively impacted native *S. confluentus* populations (Evermann 1893, Pratt & Huston 1993). The headwaters of the Clark Fork River system and portions of the Coeur d'Alene River system were contaminated by heavy metals that degraded historic *S. confluentus* habitat (USFWS 2015e). Despite these impacts, *S. confluentus* are present, often with a patchy distribution, in most of the major watersheds in the Columbia Headwaters Recovery Unit where they were historically distributed (USFWS 2015e). Between 1944 and 1976, Montana Department of Fish, Wildlife and Parks conducted a variety of projects to stock *S. confluentus* or *S. malma* into the Clark Fork and other river systems in Montana (Pratt & Huston 1993). These projects involved the translocation, captive rearing, and artificial propagation of multiple fish species. Fish were moved between river systems from areas as distant as Alaska, leading to introduction of new genetic material and hybridization between species (Pratt & Huston 1993). Many of the stocking projects that occurred from 1944 to 1976 were not closely monitored, and few data exist on project outcomes. It appears that the populations of *S. confluentus* in Lake Pend Oreille are stable and robust, while the majority of other populations in the Columbia Headwaters Recovery Unit have abundances well below historic levels or have been extirpated (USFWS 2005). Local populations in the Lower Clark Fork River are reproducing to some extent; however, overall abundance is low and there are no known self-sustaining populations between Albeni Falls Dam and Boundary Dam (Pratt & Huston 1993, Dunham et al. 2014). Recently, the USFWS has begun the planning process for a project to increase *S. confluentus* population sizes and ranges in the Clark Fork River system through establishing connectivity past dams, improving habitat, and potentially translocating fish (Dunham et al. 2014, USFWS 2015e). A future *S. confluentus* reestablishment plan will likely address existing threats and suggest actions to reestablish a self-sustaining population of *S. confluentus* (USFWS 2015e).

Hill Creek Hatchery (Other)

In British Columbia (BC), Canada, *S. confluentus* are considered a 'blue-listed' species by the BC Conservation Data Centre, a similar classification to their threatened status under the ESA in the USA. As part of a mitigation project to address the loss of *S. confluentus* as a result of the construction of Keenleyside and Revelstoke Dams on the Columbia River, the Kootenay Trout Hatchery began experimental work with *S. confluentus* in the early 1980s (Clancy et al. 1995). The goal of the project was to compensate for approximately 4000 *S. confluentus* eliminated due to dam impacts (Decker & Hagen 2008). This project was transferred to the Hill Creek Hatchery located near Upper Arrow Lake in the headwaters of the Columbia River basin where it continued from 1990 through 2000 (Fredenberg et al. 1995, BC Environment 1996). Fish propagated as part of this project were spawned from wild adults caught each year, and juvenile fish resulting from the program at Hill Creek Hatchery were scatter-planted in tributaries to the Columbia River (Fredenberg et al. 1995, BC Environment 1996). Initial monitoring to evaluate the survival of released juvenile *S. confluentus* was inadequate to assess outcomes; however, a study conducted from 2004 to 2006 provided more information on whether the Hill Creek Hatchery *S. confluentus* mitigation program successfully reached its goal of compensating for *S. confluentus* loss in the Upper Columbia River basin due to dams (Clancy et al. 1995). This 3 yr study assessed *S. confluentus* habitat, abundance, and distribution in tributaries to Arrow Lake Reservoir and found that there are approximately 900 redds annually in all tributaries, with the majority of redds in 2 relatively large glacial systems (Decker & Hagen 2008). Additional conservation measures will be needed to protect and restore *S. confluentus* habitat and encourage a self-sustaining population in Arrow Lake Reservoir and its tributaries (Decker & Hagen 2008).

McCloud River (Other)

In California, *S. confluentus* were historically only native to the McCloud River in the northern region of the state (Rode 1990). The McCloud River is a major tributary of the Sacramento River, flowing from mountainous regions in northern California south to Shasta Reservoir (Rode 1990). *S. confluentus* appeared to be extirpated from the river by the late 1970s, with the last confirmed *S. confluentus* sighting in 1975 (Rode 1990). *S. confluentus* extirpation in the McCloud River was likely due to a variety of anthropogenic factors including angling mortality, introduction of non-native salmonids, impacts from mining, road building, and timber practices, and effects of dam construction (Rode 1990). Attempts to reintroduce *S. confluentus* to the McCloud River have been made; however, little documentation is available and it appears that the majority of these projects occurred without any state or federal regulatory compliance. In 1989, more than 60 adult *S. confluentus* native to the Sprague River basin in the Klamath Recovery Unit were captured and spawned at the ODFW Klamath Hatchery (Shively et al. 2007). The resulting juveniles were stocked into the McCloud River in the spring of 1990 (Shively et al. 2007). The *S. confluentus* released in the McCloud River in 1990 were monitored for 5 yr before the project was deemed a failure and monitoring was terminated (Buchanan et al. 1997). Introduction of a relatively small number of *S. confluentus* on a single occasion may have contributed to the lack of success. While *S. confluentus* are believed to be extirpated from the McCloud River, if any fish are found, the California Department of Fish and Game plans to pursue an artificial propagation program in an attempt to recover the population of *S. confluentus* (Rode & Dean 2004).

North Fork Santiam River (Coastal Recovery Unit)

S. confluentus were historically distributed in both the North and South Santiam River basins (Goetz 1994). The last *S. confluentus* sighting in the North Santiam River basin occurred in 1945, and in 1953 the last *S. confluentus* was observed in the South Santiam River basin (Goetz 1989). Human activities including forest management practices, residential development, and the construction of dams and diversion have led to the removal of streamside vegetation, increases in water temperature, loss of in-stream large woody debris, increased erosion and suspended sediment, and additional barriers to migration (USFWS 2015a). The North Fork Santiam River, the section of the Santiam River with the greatest historical presence of *S. confluentus*, is considered a candidate location for reintroduction using translocation (USFWS 2002b). A translocation project could be modeled after similar projects that have taken place in the nearby Clackamas and Middle Fork Willamette rivers

(USFWS 2015a). A feasibility assessment will include more details on considerations and plans for an *S. confluentus* reintroduction.

Yakima River (Mid-Columbia Recovery Unit)

The Yakima Bull Trout Action Plan Working Group (YBTAPWG) is in the process of planning a project to expand the abundance and range of *S. confluentus* in the Yakima River in Washington State (Reiss et al. 2012). The Yakima River was historically connected to the Snake River and Upper Columbia River basins; however, dam construction has significantly decreased connectivity (Ardren et al. 2011, Reiss et al. 2012). Many of the same threats facing *S. confluentus* in other western river systems are present in the Yakima River, including habitat fragmentation and angling mortality (US Department of the Interior Bureau of Reclamation & State of Washington Department of Ecology 2014). The Bull Trout Task Force (BTTF), a collaborative of multiple organizations with the goal of conserving and restoring *S. confluentus* populations, plans to address the threats facing *S. confluentus* in the Yakima River basin and to continue monitoring *S. confluentus* abundance and distribution (US Department of the Interior Bureau of Reclamation & State of Washington Department of Ecology 2014). Translocation and/or supplementation of *S. confluentus* may be used as a tool to reach the project goals (US Department of the Interior Bureau of Reclamation & State of Washington Department of Ecology 2014). The YBTAPWG conducted a threat analysis to determine threats, develop a plan to address threats, and assess habitat suitability for *S. confluentus* (Reiss et al. 2012). The BTTF plans to address the major threats to *S. confluentus* in the basin while also conducting a feasibility assessment to consider whether translocation and/or supplementation is reasonable (Reiss et al. 2012). This feasibility assessment should be completed by 2017 (Reiss et al. 2012).

White Salmon River (Mid-Columbia Recovery Unit)

The White Salmon River flows from the south side of Mt. Adams to the Columbia River in Washington State. *S. confluentus* were likely present in the river prior to the construction of Condit Dam in 1913, a run-of-the-river project with no fish passage structures (Northwest Power and Conservation Council 2004, Allen et al. 2016). Two *S. confluentus* were sighted in the White Salmon River above Condit Dam between 1991 and 2011; however, recent surveys have failed to detect the species and it is believed that only a very small number, if any, *S. confluentus* remain in the river (Byrne et al. 2001, Thiesfeld et al. 2001, Silver et al. 2009a,b, 2010, 2011). Condit Dam was breached in 2011 and completely removed in 2012, leading to increased habitat availability for *S. confluentus* and the deposition of spawning gravel downstream of the dam site (Allen et al. 2016). The White Salmon Working Group, a group comprised of the USFWS, Yakima Nation, WDFW, National Marine Fisheries Service, the US Forest Service, PacifiCorp, and USGS, has analyzed *S. confluentus* distribution and habitat in the White Salmon River and may develop a reintroduction plan in the future (Silver et al. 2011, Allen et al. 2016).

Glacier National Park (Columbia Headwaters Recovery Unit)

While *S. confluentus* were historically widespread in the North and Middle Forks of the Flathead River in Glacier National Park (GNP), the introduction of non-native *S. namaycush* to the basins in the early 20th century led to significant declines in *S. confluentus* abundance and distribution (GNP et al. 2003). The Montana Cooperative Fishery Research Unit, US Geological Survey (USGS), NPS, and USFWS conducted an assessment of *S. confluentus* translocation potential in GNP (Galloway 2014, Galloway et al. 2016). The *S. confluentus* translocation process has begun, although the majority of this project is still in the planning process and has yet to be implemented (USFWS 2005, Galloway et al. 2016). Potential recipient sites were evaluated using a scoring framework that included the ability of the site to support translocated fish, possible negative impacts of a translocation on native aquatic biota, and the availability of within-basin donors (USFWS 2005, Galloway 2014). In 2014, in accordance with translocation guidelines, translocations began at the site considered to be best in terms of habitat and isolation from non-native trout (Downs et al. 2015). In 2014 and 2015, translocations occurred upstream of a barrier in Grace Lake, a location in the same drainage as the source population. While it is too early to assess the success of the 2014 and 2015 translocations, future work in GNP will focus on continuing within-basin translocations and monitoring of translocated *S. confluentus* (Galloway et al. 2016). Supplementation of translocated populations is planned and will likely utilize a second nearest neighbor source due to limited abundance of the original donor stock.

TRANSLOCATION GUIDELINES AND RECOMMENDATIONS

As the varied outcomes of the case studies included in this review suggest, thorough guidelines and recommendations should be considered prior to implementing a project involving translocation, captive rearing, or artificial propagation to reduce risk and maximize benefit. While categorizing projects as complete successes or failures is problematic because it imposes an artificial end date on the ongoing process of species recovery, all projects achieve a form of success in the information they can provide to future efforts (Jachowski et al. 2016). The varying methods used and outcomes achieved in the case studies of bull trout *Salvelinus confluentus* reintroductions reviewed here shed light on what attributes lead to more or less favorable outcomes. This information has been incorporated with the 'Guidelines for propagation and translocation for freshwater fish conservation' George et al. (2009) and is summarized in this section.

The first step to determining the necessity and appropriateness of a reintroduction involving translocation, captive rearing, or artificial propagation is to complete surveys to assess the status of existing populations (George et al. 2009). In species with sparse numbers, it may be extremely difficult to detect individuals; however, the development of environmental DNA testing may make this easier in the future. Detecting existing individuals is imperative when projects involve lethal treatment of sections of stream to eradicate non-native fish (George et al. 2009). Second, the historic range of the species should be determined (George et al. 2009). Given the changing climate and warming water temperatures, *S. confluentus* may need to be reintroduced beyond its historic range. Introducing a trout species beyond its historic range may have significant impacts on other species and should be carefully considered before beginning a project involving translocation. On the South Fork Skykomish River, *S. confluentus* were translocated above a natural barrier to a stretch where *S. confluentus* were not historically distributed (WDFW 2004). Fishless bodies of water often support unique species that may be adversely impacted by the introduction of fish (Muhlfeld et al. 2011). Trout prey on aquatic invertebrates, thereby directly impacting invertebrate populations (Luecke 1990, Schindler & Parker 2002). Trout also have cross-boundary trophic impacts on other species that rely on invertebrates, including ducks and passerine bird species (Elmberg et al. 2010, Epanchin et al. 2010). Trout may also reduce duck populations through predation of ducklings (Elmberg et al. 2010). Third, the proposed habitat for reintroduction should be considered for suitability and any necessary habitat restoration should be completed (George et al. 2009).

Many of the case studies summarized in this review utilized a variety of intensive survey techniques to determine the status of existing *S. confluentus*. In the Middle Fork Willamette River, ODFW used repeated electrofishing and snorkel surveys in an attempt to detect *S. confluentus* prior to beginning a reintroduction project. While a variety of case studies attempted to delineate the historic distribution of *S. confluentus*, this was a difficult process in many areas due to a lack of complete and accurate documentation. Almost all case studies considered the suitability of habitat for *S. confluentus* to some extent. Habitat suitability assessments generally considered attributes including water temperature, the availability of complex habitat with suitable spawning gravel availability, the presence of a prey base, and the potential for competition and hybridization with non-native trout species. Many projects also involved significant habitat restoration prior to *S. confluentus* reintroductions.

A team of stakeholders should assemble to obtain necessary permits. Regulatory considerations include determining a means for ESA coverage and obtaining transportation, scientific take, and recovery permits from appropriate agencies. Before beginning a project, the USFWS policy regarding controlled propagation requires a review of actions in the Recovery Plan, a draft environmental assessment, the presentation of the environmental assessment in the Federal Register for public comment, incorporation of comments from the public, and the finalization of the environmental assessment. Geneticists and other experts should be consulted prior to project planning to obtain advice on donor stock source, number, and frequency of stocking (George et al. 2009).

Many of the case studies included in this review either did not obtain proper regulatory authorization or means of regulatory compliance were not documented. In some instances, a lack of authorization resulted from projects occurring prior to current regulatory mandates including those required by the

ESA, or they occurred in Canada. Some of the projects that did report regulatory compliance under the ESA include the Clackamas River, which utilized Section 10(j) and Section 7, the Middle Fork Willamette River, which used a Section 6 agreement, Sun Creek, which used a Section 7 consultation, and GNP, which used the Section 10 recovery permit. The projects in which regulatory compliance was reported did not document reasons for selecting the regulatory allowance that was used. For future projects, it is critical that regulatory approval is obtained and adequately recorded to ensure that projects comply with laws and regulations and can be used as models for subsequent projects.

The number, age, and genetic composition of translocated fish should be carefully considered to minimize the impact on the donor population and maximize the benefit to the recipient population. Enough individuals should be translocated to ensure genetic diversity in the recipient population, but not so many as to cause undue risk to the donor population. The USFWS and other organizations consider a threshold of between 800 and 1000 spawning adult *S. confluentus* optimal to avoid inbreeding depression and ensure long-term persistence (USFWS 2002b, 2011, Reiss et al. 2012). While an abundance of 800 to 1000 spawning adults may be ideal, many extant wild populations of *S. confluentus* have persisted for long periods of time with numbers much lower than this threshold. Although younger fish have a lower likelihood of survival, their removal also has less of an impact on the donor population. This trade-off should be considered when selecting an age, or range of life stages, for translocated individuals. The survival of fertilized eggs or juvenile fish may be increased through captive rearing prior to release, although there are domestication issues to consider. In addition to ensuring genetic variation by selecting an appropriate number of fish to translocate, the genetic composition of the source population should match that of the historic, extirpated population as closely as possible. Maximizing the genetic diversity of donor stock in order to minimize the possibility of extirpation due to narrow genetic diversity may also be an important consideration.

The most consistently reported characteristic of projects included in the case studies portion of this review was the number of fish translocated; however, few reports provided justification for selected numbers. Many projects, including those on the Clackamas, Elwha, and Skykomish Rivers, carefully considered donor stock to minimize genetic differences between extirpated *S. confluentus* populations and reintroduced fish. Both the Clackamas and Elwha River projects involved the collection of DNA samples for future genetic analysis. The McCloud River project provides an example of how an inappropriate number of fish translocated and frequency of translocations can contribute to the failure of a project. Low numbers of fish translocated and only a single translocation event likely led to the failure to reestablish a population of *S. confluentus* in the McCloud River. Source and number of fish translocated should be carefully considered in the context of the specific characteristics of a project to achieve the best possible outcome.

If a project requires artificial propagation or captive rearing, the facility used should be as similar to the wild as possible to minimize the risk of domestication and subsequent declines in survival when returned to the wild (George et al. 2009). Fish should be handled as little as possible to minimize stress.

Few of the case studies included in this review involved artificial propagation or captive rearing, and those that did generally failed to document methods used. Projects involving translocation of fish should also prioritize careful handling of fish. The Clackamas River project reduced stress associated with handling and transport by adding a mild anesthetic to transport water (Shively et al. 2007).

Recipient habitat conditions should be considered in order to maximize survival of translocated fish (Galloway et al. 2016). A habitat suitability analysis should look at stream temperature, distribution of large woody material, pools, and spawning substrate, road density, land allocation, anticipated future conditions, and distribution, size, and connectivity of appropriate habitat (Shively et al. 2007). Other ecological components should also be analyzed, including the availability of a food source and the presence of non-native fish (Shively et al. 2007). Because translocation between watersheds always has the potential to introduce fish pathogens, fish must be screened for diseases and parasites prior to translocation (USFWS 2015a). Before translocation begins, the factors leading to the initial decline of *S. confluentus* in the area must be adequately addressed (Shively et al. 2007). Fish translocated to habitats in which the factors leading to the initial decline of the population have not been significantly mitigated or eliminated have a very low probability of long-term survival (George et al. 2009). Projects with a low likelihood of resulting in a self-sustaining population waste resources and may negatively impact donor populations.

A number of the well-documented case studies included some form of habitat analysis and restoration prior to release, although many projects did not include actions to mitigate the factors leading to the initial decline of *S. confluentus*. These projects included those on the Clackamas, Middle Fork Willamette, Wallowa, McCloud, and North Fork Santiam Rivers. A common theme of the projects that included habitat analysis and restoration was the eradication of non-native trout species in preparation for *S. confluentus* reintroductions. Another primary threat addressed prior to translocation in many case studies was the removal of dams that created barriers to *S. confluentus*. While recipient habitats should be adequate for *S. confluentus* release, as in the case of the McCloud River project, reintroductions can begin in areas already restored while planning and implementation of restoration is carried out in more degraded habitats. All factors leading to the initial decline of *S. confluentus* should be addressed prior to a translocation.

Translocated populations should be monitored to assess survival, growth, condition, movement, and genetic diversity of individuals (George et al. 2009). Evaluation methods may involve a variety of survey strategies as well as tracking using passive integrated transponder (PIT) tags and PIT arrays and radio telemetry. Long-term monitoring should be used to evaluate translocation projects, and projects should be adaptively managed based on monitoring results (George et al. 2009).

The Clackamas River, Middle Fork Willamette River, and Sun Creek projects all involved post-reintroduction monitoring. Monitoring methods used in these projects included the use of PIT arrays, snorkel surveys, fish traps, minnow traps, infrared counters, and time-lapse video. On the Clackamas River, monitoring results from the first few years of reintroductions were used to adapt and improve methods for subsequent reintroductions. A variety of factors likely contributed to the failure to monitor a number of projects. For example, a lack of funding resulted in failure to monitor following *S. confluentus* reintroduction to the Wallowa River.

Sharing projects with the public may lead to broader positive impacts. Where appropriate, projects should be shared with private landowners, commercial and recreational anglers, elected and non-elected officials, and the general public (George et al. 2009).

A few projects involved the public in the form of raising public awareness to decrease *S. confluentus* angling mortalities; however, no projects reported public involvement beyond this. Public involvement may not have been documented or these projects may not have been shared with the public.

Recording the specific methods and results of projects involving translocation, captive rearing, or artificial propagation is essential to understanding biogeography and genetic distribution of *S. confluentus* while also informing future projects (George et al. 2009). When warranted, results should be published in professional journals.

Very few of the projects included in this review adequately documented the methods used and outcomes achieved. For example, the section on Lake Pend Oreille, Flathead Lake, and other Montana and Idaho projects mostly included projects with essentially no documentation beyond the recipient location and number of fish translocated. Additionally, no documentation of outcomes was available for the project at the Hill Creek Hatchery. Many of the projects with minimal documentation occurred 50 or more years ago when documentation may not have been deemed important. However, thorough documentation of projects involving translocation is absolutely essential to future management of populations involved in those projects and to the development of other similar projects.

While translocation, captive rearing, and artificial propagation can be useful tools in species recovery, there are a variety of advantages, disadvantages, and ethical considerations associated with these practices. Artificial propagation can lead to a large number of individuals stocked with a reduced risk to the donor population; however, it is often an expensive process that may result in the loss of genetic diversity and a potential increase in the frequency of deleterious recessive alleles in the translocated population (Shively et al. 2007). Captive rearing may result in high abundance and survival of stocked individuals as well as the potential to implant PIT tags when fish reach an appropriate size, but may also be expensive and can result in disease transmission, loss of individuals due to malfunction of controlled facilities, and a possible increase in the frequency of deleterious recessive alleles (Shively et al. 2007). Because translocation is the least expensive of these methods and has the lowest possibility for loss of genetic variability and ecological diversity, it is often used to restore diminished or extirpated fish populations (Shively et al. 2007). Translocation does, however, have the highest risk to the donor population by decreasing population sizes (Shively et al. 2007).

Any project involving the transportation of fish from one location to another may have significant negative consequences (Brignon 2016). While failed reintroductions may inform future projects, they waste resources, jeopardize extant populations being used as donors, and negatively impact public perception of conservation efforts (Jachowski et al. 2016). Past translocation projects completed without appropriate consideration for potential risks have resulted in negative outcomes including the introduction of invasive, non-native species and the eradication of native species (Mueller & Hellmann 2008, Minteer & Collins 2010, Ricciardi & Simberloff 2009). Designating an appropriate range for reintroduction can also be difficult given the often insufficient, inaccurate, or nonexistent documentation of historic ranges as well as ecosystem changes resulting from anthropogenic impacts (Jachowski et al. 2016). A proposed translocation of *S. confluentus* upstream of a natural barrier in the Selway Wilderness has drawn attention to the question of whether translocations within designated wilderness areas are applicable under the Wilderness Act. The USFWS will utilize the National Environmental Policy Act to assess the feasibility of translocations within wilderness areas. The potential risks and benefits of using translocation, captive rearing, or artificial propagation as recovery tools should be considered and incorporated into the planning process in order to minimize unintended consequences (Galloway 2014).

CONCLUSION

This review was conducted in an effort to compile past projects involving the translocation of bull trout *Salvelinus confluentus*, learn from the successes and failures of these projects, and apply these findings to future translocations of *S. confluentus*. A variety of case studies involving *S. confluentus* translocations within the northwestern USA and southwestern Canada were summarized and analyzed. A secondary review with a broader scope could focus on translocations of other native fishes in the USA or throughout the world in the context of *S. confluentus* reintroductions using translocation. A variety of reviews focused on translocating native fish species have already been completed (Harig et al. 2000, Andrews et al. 2016). While translocation can be a useful tool for the conservation of threatened, endangered, or extirpated populations, it is important to consider its role within the broader context of species conservation. Increased priority should be placed on conserving habitats and extant populations to avoid extirpations and the need for costly reintroductions. This would require the implementation of proactive conservation actions in order to avoid the necessity of retroactive conservation actions including translocations. Proactive species conservation would also circumvent the societal factors influencing which species warrant reintroduction and where reintroductions should occur given the changing planet.

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