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RECOVERY POTENTIAL ASSESSMENT OF RAINBOW TROUT, *Oncorhynchus mykiss* (ATHABASCA RIVER POPULATIONS)

Adult Athabasca River Rainbow Trout, Oncorhynchus mykiss. *Photographed by Ward Hughson.*

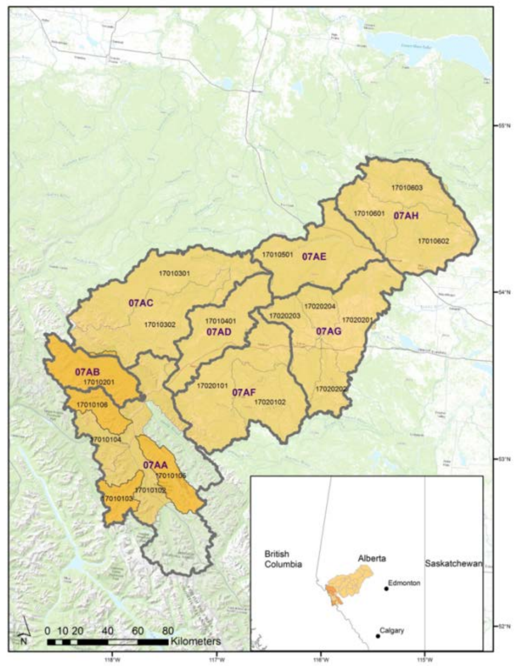

Figure 1. Distribution of Athabasca Rainbow Trout HUC8s in the Athabasca River watershed from Alberta Environment and Parks.

Context:

*Native Athabasca River populations of Rainbow Trout (*Oncorhynchus mykiss*) are considered a unique eco-type adapted to cold, unproductive headwater streams and upper reaches of main stem rivers in the Athabasca watershed. In May 2014, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Rainbow Trout, Athabasca River populations, as Endangered. Within this Designatable Unit (DU) the abundance at the majority of sites sampled has declined. Severe threats are ongoing from habitat degradation associated with resource extraction, agricultural and forestry practices, ongoing climatic change, habitat fragmentation, introgression from non-native Rainbow Trout, fishing, and competition with Brook Trout.*

Athabasca River Rainbow Trout is being considered for legal listing under the Species at Risk Act *(SARA). In advance of making a listing decision, Fisheries and Oceans Canada (DFO) Science has been asked to undertake a Recovery Potential Assessment (RPA). This RPA summarizes the current understanding of the distribution, abundance and population trends of Athabasca Rainbow Trout, along with recovery targets and times. The current state of knowledge about habitat requirements, threats to both habitat and Athabasca Rainbow Trout, and measures to mitigate these impacts are also included.*

This information may be used to inform both scientific and socio-economic elements of the listing decision, development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per sections 73, 74, 75, 77 and 78 of SARA.

This Science Advisory Report is from the December 8-9, 2016 Recovery Potential Assessment – Rainbow Trout, Oncorhynchus mykiss *(Athabasca River Populations). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.*

SUMMARY

- Native Athabasca River populations of Rainbow Trout are found in the upper reaches of the Athabasca River in Alberta. They are found in 19 HUC8s (hierarchical units within watershed boundaries).
- Many of the Athabasca Rainbow Trout populations have been declining over the past century. The total number of adults in all populations is estimated at 65,175 total mature individuals, with individual population estimates ranging from 45 to 9,497 mature individuals.
- There are two Athabasca Rainbow Trout life history types; stream residents and fluvial (residing in larger free-flowing streams or rivers as adults, returning to headwater streams to spawn). Stream residents are the dominant life history type. There are no known native adfluvial populations (residing in lakes as adults, returning to headwater streams to spawn).
- The status of most of the Athabasca Rainbow Trout populations is Poor. Population status is Good in one HUC, Fair in three HUCs, Poor in 13 HUCs and Unknown in the remaining two HUCs.
- Habitat occupied by Athabasca Rainbow Trout is characterized as cold, clean, and well oxygenated. Groundwater upwellings are an important component of Rainbow Trout overwintering habitat.
- Redds created by females for spawning and the initial development of eggs and alevins meet the SARA definition of residence.
- The greatest threats to the long-term survival and recovery of Athabasca Rainbow Trout are mortality related to fishing, sedimentation, habitat fragmentation, introduced salmonids and climate change. These are interactive threats.
- Activities that have a moderate or higher probability of jeopardizing survival or recovery include: watercourse crossings (e.g., bridges, culverts, open cut crossings); shoreline and streambank work (e.g., stabilization, shoreline protection); mineral aggregate, oil and gas exploration, extraction and/or production; instream works (e.g., channel modifications, watercourse realignments, dredging, debris removal); and structures in water (e.g., boat launches/ramps, docks).
- Based on the modelling, the dynamics of Athabasca Rainbow Trout populations are particularly sensitive to perturbations that affect survival of immature individuals. Harm to these portions of the life cycle should be minimized to avoid jeopardizing the survival and future recovery of the populations. Sensitivity of adults to fishing related mortality is evident from long-term studies within the watershed and should also be minimized.
- Demographic sustainability (i.e., a self-sustaining population over the long term) was used as a criterion to identify recovery targets for Athabasca Rainbow Trout. Under conditions with a 15% chance of catastrophic mortality event per generation, a quasi-extinction threshold of 50 adults and a probability of extinction of 1%, abundance needs to be at least

270,000 adult Athabasca Rainbow Trout, requiring 144.76 km^2 of suitable habitat when the population is made up of entirely stream resident individuals. Targets for alternative risk scenarios ranged from about 83 adults to about 549,823,287 adults and about 0.18 km^2 to about 241.2 km^2 of suitable habitat (suitable habitat calculated for a 1% probability of extinction only). Estimates are highly sensitive to the extinction threshold, the probability of catastrophic mortality, and the ratio of individuals from small and large-bodied growth trajectories in the population.

- A number of key sources of uncertainty exist for this species related to life history parameters, population connectivity and abundance estimates, the quantity and quality of available habitat and the potential impacts of threat mitigations.

INTRODUCTION

Rationale for Assessment

In May 2014, COSEWIC first assessed the native Athabasca River populations of Rainbow Trout as Endangered (COSEWIC 2014).

When COSEWIC designates a species as Threatened or Endangered, the Minister of Fisheries and Oceans (DFO) is required by the *Species at Risk Act* (SARA) to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including recovery planning and issuance of SARA permits.

The RPA for Athabasca Rainbow Trout was held December 8-9, 2016. Two research documents, that provide technical details and the full list of cited material, were reviewed during the meeting. One of the research documents provides background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (Sawatzky 2017), and the other on allowable harm, population-based recovery targets, and habitat targets (Caskenette and Koops 2017). The proceedings report summarizes the key discussions of the meetings (DFO 2017). This science advisory report summarizes the main conclusions and advice from the science peer review.

Species Biology and Ecology

Athabasca Rainbow Trout is a member of the Salmonidae family native to rivers of the upper Athabasca watershed in west-central Alberta. It is considered a unique ‘ecotype’ adapted to cold, unproductive headwater streams. This has resulted in differences in the morphology, biology and habitat use compared to other populations of Rainbow Trout. Athabasca Rainbow Trout are similar in colouration to other populations of Rainbow Trout but retain parr marks as adults. Athabasca Rainbow Trout are physically similar to Westslope Cutthroat Trout (*O. clarkii lewisi*). The lack of red slashes under the throat and basibranchial teeth of Athabasca Rainbow Trout and the comparatively smaller scales of Westslope Cutthroat Trout are the primary distinguishing features.

Athabasca Rainbow Trout exhibit stream resident and river migrant (fluvial) life history strategies. Both life history types may occur in the same population. Naturally occurring lake-dwelling (adfluvial) populations do not occur within the native range. Stream residents are smaller than river migrants, rarely exceeding 250–300 mm fork length (FL). River migrants are often greater than 400 mm FL and weigh between 0.5 and 1.3 kg. Most populations are likely greater than 90% stream resident.

A small percentage of females mature by age 3 and approximately 50% are mature by age 5. Males reach maturity as early as age 1 and most are mature by age 4. Both sexes typically live to age 8 and the oldest recorded Athabasca Rainbow Trout in the Tri-Creeks watershed (the area encompassing Wampus Creek, Deerlick Creek and Eunice Creek in the McLeod River drainage) was age 10. The sex ratio of populations is typically 1:1. Fecundity is related to body size, smaller stream resident females produce approximately 300 eggs, whereas larger river migrants have been reported to produce approximately 500 eggs. Athabasca Rainbow Trout are iteroparous and spawn annually but later than most other Rainbow Trout in southern Alberta. At higher elevations spawning has been observed in late June, while at lower elevations spawning usually occurs between late April and May. Stream resident females have shown little movement to spawning areas and males were observed moving intensely for short distances (< 1 km). Mean water temperatures during the spawning period range from 6–10 °C.

Athabasca Rainbow Trout are opportunistic feeders and strong generalists, primarily consuming aquatic and terrestrial insects throughout the summer. Stomach analyses of Athabasca Rainbow Trout from the Tri-Creeks watershed showed that heaviest feeding occurred during dawn and dusk when aquatic invertebrate drift was greatest. In stream reaches dominated by boulder/cobble substrates, the diet mainly consisted of aquatic insects, whereas in reaches with finer gravel substrates, terrestrial insects generally made up the majority of the diet. Mayflies (*Baetis* spp.) are an important food source and any land use activities that negatively influence *Baetis* spp. could impact Athabasca Rainbow Trout. In winter, stomach contents of resident fish generally contained a small number of prey items or were empty, even though the fish were active under the ice surface.

Athabasca Rainbow Trout are uniquely adapted to the cold headwater streams and upper reaches of main stem rivers they inhabit. Water temperatures ranging from 7–18 °C are preferred. Optimum embryo incubation temperature ranges from 7–10 °C with increased mortality occurring at temperatures < 3 °C or > 18.5 °C. Optimum growth temperatures for fry range from 10–15 °C. The upper lethal temperature for adults is approximately 27 °C, but temperatures from 22–24 °C are considered life threatening.

Growth patterns, stage-specific mortality, and fecundity-at-stage of Athabasca Rainbow Trout were determined using data and estimates from the literature (Caskenette and Koops 2017). This species exhibits one or more of two life history types, resulting in two growth trajectories including fish that remain small through their entire life cycle and fish that grow to larger sizes. Individual populations exhibit each growth trajectory separately, or a combination of both. There is no evidence of differential maturity or survival in the two life history types, however, the larger sized river migrant individuals have a higher fertility since fertility increases with increasing body size. Table 1 summarizes the range of values for life history parameters used to model Athabasca Rainbow Trout.

Table 1. Range of values and descriptions for parameters used to model Athabasca Rainbow Trout. See Caskenette and Koops 2018 for source details.

	Description	Symbol	Estimate		
			mean	**min**	**max**
Growth	SR asymptotic size (mm)	L_∞	224	216	232
	RM asymptotic size (mm)	$L_{\infty,RM}$	350	315	385
	Growth coefficient	k	0.26	0.23	0.28
	Age at 0 mm	t_0	-0.52	-0.62	-0.43
Survival	Young-of-the-year (YOY)	σ_{YOY}	0.11	0.003	0.42
	Juvenile	σ_J	0.25	0.01	0.90
	Adult	σ_A	0.20	0.01	0.60
Fecundity	Proportion female	φ		0.5	
	Spawning periodicity	T		1	
	Fecundity exponent	ϑ		2.06	
	Fecundity scaler	β		0.008	
	Proportion reproductive	ρ_2	0.05	7.3×10^{-6}	0.1
		ρ_3	0.35	3.5×10^{-5}	0.70
		ρ_4	0.50	0.1	1.0
		ρ_5	0.56	0.20	1.0
		ρ_6	0.75	0.50	1.0
		ρ_7	0.95	0.90	1.0
		ρ_{8+}	1.00	1.00	1.0
Age	Maximum age	t_{max}		10	
Matrix	Effective fecundity ($\lambda = 1$)	F_1	0	0	4
		F_2	18	13	52
		F_3	112	81	119
		F_4	168	128	145
		F_5	113	121	110
		F_6	98	125	101
		F_7	105	110	109
		F_{8+}	112	109	115
	Probability of transitioning	G_{1-7}	1	1	1
		P_{8+}	0.14	0.01	0.33
	Proportion in small trajectory	α	0.95	0.9	1

ASSESSMENT

Historic and Current Distribution and Trends

Rainbow Trout are native to northwestern Siberia and North America. In North America, the range of freshwater resident Rainbow Trout extends from the Kuskokwim River, Alaska to Baja, California, including coastal and inland regions of British Columbia, Washington, Idaho and Oregon and east of the Continental Divide in the Arctic drainages of the Liard, Peace and Athabasca Rivers. Anadromous ‘steelhead’ populations are restricted to the west coast of North America and have become established in the Laurentian Great Lakes. Due to their popularity as a sport and food fish, hatchery-reared Rainbow Trout have been widely stocked into lakes and rivers and now occur on all continents with the exception of Antarctica.

Athabasca Rainbow Trout are distributed throughout the headwaters of the Athabasca River system, including the Athabasca River (downstream of Sunwapta Falls) and it's major tributaries – the McLeod, Wildhay/Berland, Sakwatamau and Freeman rivers. They are found in the lower reaches of the Snaring, Maligne, Rocky and Snake Indian rivers below major waterfalls and in most of the Miette River watershed. Non-native domesticated strains of Rainbow Trout from hatcheries in the Pacific Northwest have been widely stocked in Alberta, including the Athabasca River watershed, with the first instance dating to 1919 in Jasper National Park. The headwaters of all major drainages of the Nelson/Churchill and Mackenzie River basins, including the upper Athabasca River watershed, now contain naturalized populations of non-native Rainbow Trout. The presumed historical distribution of Athabasca Rainbow Trout covered approximately 29,500 km^2. Current habitat occupancy has been estimated at 11,711 linear stream km or 102.25 km^2 (including Jasper National Park) by the Alberta Athabasca Rainbow Trout Recovery Team (2014) and at 6,890 linear stream km (including an estimate for only a portion of Jasper National Park) by COSEWIC (2014). The reported value in COSEWIC (2014) is 16,890 linear stream km, however, this is based on an incorrect entry for tertiary watershed 07AC (11,650.2 km occupied of 8,938.1 total stream km). Based on the percent occupied value in Table 4 of COSEWIC (2014) of 0.18, the value for tertiary watershed 07AC should have been entered 1,650.2 km occupied stream length rather than 11,650.2 km.

Historic and Current Abundance and Trends

Populations of Athabasca Rainbow Trout were ranked in terms of their abundance (Relative Abundance Index) and trajectory (Population Trajectory). These were then combined to determine the Population Status (Table 2). Trajectory data was only available for 45 streams in nine HUC8s. Abundance was ranked relative to the most abundant population (Wampus Creek). Current adult density from the Alberta Fish Sustainability Index (FSI) was used to determine the relative abundance index for the 10 HUC8s for which trend data is not available and current FSI rank versus historical FSI rank was used to determine the population trajectory for these HUC8s. The Relative Abundance Index was assigned as Low, Medium or High. The Population Trajectory was assigned as Increasing, Stable, Decreasing or Unknown. The Population Status was assigned as Poor, Fair, Good or Unknown.

Table 2. Relative Abundance Index and Population Trajectory of Athabasca Rainbow Trout populations in the Athabasca River watershed.

Waterbody	HUC8	Relative Abundance Index	Population Trajectory	Population Status
Cabin Creek	17010301	Low	Stable	Poor
Hendrickson Creek	17010301	Low	Increasing	Poor
Moon Creek	17010301	Low	Decreasing	Poor
Barbara Creek	17010302	Low	Decreasing	Poor
Collie Creek	17010302	Low	Decreasing	Poor
Fred Creek	17010302	Low	Increasing	Poor
Moberly Creek	17010302	Low	Decreasing	Poor
Teitge Creek	17010302	Low	Decreasing	Poor
Twelve Mile Creek	17010302	Low	Increasing	Poor
Unnamed Creek 20768	17010302	Low	Decreasing	Poor

Waterbody	HUC8	Relative Abundance Index	Population Trajectory	Population Status
Wroe Creek	17010302	Low	Decreasing	Poor
Baseline Creek	17010401	Low	Decreasing	Poor
Canyon Creek	17010401	Low	Increasing	Poor
Cold Creek	17010401	Low	Stable	Poor
Gorge Creek	17010401	Low	Decreasing	Poor
Hardisty Creek	17010401	Low	Decreasing	Poor
Seabolt Creek	17010401	Low	Decreasing	Poor
Solomon Creek	17010401	Low	Stable	Poor
Unnamed Creek 20239	17010401	Low	Decreasing	Poor
Unnamed Creek 25206	17010401	Low	Decreasing	Poor
Chickadee Creek	17010501	Low	Increasing	Poor
Carson Creek	17010601	Low	Increasing	Poor
Anderson Creek	17020101	Low	Decreasing	Poor
Antler Creek	17020101	Low	Increasing	Poor
Berry's Creek	17020101	Low	Increasing	Poor
Deerlick Creek	17020101	High	Increasing	Fair
Eunice Creek	17020101	Low	Decreasing	Poor
Little Mackenzie Creek	17020101	Low	Decreasing	Poor
Mary Gregg Creek	17020101	Medium	Increasing	Poor
McPherson Creek	17020101	Low	Stable	Poor
Sphinx Creek	17020101	Low	Decreasing	Poor
Teepee Creek	17020101	Medium	Increasing	Fair
Trapper Creek	17020101	Low	Increasing	Poor
Unnamed Creek 20461	17020101	Low	Increasing	Poor
Wampus Creek	17020101	High	Increasing	Good
Bacon Creek	17020102	Medium	Decreasing	Poor
Bryan Creek	17020102	Low	Decreasing	Poor
Dummy Creek	17020102	Low	Decreasing	Poor
Erith River	17020102	Low	Increasing	Poor
Halpenny Creek	17020102	Low	Decreasing	Poor
Lambert Creek	17020102	Low	Increasing	Poor
Luscar Creek	17020102	Low	Decreasing	Poor
Unnamed Creek 20576	17020102	Low	Decreasing	Poor
Unnamed Creek 21517	17020201	Medium	Increasing	Fair
Unnamed Creek 22441	17020202	Low	Increasing	Poor

Waterbody	HUC8	Relative Abundance Index	Population Trajectory	Population Status
Upper Athabasca River and Brule Lake*	17010102	Low[1]	Unknown	Poor
Whirlpool River	17010103	Low[1]	Decreasing[2]	Poor
Miette River and tributaries*	17010104	Low[1]	Unknown	Poor
Maligne River	17010105	Low[1]	Decreasing[2]	Poor
Snaring River	17010106	Unknown[1]	Stable[2]	Unknown
Snake Indian River	17010201	Unknown[1]	Increasing[2]	Unknown
Athabasca River (Whitecourt to Ft. Assiniboine)*	17010602	Low[1]	Stable[2]	Poor
Freeman River*	17010603	Low[1]	Decreasing[2]	Poor
Edson River*	17020203	Low[1]	Decreasing[2]	Poor
Trout Creek*	17020204	Low[1]	Decreasing[2]	Poor

* HUC8 name
[1] Based on current Adult Density from Table 2 in Sawatzky (2017)

[2] Based on Current FSI rank versus Historical FSI rank from Table 4 in Sawatzky (2017)

Habitat Requirements

Rainbow Trout, in general, are a cold-water species with preferred temperatures ranging from 7 to 18 °C. The upper lethal temperature for adults is approximately 27 °C. Stream resident Athabasca Rainbow Trout spend their entire lives in small headwater streams. River migrants inhabit main stem rivers and migrate into smaller tributaries in the spring to spawn. They use the same spawning habitat as the stream residents, but return to the larger rivers after spawning to summer and overwinter.

Athabasca Rainbow Trout are not often found in first-order streams since these streams are often ephemeral; however, first-order streams with perennial flow and channel widths greater than 0.75 m provide suitable habitat and are often occupied solely by Athabasca Rainbow Trout.

Important habitat components for this species include cold, clean well oxygenated water, sediment-free substrates, instream cover (e.g., large woody debris), and a variety of habitats with lower water velocities. Adult riverine Rainbow Trout occupy habitat with riffles, runs, glides and pool structures and generally occur in deeper, faster moving water than juveniles. Cover is a critical habitat component in small streams.

Spawning occurs in late May to early June in small tributaries to rivers or inlet or outlet streams of lakes. Athabasca Rainbow Trout spawn later than introduced Rainbow Trout (April to May) in southern Alberta. Peak spawning in the Tri-Creeks watershed has been reported to occur approximately 104 to 122 days after ice-out (usually the first 10 days of June) at a mean temperature of 6 °C or a maximum of 8 °C. Spawning will occur later at higher elevations and earlier at lower elevations. Suitable water velocity and depth for Rainbow Trout spawning range from 0.30 to 0.90 m/s and 0.15 to 2.5 m, respectively. Athabasca Rainbow Trout generally spawn in habitat at the lower end of these ranges in habitat with small to medium gravel beds, which are typically located upstream of riffle crests in small to medium perennial streams. Athabasca Rainbow Trout generally spawn in finer gravel substrates than introduced Rainbow Trout in southern Alberta. When stream flow is high during the spawning period, redds are often constructed along stream margins, leaving them vulnerable to exposure (and egg mortality) during summer low flow. When stream flow is low during spawning, redds are often constructed closer to the center of the channel and are therefore vulnerable to scour during summer high flow. The location of spawning substrate (gravel) varies depending on flow.

In the Tri-Creeks watershed, the accumulation of approximately 590 degree-days was required before fry began to emerge. Emergence usually occurs in mid-summer, but may be delayed until late August or September in some habitats. Fry emerge in flowing water and move to shallow water along stream margins. Stream margins, un-embedded large gravel and small to medium cobble substrates next to spawning areas are important rearing habitats.

Athabasca Rainbow Trout typically overwinter in primary pools that span the width of the channel in main stem rivers and smaller tributaries. In the Tri-Creeks watershed, stream residents overwintered in primary pools in third- and fourth-order streams with a mean maximum depth of 0.63 m and a mean volume of 7.2 m^3 prior to freeze-up. Generally, stream residents overwinter in second- to fourth-order streams, while river-migrants overwinter in fifth-order or larger rivers.

Functions, Features and Attributes

Table 3 describes the functions, features and attributes associated with Athabasca Rainbow Trout habitat. The habitat required for each life stage of Athabasca Rainbow Trout has been assigned a function that corresponds to a biological requirement and features considered the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. Habitat attributes associated with current records may differ from optimal habitat as Athabasca Rainbow Trout may be occupying sub-optimal habitat where optimal habitat is not available. There are no data to quantify how the biological functions that specific habitat features provide vary with the state or amount of habitat, including carrying capacity limits.

The spatial extent of the areas likely to have the habitat properties outlined in Table 3 for spawning and incubation for stream residents and river migrants and overwintering for stream residents have been mapped by the Alberta Athabasca Rainbow Trout Recovery Team (2014) and these maps are included in Sawatzky (2017). Overwintering habitat for river migrants is not considered limiting as these populations overwinter in large rivers. The spatial extent of ecologically significant habitat may change as more information becomes available.

Table 3. Summary of the essential functions, features and attributes for each life stage of Athabasca Rainbow Trout. Modified from COSEWIC (2014).This information is provided to guide the future identification of critical habitat. See Sawatzky (2017) for the full list of citations.

Life Stage	Function	Feature(s)	Attributes
Egg / Embryo – spawning through emergence); for resident (non-migratory) and fluvial (migratory) populations	Spawning Incubation and early rearing (mid-May to mid-August)	• Clean, small–medium gravel; gravel beds generally found upstream of riffle crests in small to medium perennial streams (often Strahler Order 2–4) • Redds are often constructed in areas with sub-gravel flow	• Gravel beds with rounded or angular gravel with mean particle sizes ranging from 4–15 mm • Water depth over gravel beds ranging from 5–40 cm, where flow is non-turbulent with velocities ranging from 12–70 cm/s • Fine sediment and silt (< 2.0 mm) in spawning gravels does not exceed 15–20% • Optimum dissolved oxygen (DO) saturation > 90% and minimum optimum DO concentration > 8 mg/L • Fluvial populations migrate on the descending limb of the snowmelt hydrograph at temperatures ranging from 4–6 °C • Mean water temperatures during the spawning period range from 6–10 °C • Optimum water temperature during incubation ranges from 8–12 °C; temperatures < 3 °C or > 18.5 °C cause increased embryo mortality • Unimpeded access to spawning areas for fluvial Athabasca Rainbow Trout
Fry (Young-of-year to age 1) for resident and fluvial populations	Nursery	• A variety of habitats with reduced water velocity in small to medium perennial streams (often Strahler Order 2–4) including riffles, riffle crests, stream margins, boulders, riparian vegetation and large woody debris	• Optimum growth temperature ranges from 10–15 °C • Temperatures ≥ 22–24 °C and ≤ 0 °C are considered life threatening • Shallow stream margins with a variety of abundant cover (aquatic vegetation or woody debris), non-embedded (free of fine sands, silts and clays < 2 mm diameter) large gravel and cobble and reduced flow velocities.

Life Stage	Function	Feature(s)	Attributes
Juvenile Adult	Feeding Cover	• Small to medium perennial streams (often Strahler Order 2–4) with riffles, runs, glides and pools and cover (large woody debris or aquatic vegetation). Adults tend to occupy deeper and faster-moving water than juveniles.	• Preferred water temperatures range from 7–18 °C • The upper lethal temperature for adults is approximately 27 °C but temperatures from 22–24 °C and as low as 0 °C are considered life threatening • Recommended oxygen concentration for Rainbow Trout in general: 7 mg/L if < 15 °C; > 9 mg/L if > 15 °C • Lower lethal oxygen concentration: 3 mg/L • Preferred water velocity for Rainbow Trout in general ranges from 0.20–0.30 m/s • Adults have been recorded at sites with substrates dominated by medium sized (64–255 mm) cobble Cover: large woody debris (also important for channel structure) or riparian vegetation (Rainbow Trout in general)
Fry Juvenile Adult	Over-wintering	• Primary pools (complex pools that span the entire channel width), beaver ponds and areas of hyporheic flow in perennial streams	• Primary pools with a mean pre-freeze-up minimum depth of 0.65 m and volume of 7.2 m^3 (Tri-Creeks) • Large cobble, free of fine sands, silts and clays in regions of hyporheic flow • Unimpeded access to/from additional overwintering areas • Water temperatures between 4 °C and 15 °C, lower temperatures may be tolerated but frazil ice forms near 0.2 °C • Lower lethal oxygen concentration: 3 mg/L • Water velocities ranging from: 0.01 – > 1.0 m/s • Stream residents overwinter in second- to fourth-order streams; river migrants overwinter in fifth-order or larger rivers where overwintering habitat is not considered limiting Landscape function is important to maintain groundwater flow

Residence

Athabasca Rainbow Trout redds meet the SARA definition of residence. Females select spawning sites in areas with subgravel flow. Prior to spawning, the female excavates a nest by turning on her side and forcefully moving her caudal fin, causing gravel to be moved downstream by the current. A few larger stones are usually kept and used to form a pocket to hold the eggs. During nest construction, the female is accompanied by a dominant male and one to several satellite males. Once nest excavation is complete they descend into it and eggs and sperm are released simultaneously. The female then moves immediately upstream and begins excavating another nest, covering the fertilized eggs in the previous nest. The female may excavate three to four nests sequentially, forming a redd. The female guards the redd usually for less than two days and then abandons the site. Dominant males remain active and may spawn with several females. The eggs, and later alevins, remain in the nest until emergence.

Limiting Factors

The most significant natural limiting factor for Athabasca Rainbow Trout is its habitat specificity, particularly water temperature (preferred range: 7–18 °C) and spawning and rearing habitat requirements. These habitat requirements strongly influence the distribution of Athabasca Rainbow Trout. The restricted distribution of Athabasca Rainbow Trout also makes it vulnerable to stochastic processes. Natural barriers (e.g., waterfalls, beaver dams) may limit distribution. The locations of impassable waterfalls within the range of Athabasca Rainbow are shown on the ecologically significant habitat maps in Sawatzky (2017). Additionally, Athabasca Rainbow Trout do not have an outside source of individuals to repopulate (i.e., there is no chance of a rescue effect).

Threats

Five broad threat categories impacting Athabasca Rainbow Trout have been identified. These include: Invasive Species; Habitat Loss or Degradation; Mortality; Contaminants and Toxic Substances; and Climate Change. These threats do not occur in isolation and may interact to have cumulative and synergistic effects.

Invasive Species

Non-native species, including fish, aquatic invertebrates, plants and micro-organisms, may become invasive and impact Athabasca Rainbow Trout by contributing to decreased resiliency, range contractions and/or acute mortality. Three subcategories of this threat are considered: Hybridization and Competition; Algae and Aquatic Invertebrate Species; and Pathogens.

Hybridization and Competition

Non-native Rainbow Trout, Brook Trout and Cutthroat Trout pose a threat to the survival and recovery of Athabasca Rainbow Trout. The range of these species (primarily non-native Rainbow Trout and Brook Trout) has expanded such that they now threaten Athabasca Rainbow Trout and other native Alberta fish species in areas where they have not been stocked. Negative impacts to Athabasca Rainbow Trout include: hybridization/genetic introgression; competition; predation; range constriction; replacement or displacement; and possible exposure to parasites or diseases. Genetic research on hybridization with other species (e.g., Golden Trout, Atlantic Salmon) is continuing.

Algae and Aquatic Invertebrate Species

Invasive invertebrate (e.g., Mud Snails, Zebra Mussels) and algae species have not yet been found in Alberta and generally do not occur in cold streams, put potential exists. *Didymosphenia geminata*, a freshwater diatom native to North America (not considered invasive), has been found in Jasper National Park and one small bloom has been observed. Large blooms decrease habitat for fish and invertebrates, but are unlikely to be found in the small, cold streams inhabited by Athabasca Rainbow Trout. Stockings of invertebrates have occurred in the past and these locations are being monitored.

Pathogens

Pathogens present in Alberta that may impact Athabasca Rainbow Trout include: *Aeromonas salmonicida* (bacterium causing furunculosis), Infectious Pancreatic Necrosis (IPN) virus, and *Myxobolus cerebralis* (parasite that causes whirling disease). Furunculosis has been confirmed within the range of Athabasca Rainbow Trout, in Obed Lake, likely introduced with stocked trout. Transmission via infected fish and contaminated water is possible, thus introduction to the Athabasca River may represent a significant risk to Athabasca Rainbow Trout, particularly if other stressors are present. The IPN virus was introduced into the upper Athabasca watershed through effluent discharge from the Jasper National Park fish hatchery. It may also have been introduced into the Wildhay River watershed via Lake Trout stocked in Rock Lake in the mid-1980s. Juvenile Athabasca Rainbow Trout rarely congregate in the densities necessary for the spread of IPN. The first case of whirling disease in Canada was confirmed in Johnson Lake in Banff National Park, Alberta in August 2016. It is believed to have been introduced via infected hatchery fish. Work is continuing to determine the geographic extent of the disease and it has not yet been confirmed within the range of Athabasca Rainbow Trout. Severe population declines rarely occur and the Athabasca River watershed is the least susceptible to whirling disease of all watersheds in Alberta due to its water temperature and sediment regimes.

Habitat Loss or Degradation

Various activities such as residential and industrial development, mining, grazing, agriculture, forestry, irrigation, dams, road construction and recreational development can damage or destroy habitat properties by altering natural flow regimes, increasing sediment input and/or altering stream thermal regimes. These activities may also lead to contaminant and toxic substance inputs and nutrient loading. Sawatzky (2017) describes the impacts on Athabasca Rainbow Trout.

The activities that may have directly or indirectly affected Athabasca Rainbow Trout habitat include: watercourse crossings (e.g., bridges, culverts, open cut crossings); shoreline and streambank work (e.g., stabilization, shoreline protection); mineral aggregate, oil and gas exploration, extraction and/or production; instream works (e.g., channel modifications, watercourse realignments, dredging, debris removal); and structures in water (e.g., boat launches/ramps, docks).

DFO's Fisheries Protection Program database (Program Activity Tracking for Habitat; PATH) includes information on works, activities and projects reported to DFO. Table 4 summarizes the 97 projects undertaken within the range of Athabasca Rainbow Trout between January 2011 and December 2015 and reported to DFO. Locations of works, activities and projects are shown in Figure 2.

Table 4. Summary of works, projects and activities that have occurred during the period of January 2011 to December 2015 in areas known to be occupied by Athabasca Rainbow Trout. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Athabasca Rainbow Trout sub-watershed, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects from Coker et al. (2010) have been indicated for each threat associated with a work, project or activity (1 - Vegetation clearing; 2 – Grading; 3 –Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity		**Threats** (associated with work/project/activity)						**Sub-watershed** (number of works/projects/activities 2011–2015)							
	Alteration of Natrual Flow Regimes	**Alteration of Stream Temperature**	**Suspended and Deposited Sediments**	**Contaminants and Toxic Substances**	**Nutrient Loading**	**Alteration of Groundwater Quality or Quantity**	**Invasive species**	**07AA**	**07AB**	**07AC**	**07AD**	**07AE**	**07AF**	**07AG**	**07AH**
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 3, 7, 8, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16	3	14, 17								
Watercourse crossings (e.g., bridges, culverts, open cut crossings)	✓		✓	✓	✓			–	–	7	7	9	11	13	13
Shoreline, streambank work (e.g., stabilization, shoreline protection)	✓	✓	✓	✓	✓			–	–	–	2	4	3	1	4
Mineral Aggregate, Oil & Gas Exploration, Extraction, Production	✓	✓		✓		✓		–	–	–	–	–	1	–	–

Work/Project/Activity	Threats (associated with work/project/activity)							Sub-watershed (number of works/projects/activities 2011–2015)							
	Alteration of Natrual Flow Regimes	Alteration of Stream Temperature	Suspended and Deposited Sediments	Contaminants and Toxic Substances	Nutrient Loading	Alteration of Groundwater Quality or Quantity	Invasive species	07AA	07AB	07AC	07AD	07AE	07AF	07AG	07AH
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 3, 7, 8, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16	3	14, 17								
Instream works (e.g., channel modifications, watercourse realignments, dredging, debris removal)	✓		✓	✓	✓			3	–	–	–	4	–	–	2
Structures in water (e.g., boat launches/ramps, docks, effluent outfalls, water intakes)	✓	✓	✓					1	–	–	–	–	–	–	1
Other (e.g., conduit installation on bridge, bridge washing)								1	–	–	–	–	3	4	3
Invasive species introductions (authorized and unauthorized)							✓	–	–	–	–	–	–	–	–

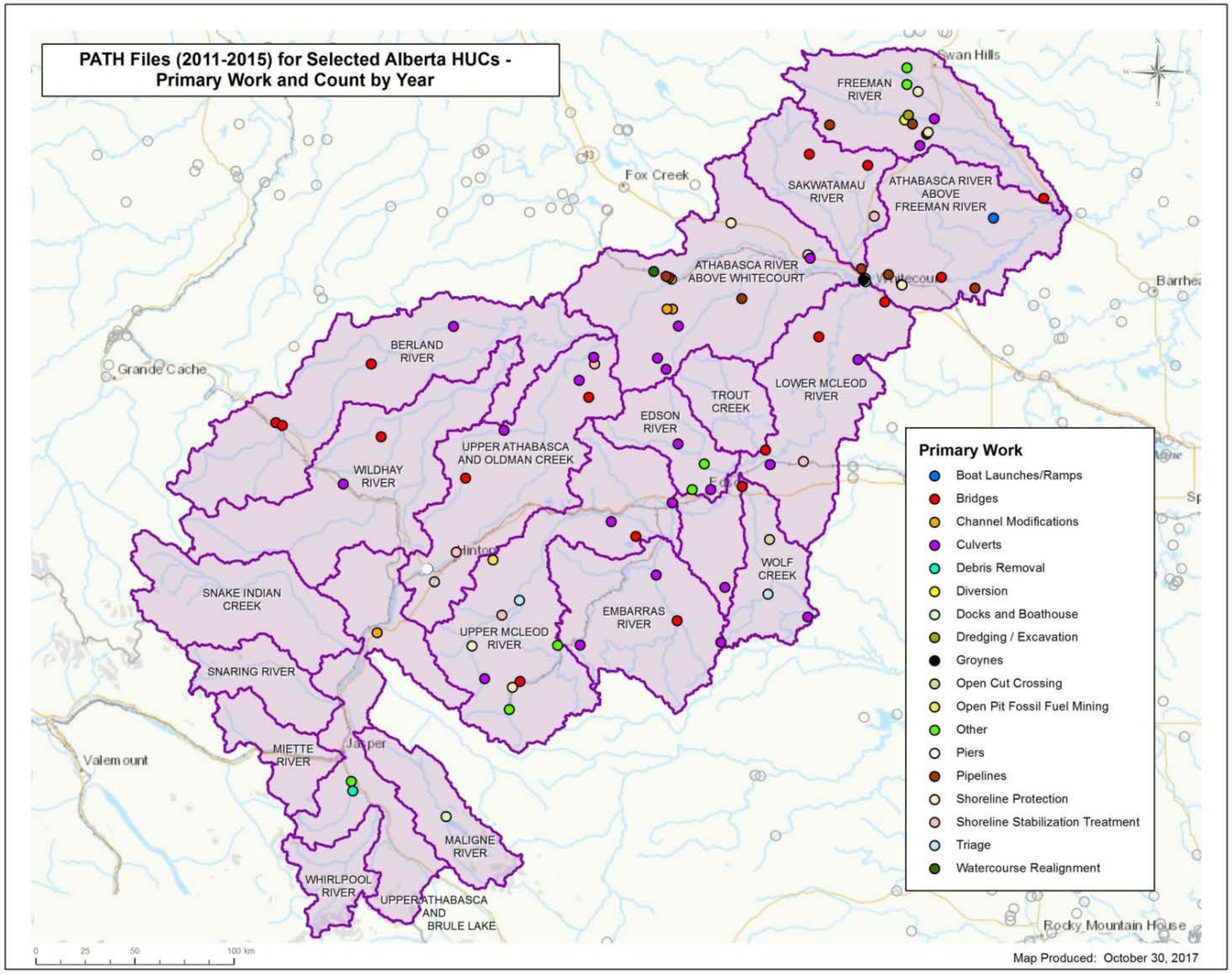

Figure 2. Locations of projects and activities that took place within the range of Athabasca Rainbow Trout and were reported to DFO between January 2011 and December 2015 (source: DFO Program Activity Tracking for Habitat [PATH] database). Activity type is indicated by colour as shown in the legend.

Habitat Fragmentation

Connectivity (i.e., unobstructed passage through watersheds) is a key habitat requirement for migratory Athabasca Rainbow Trout. It is important in linking spawning, rearing and overwintering habitats and in linking populations to facilitate gene flow and aid in the reestablishment of declining populations.

Habitat fragmentation is caused by the creation of migratory barriers including elevated or undersized culverts, dams without fish passage facilities, and land use practices (e.g., mining) that negatively impact habitat making it uninhabitable for Athabasca Rainbow Trout. Impacts to Athabasca Rainbow Trout may include range contractions and population declines. Barriers may also impede or preclude fish assemblage recovery following a disturbance. In some cases, if habitat fragmentation was reduced it would allow recolonization in the event of local extirpations; however, it may also allow other competing species (e.g., non-native Rainbow Trout, Brook Trout) access to the same habitat resulting in increased competition and/or hybridization.

The extent of spatial configuration constraints in areas occupied by Athabasca Rainbow Trout has not been quantified. However, it is possible that potential pathways of genetic interchange have been lost through the reduction in connectivity or the construction of barriers. The current locations of dams and weirs are identified in Figure 3 with additional details on the characteristics of them in Sawatzky (2017).

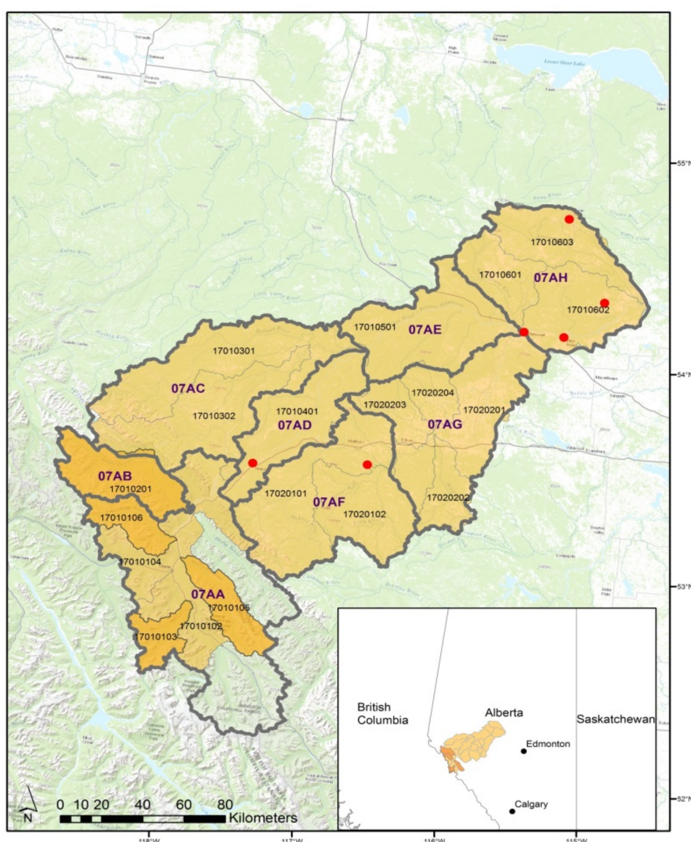

Figure 3. Location of dams and weirs that may act as barriers to fish passage within the range of Athabasca Rainbow Trout.

Mortality

Intentional harvest of Athabasca Rainbow Trout has been prohibited in all streams and rivers throughout their range (with the exception of Jasper National Park where anglers are permitted two per day) since 2012. Illegal harvest, however, does occur and impacts to small, isolated populations could be severe. Post-release mortality rates for Athabasca Rainbow Trout are unknown, but data for other salmonid populations in Alberta suggests a mortality rate of 3–5% or higher (possibly up to 25% when water temperatures are high or bait is used). Such rates may result in significant population-level impacts. Indigenous fishing within the range of Athabasca Rainbow Trout occurs in specific lakes that support Lake Whitefish and non-salmonids and is not considered a risk to Athabasca Rainbow Trout.

If harvest quotas for Brook Trout were increased to reduce competition with Athabasca Rainbow Trout, the potential for misidentification and therefore mortality could pose a threat to Athabasca Rainbow Trout. Fish caught with bait or artificially scented bait display higher post-release mortality, thus allowing the use of bait in some waters for the harvest of Mountain Whitefish also poses a threat to Athabasca Rainbow Trout. If Rainbow Trout harvest were to be allowed in the future to reduce hybridization between non-native Rainbow Trout and Athabasca Rainbow Trout, restrictions on gear type, fish size and season would be needed to reduce the risk to Athabasca Rainbow Trout.

Scientific sampling is a low risk threat, but is a potential source of mortality. This activity is controlled by permitting and sampling protocols are followed.

Climate Change

The main ways by which climate change affects Athabasca Rainbow Trout include: altered thermal regimes (and corresponding oxygen levels); altered water volume and delivery schedules that affect snow pack (winter delivery and/or spring freshet) and/or heavy precipitation events that cause flooding (increases sediment and phosphorous inputs) and habitat scouring; and effects of late summer flows as a result of glacial drawdown over sequential seasons. Streams with healthy, intact riparian zones and/or groundwater inputs are less likely to be impacted by warmer air temperatures and genetic diversity in populations can offer resilience to the effects of climate warming.

In parts of Alberta, the mean temperatures of the warmest month have increased by at least 1 °C, the frost-free period has increased by close to 20 days and growing-degree-days (GDD) have increased by up to 200 GDD > 5 °C. One impact of the extended frost-free period is increased access for recreationalists. Precipitation-as-rain has been increasing in the northern mountains, parkland and northern foothills, and has been stable or declining in other areas of the province. Precipitation-as-snow is stable, or possibly declining, in most regions. With little to no increase in precipitation and warmer temperatures, the amount of water being lost to evaporation is not being replaced at the same rate, compounding the effects of warmer temperatures on fishes. The Intergovernmental Panel on Climate Change models downscaled to Alberta predict that in five regions of the province (boreal, foothills, montane, parkland and prairies) the mean temperature of the warmest month will increase by approximately 3 °C by 2080. The worst case scenario of the Environment Canada CESM2 model downscaled to Alberta predicts that the impacts of climate change will cause the extirpation of Athabasca Rainbow Trout within 100 years. Thus, while not an immediate threat to Athabasca Rainbow Trout, climate change is a significant future threat.

Interactive and Cumulative Effects

Cumulative environmental effects result from the incremental effect of an action when added to past, present and reasonably foreseeable future actions. Climate change can interact with other stressors by affecting the timing, spatial extent and/or intensity of effects of those stressors and may also limit the ability of an ecosystem to recover following a disturbance. Some stressors may also make ecosystems more vulnerable to climate change. For example, damage caused by deforestation (e.g., reduction of shade in riparian areas) can decrease the resiliency of an ecosystem to climate change and may even contribute to climate change by releasing stored carbon into the atmosphere. Deforestation may also cause local warming and reduced rainfall, exacerbating climate change impacts. Water withdrawals for agricultural purposes may increase with reduced precipitation or drought, further exacerbating impacts of climate change on freshwater systems. Alberta Environment and Parks (AEP) is currently working on a cumulative effects modelling approach to aid in the determination of the primary threats to watersheds.

The potential ecological impacts of threats to Athabasca Rainbow Trout were not evaluated for co-occurring species and there was no evaluation of the benefits and disadvantages of threat abatement to Athabasca Rainbow Trout or other co-occurring species.

AEP conducts much of the ongoing Athabasca Rainbow Trout research and monitoring. No specific monitoring efforts were identified for Athabasca Rainbow Trout and other co-occurring species associated with each of the threats nor were specific knowledge gaps identified.

Threat Assessment

Sawatzky (2017) determined threat levels at the HUC, watershed and range levels. Climate change was assessed at the range level only. The highest level of risk for a given HUC was retained for each watershed and the highest level of risk for a given watershed was retained for the range. Table 5 summarizes the threat levels at the range level. HUC and watershed level threats assessments are included in Sawatzky (2017).

Mitigation and Alternatives

Threats to survival can be minimized by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Athabasca Rainbow Trout habitat. DFO has developed guidance on mitigation measures for 19 pathways of effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation measures and alternative strategies for habitat-related threats. Table 4 summarizes applicable pathways of effects associated with each activity reported to DFO that have occurred from January 2011–December 2015 in Athabasca Rainbow Trout watersheds.

To minimize interaction with introduced species, the following mitigations may be appropriate:

- Use existing Alberta Support Emergency Response Team (ASERT) reporting and action system.
- Physically remove non-native species from areas known to be inhabited by Athabasca Rainbow Trout.
- Monitor range of Athabasca Rainbow Trout for invasive species that may negatively impact Athabasca Rainbow Trout directly or affect their preferred habitat.
- Develop a plan to address potential risks, impacts and proposed actions if monitoring detects the arrival or establishment of invasive species.
- Introduce a public awareness campaign and encourage the use of existing invasive species reporting systems.

Table 5. Range-level Threat Risk (RTR), Threat Occurrence (RTO), Threat Frequency (RFT) and Threat Extent (RTE). When rolling up from the tertiary watershed-level Threat Risk, the highest level of risk for a given watershed was retained. Historical (H), Current (C), Anticipatory (A), Continuous (CONT), Recurrent (REC), Extensive (EXT), Restricted (RES).

THREAT	RTR	RTO	RTF	RTE
Invasive Species – Hybridization and Competition				
Non-native Rainbow Trout	High	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation				
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Medium	H / C / A	REC	Broad
Suspended and Deposited Sediments	Medium	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Medium	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practice	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT
Mortality				
Angling Mortality	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES
Other				
Contaminants and Toxic Substances	Low	H / C / A	REC	Narrow
Climate Change	High	H / C / A	CONT	EXT
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT

There are no alternatives to unauthorized introduction. Authorized introduction should use only native species, use only 3N (i.e., triploid) Rainbow Trout and Brook Trout that have been certified disease-free, only stock in systems with no outflows and follow the National Code on Introductions and Transfers of Aquatic Organisms.

To minimize impacts of fishing-related mortality, the following mitigation measures may be appropriate:

- Recovery rest periods.
- Catch and release only (intentional harvest of Athabasca Rainbow Trout prohibited throughout range since 2012 with the exception of Jasper National Park where anglers are permitted to keep two per day).
- Public education to reduce misidentification and increase awareness of regulations.
- In 2016 Alberta implemented a total bait ban to reduce hooking mortality. Artificial lures and flies are permitted.
- Temporary sport fishery closures during low water and high temperature conditions.
- Restrict lethal scientific sampling of Athabasca Rainbow Trout.

Consideration should be given to allowable-harm recommendations when collection for scientific purposes is necessary.

Strategies to mitigate the negative impacts of climate change are becoming increasingly important. For freshwater trout species, conserving the connectivity, size and extent of high quality habitats and helping to guide habitat restoration efforts are important strategies to mitigate the effects of climate change. Areas with the coldest water temperatures and low human footprint have the best long-term potential to support Athabasca Rainbow Trout, and genetic diversity in populations may offer resilience to climate warming.

Alberta Environment and Parks has recently developed a cumulative effects modelling process to help focus recovery efforts and will be undertaking adaptive management experiments to assess the accuracy of the model.

The mitigation measures outlined are consistent with the goal of increasing survivorship by reducing threats to the species directly or indirectly by improving habitat quality.

Population Sensitivity

Athabasca Rainbow Trout population growth was most sensitive, on average, to changes in the proportion of stream resident and the survival of young of the year and ages 1 and 2 fish for all population growth rates.

Productivity and survivorship parameters can be increased if the listed threats to the different life history stages are reduced. For example, reducing fishing mortality will increase juvenile/adult survival.

For populations with a declining population ($\lambda < 1$), the amount of change to vital rate required to increase the population growth rate to 1 (stable) can be calculated. An increase in the young-of-the-year or age 1–4 survival rates (σ_{YOY} or $\sigma_{1\text{-}4}$) of 29% or 16%, respectively, could increase λ from 0.95 to 1. An increase in the survival rates (σ_{YOY} or $\sigma_{1\text{-}4}$) of 54% or 24%, respectively, could increase λ from 0.69 to 1. Values that do not fall between 0 and 1 (or 0 and -1 in the case of parameters that would decrease if λ increased) indicate that the population is not sufficiently sensitive to changes in these vital rates at the specified λ to achieve survival or recovery if all other vital rates are held constant. No amount of change to that individual vital rate could bring the population growth rate up to one. It is important, however, to consider that there may be biological limits to increasing vital rates. Recovery efforts that increase vital rates for more than one life stage should be considered preferential over those that only target one life stage.

Recovery Targets

Abundance Targets (MVP)

Demographic sustainability was used as a criterion to identify recovery targets for Athabasca Rainbow Trout. Demographic sustainability is related to the concept of a minimum viable population (MVP) and was defined as the minimum adult population size that results in the desired probability of persistence over 100 years (approximately 20 generations for Athabasca Rainbow Trout). MVP targets were chosen to optimize the benefit of reduced extinction risk and the cost of increased recovery effort. The reduction in extinction risk per investment in recovery is maximized at approximately 1% probability of extinction. MVP at 1% probability of extinction, an extinction threshold of 2 adults after 100 years, and 15% risk of catastrophe, ranged from 866 adults to 1,422 adults depending on the proportion of the population that was considered stream resident (Caskenette and Koops 2018). The highest MVP estimates occurred when the population was evenly split between stream residents and river migrants, or when the population was either completely stream resident or river migrant. A higher quasi-extinction threshold (i.e., if the population is considered effectively extinct before it declines to 1 female) results in large increases in MVP. For example, if the quasi-extinction threshold is increased to 50 adults and the chance of catastrophe is 15% per generation, the mean MVP increases from 136,000 to 270,000. Thus, if the true extinction threshold is greater than 1 adult female, larger recovery targets should be considered. Appendix 1 presents the MVP estimates for a range of extinction probabilities, probabilities of catastrophe, extinction thresholds and proportion of stream residents in the population.

There are insufficient data to provide meaningful population trajectories for Athabasca Rainbow Trout. There are limited data on long term population trends for most of the Athabasca Rainbow Trout populations with the exception of the three tributaries in the Tri-Creeks watershed. A total of 19 HUCs were delineated within the range of Athabasca Rainbow Trout. Population trajectory data was available for 45 streams in nine HUCs. Four of these streams had stable trajectories, 23 had decreasing trajectories and 18 had increasing trajectories. The estimated current abundance of Athabasca Rainbow Trout in all HUCs is 65,175 mature fish.

A best case scenario for the population trajectories at the upper 95% confidence interval of the observed population growth rate ($\lambda = 1.2$) is shown in Figure 4. At this growth rate, most HUCs could reach the potential abundance within 10–15 years, based on the benchmark of 23 adult fish/0.1 ha if connectivity between HUCs is zero. For the most conservative MVP of 270,000 adult fish, only two of the HUCs would reach the MVP within 20 years.

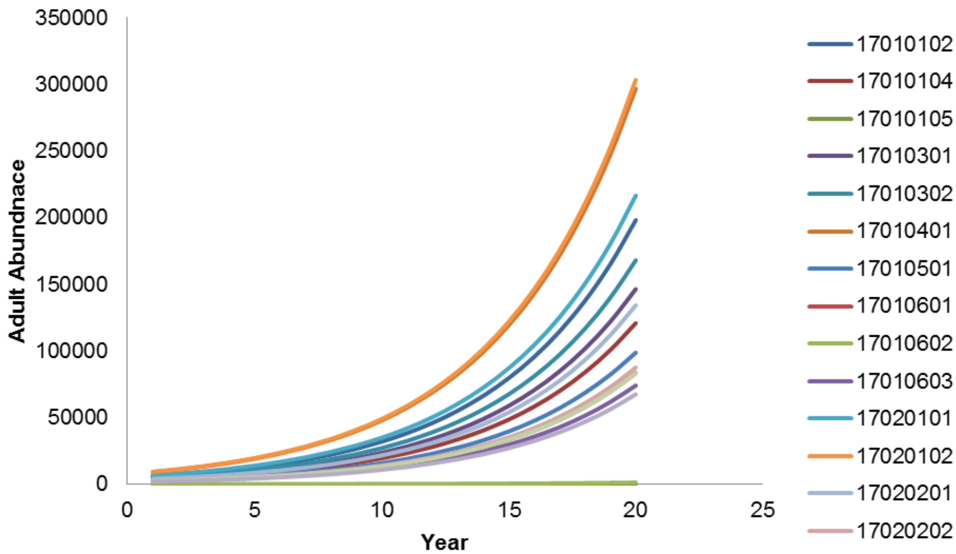

Figure 4. The projected adult abundance for each HUC if the Athabasca Rainbow Trout populations were growing at a rate of λ = 1.2.

Habitat Targets (MAPV)

Minimum area for population viability (MAPV) is a quantification of the amount of habitat required to support a viable population with the desired probability of persistence. Variables included in the MAPV assessment include MPV values and area required per individual (API values). API values were estimated from an allometry for river environments from freshwater fishes. MAPV ranged from 0.18 km^2 to 241.2 km^2. The most conservative MAPV (probability of catastrophe of 15%, extinction threshold of 50 adults and extinction risk of 1%) was 144.76 km^2 of suitable habitat. This is the minimum amount of habitat required to meet the MVP of 270,000 adult fish for an entirely stream resident population. None of the individual populations would have sufficient area to meet this requirement if the HUCs are considered isolated. There is, however, sufficient habitat to reduce the risk of extinction below 2% in 100 years for 16 HUCs if abundance could be recovered to historical benchmarks (23 adults/0.1 ha). The MAPV estimates assume that the entire area is suitable habitat. If certain areas of the current available habitat are deemed partially unsuitable, the total minimum required area should be increased.

The feasibility of applying mitigation measures (e.g., habitat restoration) has not been assessed. A more complete estimate of available and suitable habitat is needed including information on the amount of habitat present that could be restored. Restoration may not be feasible in some watersheds due to the extent and nature of changes in the watershed. AEP has, however, identified priority watersheds on which to focus recovery efforts.

Allowable Harm

Allowable harm is defined as harm to the population that will not jeopardize population recovery or survival. Chronic harm refers to a negative alteration to a vital rate (survival, fecundity, etc.) that reduces the annual population growth rate permanently or over the long term. Transient harm refers to a one-time removal of individuals such that survival (and therefore population growth rate) is only affected in the year of the removal.

For a population that is experiencing positive growth, human-induced harm to fecundity and the annual survival of juveniles should be minimal to avoid jeopardizing the survival and future recovery of Athabasca Rainbow Trout.

Analyses of chronic harm show that the Athabasca Rainbow Trout population would have the lowest allowable harm for fecundity of the stream resident life history type with a maximum allowable reduction of 23% for a population experiencing positive growth ($\lambda = 1.2$). There would also be a limit to the allowable harm for the survival of the young-of-the-year and ages 1 to 3, with a maximum allowable reduction of 41%, 41%, 55% and 95%, respectively. The population is also sensitive to harm to the river migrants. If more than one vital rate were to be harmed, the allowable harm would be lower.

Transient harm may be applied without jeopardizing the survival or recovery if the population is not in decline. A one-time removal of approximately 35% of the total population will result in a 0.05% decline in population growth rate for a stable population. Removal of > 75% of all individuals once every 10 years will reduce the growth rate below 1 if the population is growing at $\lambda = 1.2$ (i.e., removal of a greater number of individuals will result in a decreasing population). Absolute numbers for removal should be chosen based on the population abundance. Allowable transient harm may be smaller if the population is growing at a slower rate. We caution that any removal affects population growth rate and will delay recovery and that the current population abundance estimates are uncertain.

Sources of Uncertainty

There is a need for more information about current population trends at the HUC level. There is also a need for life history data from a wider geographic area and from more recent years (most of the existing data was collected several years ago from only the Tri-Creeks watershed). In particular, data are needed to determine if the life history parameters for the river migrant populations are different than those of the stream resident populations. In addition, the relative proportion of stream residents and river migrants in the different populations at the HUC level is unclear.

Estimates of MAPV are based on a general relationship between benchmark Athabasca Rainbow Trout density and area (API) and may not effectively represent area required to complete all life stages and/or migration. Species-specific estimates of API that are based on Athabasca Rainbow Trout movements and habitat use will reduce uncertainty in this estimate. The estimate of required habitat (MAPV) assumes that habitat is of high quality throughout the range of Athabasca Rainbow Trout. There is not sufficient data to either confirm or refute this assumption; however, one of the main potential threats to Athabasca Rainbow Trout is habitat degradation.

Numerous threats have been identified for Athabasca Rainbow Trout. There is a need for more causative studies to evaluate the impact of each threat on Athabasca Rainbow Trout with greater certainty. Examples include:

- angling pressure is extremely important but difficult to measure. Modelling suggests that nearly undetectable levels can have severe impacts;
- the importance of sediment as a threat is uncertain. Sediment may be less important than indicated by AEP models. It could, however, be an important driver over a certain threshold. Mobilized sediment is a problem, but suspended sediment in the Tri-Creeks area was extremely high and some of the healthiest Athabasca Rainbow Trout populations occur there; and

- it is uncertain whether non-native species are replacing or displacing Athabasca Rainbow Trout. Are they a symptom or a cause of population decline?

The effects of potential mitigation measures, for example the impact of non-native species removal on the persistence of Athabasca Rainbow Trout populations, should also be investigated. Threats were assessed at the HUC level and rolled up to the watershed and range levels. However, the degree of Athabasca Rainbow Trout movement between HUCs is largely unknown and therefore was not accounted for.

SOURCES OF INFORMATION

This Science Advisory Report is from the December 8-9, 2016 Recovery Potential Assessment of Rainbow Trout, *Oncorhynchus mykiss* (Athabasca River populations). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

Alberta Athabasca Rainbow Trout Recovery Team. 2014. Alberta Athabasca Rainbow Trout Recovery Plan 2014–2019. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 36, Edmonton, AB. 111 p.

Caskenette, A.L., and Koops, M.A. 2018. Recovery potential modelling of Rainbow Trout, *Oncorhynchus mykiss* (Athabasca River populations) in Alberta. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/021: iv + 30 p.

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the Species at Risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904: vi + 40 p.

COSEWIC [Committee on the Status of Endangered Wildlife in Canada]. 2014. COSEWIC assessment and status report on the Rainbow Trout *Oncorhynchus mykiss* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. xi + 60 p.

DFO. 2018. Proceedings of the regional recovery potential assessment (RPA) of Rainbow Trout, *Oncorhynchus mykiss* (Athabasca River populations). DFO Can. Sci. Advis. Sec. Proceed. Ser. 2018/004.

Sawatzky, C.D. 2018. Information in support of a recovery potential assessment of Rainbow Trout, *Oncorhynchus mykiss* (Athabasca River populations). DFO. Can. Sci. Advis. Sec. Res. Doc. 2018/022: vi + 162 p.

APPENDIX

Table A1. Estimates of the minimum viable population (MVP) and the respective parameters (a, b) for the equation to estimate the probability of extinction (P_{ext}) for the extinction thresholds of 2 and 50 adults, and the probability of catastrophe per generation of 10% and 15%. Results are broken down for populations with the proportion of the population that are stream residents (α) of 0, 0.25, 0.5, 0.75, and 1.

α = 0

Extinction Threshold	2		50	
Probability of Catastrophe	**10**	**15**	**10**	**15**
a	0.08	0.12	0.21	**0.29**
b	-0.38	-0.34	-0.30	**-0.29**
0.1% Probability of Extinction	220,325	2,262,015	86,331,803	**597,384,391**
1% Probability of Extinction	528	2,722	45,277	**216,542**
3% Probability of Extinction	30	110	1,232	**4,942**
5% Probability of Extinction	8	25	231	**852**
7.5% Probability of Extinction	3	8	61	**211**
10% Probability of Extinction	1	3	24	**78**

α =0.25

Extinction Threshold	2		50	
Probability of Catastrophe	**10**	**15**	**10**	**15**
a	0.08	0.11	0.24	**0.31**
b	-0.41	-0.32	-0.33	**-0.30**
0.1% Probability of Extinction	98,070	3,627,710	35,063,912	**297,858,976**
1% Probability of Extinction	346	3,032	32,316	**153,654**
3% Probability of Extinction	23	103	1,151	**4,150**
5% Probability of Extinction	7	21	244	**774**
7.5% Probability of Extinction	2	6	71	**204**
10% Probability of Extinction	1	3	30	**79**

α =0.5

Extinction Threshold	2		50	
Probability of Catastrophe	**10**	**15**	**10**	**15**
a	0.14	0.12	0.32	**0.37**
b	-0.43	-0.32	-0.32	**-0.30**
0.1% Probability of Extinction	190,002	6,064,467	121,920,078	**599,908,605**
1% Probability of Extinction	882	4,551	93,480	**300,360**
3% Probability of Extinction	68	147	3,050	**7,997**
5% Probability of Extinction	21	30	621	**1,482**
7.5% Probability of Extinction	8	8	176	**389**
10% Probability of Extinction	4	3	72	**150**

α =0.75

Extinction Threshold	2		50	
Probability of Catastrophe	**10**	**15**	**10**	**15**
a	0.10	0.11	0.27	**0.35**
b	-0.39	-0.38	-0.33	**-0.32**
0.1% Probability of Extinction	210,185	524,739	50,226,845	**194,424,469**
1% Probability of Extinction	613	1,210	44,540	**139,967**
3% Probability of Extinction	38	67	1,558	**4,432**
5% Probability of Extinction	10	17	328	**890**
7.5% Probability of Extinction	4	6	95	**249**
10% Probability of Extinction	2	3	39	**101**

α =1

Extinction Threshold	2		50	
Probability of Catastrophe	**10**	**15**	**10**	**15**
a	0.14	0.13	0.28	**0.36**
b	-0.43	-0.39	-0.31	**-0.30**
0.1% Probability of Extinction	166,520	489,236	207,317,375	**549,823,287**
1% Probability of Extinction	818	1,422	112,060	**270,425**
3% Probability of Extinction	65	88	3,095	**7,139**
5% Probability of Extinction	20	24	583	**1,317**
7.5% Probability of Extinction	8	9	155	**344**
10% Probability of Extinction	4	4	61	**133**

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