GCDAMP Knowledge Assessment: Drivers & Constraints

Resource Topic:	Rainbow trout fishery
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Resource Characteristic	Driver or Constraint	Strength	Direction	Confidence	Rationale: Strength & Direction	Rationale: Confidence	Recommendations
LCR Inflow Area & Marble Canyon Rainbow Trout Fishery - Movement	Controlled high and/or steady flows (incl. equalization)	Weak	No Effect	Low	Trout > 75 mm (fork length) demonstrate limited movement based on differences between release and recapture locations. 95% of recaps moved no more than -2.7 km upstream and 2.9 km downstream (movement based on PIT-tag recaptures [N>16,000]; Korman et al. 2016, and analysis updated with other unpublished data as per Natal Origin project). Don't know effects of controlled flows on movement. One could argue that 2011 data show greater movement than in other years.	Controlled floods (fall HFE), steadier flows or variable flows appear to have no measureable effect on the movement of rainbow trout (> 75 mm FL). There is a low probability for an individual fish to move large distances. If macroinvertebrate flows (see Experimental & Management Actions) improve food base in Glen Canyon, trout may be even less likely to move - i.e., recent condition of limited movement of RBT > 75 mm FL may be affected by other variables than flow conditions. Also, CPUE data do not align completely with tag release/recapture data.	
LCR Inflow Area & Marble Canyon Rainbow Trout Fishery - Recruitment	Controlled high and/or steady flows (incl. equalization)	Weak	No Effect	Low	Electrofishing data collected between 1991 and 2016 indicate that Glen Canyon may be the primary source of rainbow trout for Marble Canyon: Sources include: Makinster et al. 2010; Coggins et al. 2011; Korman et al. 2012; Korman et al. 2016; and Yard et al. 2016. Over 70% of the variation in modeled emigration rates was explained by variation in recruitment in Glen Canyon. Evidence based on (a) the trend in catch per unit effort (CPUE) in Marble Canyon lags behind the trend in Glen Canyon by a few years (Makinster et al. 2010; Rogowski unpublished data); (b) there is a strong declining gradient in rainbow trout density with increasing distance from Lees Ferry (Gloss and Coggins 2005); (c) age-0 trout sampled by electrofishing make up a large proportion of the length–frequency distribution in Glen Canyon, but are rare in Marble Canyon (Korman et al. 2016); and (d) following recruitment events in Glen Canyon, high densities of age0 are detected throughout upper Marble Canyon, a substantive length frequency distribution that occurs spontaneously without indication of presence in previous sampling months (Natal Origin unpublished data).	Not clear if the observed dispersion of Age0 RBT from Lees Ferry into Marble Canyon during the late-summer and fall is related to flows in any way, versus other factors, or may be affected by flows only when other conditions are in place. For example, We know more in some situations than others. For example we have 4 data points for Fall HFEs when LF RBT numbers were low and 1 data point for Spring HFE when LF RBT numbers were high. Also, tag release/recapture data do not align completely with CPUE data.	Continue monitoring the recruitment of age0 fish that disperse from Lees Ferry into Marble Canyon during the late-summer and fall at Houserock Reach. Hydrological and morphological characteristics of this reach are not deemed to be ideal for reproduction.

Lees Ferry Rainbow Trout Sport Fishery - Age0 Growth	Spring 2008 HFE	Strong	Positive Effect	Low	The size of age-0 rainbow trout was slightly larger in 2008 and 2009 (year after the controlled flood) than in the majority of years before the flood. Average growth rates (Age0) were nearly as high in 2008 (0.44 mm/d) and 2009 (0.45 mm/d) even though abundance during the summer was eightfold higher (in 2008) or fivefold higher (in 2009).	During the 2008 controlled flood, it is very likely that the interstitial spaces increased in the gravel substrate of the streambed. It is also likely that the 200-fold increase in the ratio of palatable invertebrate drift taxa relative to the total drift and the twofold to sixfold increase in the biomass of palatable taxa in the drift, both of which occurred within a few months of the 2008 controlled flood (Rosi-Marshall et al. 2010; Cross et al. 2013)	
Lees Ferry Rainbow Trout Sport Fishery - Age0 Survival	Spring 2008 HFE	Strong	Positive Effect	Low	Multiple lines of evidence indicated that the March 2008 controlled flood resulted in a large increase in the early survival rates of rainbow trout within the Lees Ferry reach; this survival increase was probably attributable to an improvement in habitat conditions and food availability for recently emerged fish. Hatch date analysis indicated that early survival rates were much higher for cohorts that emerged 2months or more after the flood.	It is likely that strong compensation in survival rates shortly after emergence mitigated the impact of incubation losses caused by increases in flow fluctuations. Direction of effect is dependent on state of the fishery and ability of fishery to sustain a boost. Some would argue that a boost in food base will boost trout but this may not be sustainable and one could be prompting a die off. Others might disagree. This shows need for further evaluation to reduce uncertainty.	
Lees Ferry Rainbow Trout Sport Fishery - Growth and condition	Algae and invertebrate production	Strong	Positive Effect	Low	Algae and invertebrate production should strongly influence the growth and condition of rainbow trout, and in turn be strongly influenced by nutrient supply governed by inflow hydrology and fluxes within the reservoir should influence algae and invertebrate production in the river (Cross et al. 2013; Hall et al. 2015). Although trout densities are probably regulating availability of drift, it is uncertain whether the recent system-wide decline in trout growth and condition can be attributed to an overall top down effect on benthic prey density, or to changes in the benthos caused by other biological and environmental factors, driven by nutrient dynamics in the reservoir and river outflow.	The recent decline in relative condition of larger trout in Glen Canyon was likely caused by reduced production and availability of invertebrate prey items, coupled with increased metabolic demand due to high trout biomass and elevated water temperatures.	Monitor trout population dynamics in response to changes in nutrients. This appears to be a promising area of research to better understand what drives RBT abundance, growth, and condition.

Lees Ferry Rainbow Trout Sport Fishery - Recruitment	High annual, summer, and spring flow	Moderate	Negative Effect	Medium	Metadata analysis for rainbow trout in tailwaters across western North America showed that recruitment was negatively correlated with high annual, summer, and spring flow and dam latitude, and positively correlated with high winter flow, sub-adult brown trout catch, and reservoir storage capacity (Dibble et al. 2015; see also Korman (2012).	High annual, summer, and spring flows should be detrimental to the tailwater RBT fishery based on the regional analysis but relationship needs to be tested specifically for CRe. [The net effect on native fish is uncertain. Larger rainbow trout will be more effective predators and competitors of native fish (Yard et al. 2011), and increased condition may lead to local reproduction and increased abundance near the LCR. Alternatively, increased condition of trout in Glen and Marble canyons may limit the extent of downstream dispersal, thereby reducing trout abundance at the LCR and lowering the extent of competition and predation on native fish (Coggins et al. 2011).]	Continue to monitor trout population dynamics both in the LCR inflow area and the Lees Ferry Sport Fishery.
Lees Ferry Rainbow Trout Sport Fishery - Recruitment	High winter flow and/or low spring flow	Strong	Positive Effect	Medium	Using data from 29 tailwaters in the western US, we determined that the primary driver of RBT recruitment (i.e., sub-adult catch) is hydrologic flow, with high winter and/or low spring flow is associated with increased trout recruitment within tailwaters. More generally, this metadata analysis showed that recruitment was negatively correlated with high annual, summer, and spring flow and dam latitude, and positively correlated with high winter flow, sub-adult brown trout catch, and reservoir storage capacity (Dibble et al. 2015; see also Korman (2012).	The primary driver of recruitment was determined using an analysis that assesses whether a result was due to large differences between dams or whether there was a within-dam trend. The latter was the case for the primary driver. However, relationship needs to be tested specifically for CRe. [The net effect on native fish is uncertain. Larger rainbow trout will be more effective predators and competitors of native fish (Yard et al. 2011), and increased condition may lead to local reproduction and increased abundance near the LCR. Alternatively, increased condition of trout in Glen and Marble canyons may limit the extent of downstream dispersal, thereby reducing trout abundance at the LCR and lowering the extent of competition and predation on native fish (Coggins et al. 2011).]	This analysis suggests that higher flow in winter and lower flow in spring increases the number of trout in a system. If managers wish to decrease recruitment, they may wish to increase flow volume in spring during a time when trout are spawning or when they are in their early life history stages. Continue to monitor trout population dynamics both in the LCR inflow area and the Lees Ferry Sport Fishery.
Lees Ferry Rainbow Trout Sport Fishery - RTELSS Age0 recruitment	Controlled high and/or steady flows (incl. equalization)	Moderate	Positive Effect	Medium	Increase in Age 0 recruitment under higher consistent flows (equalization) and spring HFE's	Avery and others 2015, Korman and Others 2011.	Need to determine the efficacy of TMFs (magnitude, duration, frequency).
Lees Ferry Rainbow Trout Sport Fishery - Spawning magnitude/hatch success	Controlled high and/or steady flows (incl. equalization)	Moderate	Positive Effect	Medium	Increase in magnitude and hatch success under higher consistent flows (equalization) and spring HFE's	Avery and others 2015, Korman and Others 2011.	
Rainbow Trout Maximum Size	Rainbow trout density (# fish/km, >150mm)	Strong	Negative Effect	Low	Using data from 29 tailwaters in the western US, we determined that the primary driver of rainbow trout adult size was fish density. High density of rainbow trout decreased mean adult size within tailwaters.	The primary driver of adult size was determined using an analysis that assesses whether a result was due to large differences between dams or whether there was a within-dam trend. The latter was the case for the primary driver.	This analysis suggests that fish density does have a negative influence on trout size, so if managers wish to increase adult rainbow trout size they might take steps to decrease density/recruitment into the population.
Rainbow Trout Maximum Size	Invertebrate drift availability	Strong	Positive Effect	Medium	Modelling of the effects of drift availability on rainbow trout maximum size supports the positive relationship (Dodrill et al. 2016).	Both empirical and modelling efforts support the positive effect of increased drift on rainbow trout growth.	Consider actions which likely increase benthic production of invertebrates (the ultimate source of invertebrate drift), including the role nutrients play.

Rainbow Trout Maximum Size	Prey-size and abundance	Strong	Positive Effect	Low	Predicted growth under a range of alternative prey scenarios, found that prey abundance and overall small size of prey both constrain maximum mass of rainbow trout (Dodrill et al. 2016). The addition of larger prey (13 and 16 mm) increased both predicted mass-at-age, particularly for ages 2 and 3, and maximum lifetime mass.	Predicted growth under prey limitation will likely limit maximum mass of rainbow trout. At higher levels of prey availability, growth was similar among warm, cool, and average temperature regimes. Faster growth was predicted for immature fish (< age 3), then growth slowed because of the energetic costs of reproduction (Dodrill et al. 2016).	Evaluation of this possible relationship could be very valuable for understanding the factors that control this resource.
Rainbow Trout Maximum Size	Invertebrate drift size distribution	Strong	Positive Effect	Low	Modelling the effects of the invertebrate size distribution on rainbow trout maximum size supports the positive relationship (Dodrill et al. 2016). This is due to the energetics of foraging on small prey in the river current and the increased return (in terms of energy) from foraging on larger invertebrates.	Studies of rainbow trout drift-foraging both within the Colorado River and other systems support the importance of prey size on rainbow trout growth, ultimately increasing the maximum size fish can attain.	Increase food base diversity to include larger taxa, potentially through macroinvertebrate production flows. Evaluation of this possible relationship could be very valuable for understanding the factors that control this resource.
Rainbow Trout Maximum Size	Temperature in CR	Strong	Negative Effect	Low	At higher levels of prey availability, growth was similar among warm, cool, and average temperature regimes. Faster growth was predicted for immature fish (< age 3), then growth slowed because of the energetic costs of reproduction (Dodrill et al. 2016).	Predicted growth under prey limitation, will likely limit maximum mass of rainbow trout. At higher levels of prey availability, growth was similar among warm, cool, and average temperature regimes. Faster growth was predicted for immature fish (< age 3), then growth slowed because of the energetic costs of reproduction (Dodrill et al. 2016).	Evaluation of this possible relationship could be very valuable for understanding the factors that control this resource.