GCDAMP Knowledge Assessment: Drivers & Constraints	
Resource Topic:	Humpback chub
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Resource Characteristic	Driver or Constraint	Strength	Direction	Confidence	Rationale: Strength & Direction	Rationale: Confidence	Recommendations
Juvenile chub population in CR near the LCR	Humpback chub recruitment from LCR	Moderate	Positive Effect	Medium	Over short time scales, this is the most important driver, however over longer time periods it may be less important if year-to-year variation averages out. On the other hand, if there are long-term trends in recruitment (related to declining peaks flows for example), this could have huge impacts for chub population dynamics.	Recruitment to juvenile size classes of the CR portion of the LCR population is driven by both production in the LCR (which appears to be highly variable) and outmigration rates (which appear to be highly variable). The variability in juvenile production is likely to be driven by LCR hydrology. The variability of outmigration may be caused by differences in starting density and/or by the extent of summer monsoonal flooding. By late fall, much of this variability in outmigration appears to have ceased (fall LCR juvenile estimates typically track estimates of LCR spring age-1 fish). Variation in initial juvenile production and monsoon outmigration have only been well studied for a few years.	
Juvenile chub population in CR near the LCR	Temperature in CR near the LCR regularly < 12°C	Strong	Negative Effect	High	If temperatures are below 12°C year-round in the CR, it is almost certain that juveniles will grow too slowly to recruit to large size classes (Robinson and Childs 2001). However, the importance of temperature becomes less clear at higher temperatures.	We have high confidence that temperatures below 12°C result in poor growth of juvenile humpback chub.	
Juvenile chub population in LCR and CR near the LCR	Temperature in CR near the LCR regularly > 15°C	Strong	Negative Effect	Medium	If temperatures regularly exceed 15°C (i.e., temperature = 16°C or higher) for extended periods of time during the year, non-native warm-water fish may invade and reproduce in CR near LCR, increasing competitive and predatory pressures on juvenile HBC. But this is not an abrupt transition. For example, although smallmouth bass generally spawn near temps of 15°C, they can spawn at 13°C and have been shown to extend spawning into late summer.	If warm-water predators establish in the the LCR and CR near LCR or western Grand Canyon, significant impacts are highly likely (see upper basin experience). CO_2 levels in LCR may reduce risk of establisment of some warm-water species, but CO_2 relationship is highly species dependent.	
Juvenile chub population in CR near the LCR	Turbidity	Moderate	Positive Effect	Medium	Various analyses suggest that turbidity in the Colorado River plays a vital role in growth of early life stages of humpback chub.	There is some evidence that juvenile survival declines when turbidity is higher under field conditions, however, these effects appear to be weaker than positive effects on growth.	
Juvenile chub population in CR near the LCR	Predation and displacement by rainbow trout	Moderate	Negative Effect	High	Rainbow trout play a modest role in juvenile chub survival and the relationship is clearly negative. Rainbow trout also appear to displace humpback chub juveniles from near shore habitat and may lower growth.	Recent analyses strongly suggest that higher abundances of RBT are associated with lower chub survival, as well as growth. Past diet analyses have found chub in the stomachs of RBT. Lab experiments suggest lower chub survival when RBT are present.	

Juvenile chub population in CR near the LCR	Aquatic foodbase	Moderate	Positive Effect	Low	Prior food web studies suggest chub may be food-limited in the CR (as well as in LCR). In 2014, when food appeared to be scarce, condition of juvenile chub was low.	The links between food base and juvenile chub are less clear than for large chub. Whereas adult chub condition has been low since mid-2014 in agreement with low drift in 2014 and 2015 (2016 is still being analyzed), juvenile condition improved more quickly. Increased food may not change the growth of juveniles as much as it allows them to spend less time foraging and thus makes them less vulnerable to predation.	
Adult population that spawns in the LCR	Humpback chub recruitment from smaller size classes	Strong	Positive Effect	High	Assuming adult survival rates are fairly constant, this should be the main driver of variation in adult abundances. Recruitment will be determined by the variety of factors that affect the juvenile chub population, as well as growth through sub-adult size classes, which is strongly driven by temperature.	We are highly confident that recruitment over multiple years is the primary driver of adult abundance.	
Adult population that spawns in the LCR	High-sediment floods in LCR	Unknown	Negative Effect	Low	There is some evidence (one year in 2010) that high sediment loads in the LCR either resulted in some mortality, or displaced translocated HBC from reaches in the LCR above ~12.5 km. Additionally, there has been concern among scientists that high suspended sediment floods in the LCR may have either killed some chub (fall 2014), or forced them to emigrate from the LCR. The strength of this effect is unclear.	There is uncertainty over the extent to which this factor may have driven the Chute Falls decline in 2010. Further, there is uncertainty and some disagreement in how much suspended sediment (Sept 2014) may have played a role in causing the latest apparent decline in the spring abundance estimates of sub-adult and adult chub in the LCR.	
Adult population that spawns in the LCR	Aquatic foodbase	Moderate	Positive Effect	Medium	Adult chub in the CR have been in poor condition since mid-2014 coincident with a decline in the food base. Based on other species, we might expect decreased spawning when adults are in poor condition. Poor condition could also lead to reduced adult survival, although this possibility is considered less likely.	There is uncertainty over the extent to which this factor may have driven recent apparent declines in sub-adult and adult abundances in the LCR. There is also uncertainty in whether or not these declines demonstrate a trend.	
Juvenile chub population in western Grand Canyon	Temperature in CR in western Grand Canyon	Unknown	Positive Effect	Medium	Increased temperatures in the western canyon could be improving conditions for mainstem spawning and/or juvenile rearing, however temperatures have been warm in past years that did not show evidence of higher juvenile abundances and its unclear if the temperatures downstream were ever as limiting for growth as they were near the LCR.	Data currently being collected allows only limited critical evaluation of different potential drivers. However, ongoing monitoring of humpback chub aggregations has shown increased relative abundance and presence of multiple size classes, which may reflect that multiple sequential years of warmer waters are needed for population growth and expansion.	

Juvenile chub population in western Grand Canyon	HFE frequency	Unknown	Positive Effect	Low	HFEs could be improving habitat in the western GC, specifically backwaters. Although backwaters are not important for the LCR population, they may play a more important role in the western GC. Alternatively, it is possible that adult humpback chub are utilizing the stochastic presences of gravel debris fans from side tributaries for spawning. If so, HFE's inundate these with sand.	Data currently being collected allows only limited critical evaluation of different potential drivers. We still have a poor understanding of the importance of backwaters to humpback chub and other native fishes. Backwaters can provide thermal refuge on a limited basis. Studies near the LCR suggest that because of their limited presence, and use of alternative habitat by humpback chub (e.g., talus and vegetated shorelines) they are unlikely to be an important driver for the LCR population. However, this may not be the case in Marble Canyon or in western Grand Canyon. Further, although HFEs create backwaters, they also cover gravel spits from side tributaries, that could be functioning as spawning habitat, particularly in western Grand Canyon. We still know little about these processes.	
Juvenile chub population in western Grand Canyon	Aquatic foodbase	Unknown	Positive Effect	Low	Our understanding of food base patterns in western GC is poor.	Data currently being collected allows only limited critical evaluation of different potential drivers.	
Adult population in western Grand Canyon	Humpback chub recruitment from smaller size classes	Strong	Positive Effect	High	Assuming adult survival rates are fairly constant, this should be the main driver of variation in adult abundances. Recruitment will be determined by the variety of factors that affect the juvenile chub population, as well as growth through sub-adult size classes.	NA	
Juvenile chub population in CR near the LCR	Temperature in CR near the LCR regularly 12-15°C	Moderate	Positive Effect	High	Although it is almost certain that juveniles in the CR will grow too slowly to recruit to large size classes if temperatures there are below 12°C year-round, the importance of temperature becomes less clear at higher temperatures. In the LCR, temperatures 13-14°C with occasional increases to higher temps encourage growth and reproduction. However, food limitations in the CR at higher temperatures may become important in determining growth: In the CR, it is possible that the presentday conditions that lead to warmer temperatures (i.e., warmer dam releases) may sometimes negatively affect the food base.	Within the range of temperatures typically seen in the CR, it seems likely that higher temperatures are always better for juveniles. However, there is some uncertainty in whether other factors that covary with temperature (i.e., nutrients) may lessen growth during some periods.	