

**GCDAMP Knowledge Assessment: Drivers & Constraints**

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|-----------------|--|
| Resource Topic: | Riparian vegetation  |
| Preparer(s):    | Emily Palmquist, Barb Ralston, Joel Sankey, John Spence, Larry Stevens, without ratings; with rating values and additional notes and edits by D. Braun & Seth Shanahan |
| Version Date:   | 1/11/2017, with rating values and additional notes and edits by D. Braun & Seth Shanahan 3/16-21/17  |

| Resource Characteristic | Driver or Constraint                       | Strength | Direction       | Confidence | Rationale: Strength & Direction   | Rationale: Confidence  | Recommendations                              |
|-------------------------|--|----------|-----------------|------------|---|--|--|
| Species richness        | Inundation disturbance interval and timing | Moderate | Unknown         | Medium     | <p>Intermediate amounts of disturbance often result in the highest amounts of richness/diversity, per ecological theory. However, this relationship has not been studied in Grand Canyon and "intermediate" for this study area is as yet undefined. Further, species richness can change due to many factors, not just flow regulation affecting hydrologic disturbance. Increases and decreases in richness may not be tied only to dam operations but may be also be affected by other disturbance processes such as fire, insect invasions, air temperatures (affecting ET), and so forth.</p> <p>Note 1: The original assessment team assessed strength and direction as "unknown" for this and many other drivers because of a lack of clear objectives for resource condition.</p> <p>Note 2: The Knowledge Assessment guidance defines the Riparian Vegetation resource as follows: "Integrity of native vegetation communities and wildlife habitat, stand maturity, species diversity, overall abundance, and recruitment." Ratings for strength and direction thus should incorporate this definition and not consider how any given driver may affect other resource values such as recreation (campsite area) or archaeological site condition. The statements of the original assessment team indicate that disturbance interval and timing "often" have the potential to affect species richness. This suggests a rating of "Moderate" for strength, if one takes a broad definition of disturbance (i.e., not confined to</p> | <p>This has not been studied in Grand Canyon, and knowledge of what is "intermediate" for this study area is unknown.</p>  |  |
| Species richness        | Past vegetation restoration                | Weak     | Positive Effect | Low        | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.   | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects on species richness unknown.                         | See Experimental & Management Actions table. |
| Community heterogeneity | Past vegetation restoration                | Weak     | Positive Effect | Low        | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.   | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown. | See Experimental & Management Actions table. |

|                            |  |          |                 |        | RIPARIAN VEGETATION   |  |  |  |
|----------------------------|--|----------|-----------------|--------|---|--|--|--|
|                            |  |          |                 |        |   |  |  |  |
| Community heterogeneity    | Inundation disturbance interval and timing | Moderate | Unknown         | Medium | <p>Intermediate amounts of disturbance often result in the highest amounts of community heterogeneity, per ecological theory. However, this relationship has not been studied in Grand Canyon and "intermediate" for this study area is as yet undefined. Further, community heterogeneity can change due to many factors, not just flow regulation affecting hydrologic disturbance.</p> <p>Increases and decreases in community heterogeneity may not be tied only to dam operations but may be also be affected by other disturbance processes such as fire, insect invasions, air temperatures (affecting ET), and so forth.</p> <p>Note 1: The original assessment team assessed strength and direction as "unknown" for this and many other drivers because of a lack of clear objectives for resource condition.</p> <p>Note 2: The Knowledge Assessment guidance defines the Riparian Vegetation resource as follows: "Integrity of native vegetation communities and wildlife habitat, stand maturity, species diversity, overall abundance, and recruitment." Ratings for strength and direction thus should incorporate this definition and not consider how any given driver may affect other resource values such as recreation (campsite area) or archaeological site condition. The statements of the original assessment team indicate that disturbance interval and timing "often" have the potential to affect community heterogeneity. <u>This suggests a rating of "Moderate" for</u></p> | <p>This has not been studied in Grand Canyon, and knowledge of what is "intermediate" for this study area is unknown.</p>  |  |  |
| Native to non-native ratio | Tamarisk beetle                            | Moderate | Positive Effect | Medium | <p>The tamarisk beetle has defoliated Tamarix spp. along the corridor, reducing the amount of Tamarix spp. cover. Recent riparian monitoring suggests that native cover is coming in underneath the defoliated Tamarix, but this could change over time. There is no consensus about whether beetle-driven defoliation in Grand Canyon is "good" or "bad," (i.e., what objectives need to be for this resource characteristic) as discussed in the Status &amp; Trend table (see "Native to Non-Native Ratio" in that table). However, the beetle clearly does affect the native to non-native ratio, decreasing the incidence of Tamarix; and it appears that native species benefit. Given the formal definition of the Riparian Vegetation resource topic, "Integrity of native vegetation communities and wildlife habitat, stand maturity, species diversity, overall abundance, and recruitment," this suggests that the direction of effect should be rated as Positive."</p>  | <p>We are confident that the Tamarisk beetle is reducing the cover of Tamarix spp. along the river. We are moderately confident that native species are currently filling in those gaps in cover, but this could change over time.</p> | <p>Current riparian monitoring (ground based and remotely sensed) will be able to track shifts in Tamarix defoliation and subsequent infilling by other species. Without management, defoliated and/or dead tamarisk are likely to persist on the landscape for a long time.</p> |  |

| RIPARIAN VEGETATION        |                             |          |                 |     |  |  |
|----------------------------|-----------------------------|----------|-----------------|-----|--|--|
| Native to non-native ratio | Past vegetation restoration | Weak     | Positive Effect | Low | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.  | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>See Experimental & Management Actions table. |
| Native to non-native ratio | Harvesting by beaver        | Moderate | Unknown         | Low | Beaver have been shown to prefer native species over non-native species on other rivers. One study indicates that beaver do not generally negatively impact coyote willow, but may benefit Tamarix spp. through selective pressures. No studies have been conducted on Cottonwood and beaver in the CRe. There is some informal indication that beaver are reducing the cover of Cottonwood and Willow species along the CRe, but the extent and overall impact of beaver harvesting is unknown. Larry Stevens reports (personal communication) that planted cottonwood and willow at rehabilitation sites need to have protective barriers installed around them to prevent beaver from destroying all. On the other hand, beaver harvesting would have been a natural disturbance process in riparian communities prior to river regulation and beaver decimation. In sum, a rating of at least "Moderate" for strength would address the limited facts indicating a potential effect, with Low confidence. There is not sufficient information to assess the potential direction of effect. | One study indicates that beaver do not generally negatively impact coyote willow, but may benefit Tamarix spp. through selective pressures. No studies have been conducted on Cottonwood and beaver.   |
| Total vegetation cover     | Past vegetation restoration | Weak     | Positive Effect | Low | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.  | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>See Experimental & Management Actions table. |

|                        |                                  |        |         |        |   | RIPARIAN VEGETATION   |  |  |
|------------------------|----------------------------------|--------|---------|--------|---|---|--|--|
|                        |                                  |        |         |        |   |   |  |  |
| Total vegetation cover | Magnitude and duration of floods | Strong | Unknown | Medium | Prior to river regulation, the magnitude and duration of floods, and the length of time between extreme floods, were dominant drivers shaping riparian vegetation cover along the CRe and all other rivers in the southwest. Even with river regulation, flows equivalent to the 1983 flows (>90,000 cfs) can still remove > 50% of riparian vegetation. In contrast, present-day HFE's are not of sufficient magnitude and duration to remove substantial vegetation. HFE's may deposit nutrients, which could increase vegetation, but this has not been studied. Other disturbances (e.g., from wild and prescribed fire) can also affect total vegetation cover in ways that may resemble the effects of flood scouring. The driver thus has the potential to strongly affect total vegetation cover, but the experts express less confidence that this potential can be realized. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate whether removal of riparian vegetation would be regarded as a "good" or "bad" effect of flooding, from the standpoint of riparian community integrity. Natural scouring events were a natural feature of riparian community dynamics prior to river regulation, but the community is now part of a highly managed system. | We are confident that very large floods are capable of removing vegetation and that the current HFE's are not large enough or long enough to remove vegetation. We are not confident about if vegetation is benefited by a nutrient pulse delivered by HFE's. | Although, we do not know how long an individual flood needs to be to drown vegetation, previous studies indicate that over multi-year time periods, inundation for more than 10 % of the given time frame should keep vegetation cover below 12% (i.e., keep vegetation cover relatively low). It is possible, but not certain, that inundating the riparian area for at least 10% of each year may reduce or stop expansion of riparian vegetation. |  |
| Total vegetation cover | Base flows                       | Strong | Unknown | Medium | Multiple studies show that present-day base flows result in increased vegetation within the new floodplain. Specifically, increased base flows (discharge greater than in pre-dam base flows throughout the year) support an expansion of riparian vegetation below the 45,000 cfs shoreline. The driver thus has the potential to strongly affect total vegetation cover, but the experts express less confidence that this potential can be realized. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate whether the expansion of vegetation below the 45,000 cfs shoreline would be regarded as a "good" or "bad" effect, from the standpoint of riparian community integrity. Inter- and intra-annual variation in base flows was a natural feature of riparian community dynamics prior to river regulation, but the community is now part of a highly managed system.   | Current flows have been shown in multiple studies to increase vegetation within the new floodplain.   | Although, we do not know how long an individual flood needs to be to drown vegetation, previous studies indicate that over multi-year time periods, inundation for more than 10 % of the given time frame should keep vegetation cover below 12% (i.e., keep vegetation cover relatively low). It is possible, but not certain, that inundating the riparian area for at least 10% of each year may reduce or stop expansion of riparian vegetation. |  |

| RIPARIAN VEGETATION      |                                  |        |                 |     |   |   |
|--------------------------|----------------------------------|--------|-----------------|-----|---|---|
|                          |                                  |        |                 |     |   |   |
| Functional group cover   | Past vegetation restoration      | Weak   | Positive Effect | Low | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.   | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>See Experimental & Management Actions table.  |
| Functional group cover   | Magnitude and duration of floods | Strong | Unknown         | Low | Theory and evidence from other rivers in the southwest indicate that floods should change the functional composition of vegetation cover due to different selective pressures. We expect higher magnitude/longer duration floods to select for species adapted to those conditions, thus altering functional group cover. However, the effects on functional groups due to flooding have not yet been studied in the CRe. Current work is examining aspects of this. As noted in the Status & Trend table, further, clear objectives do not yet exist for functional group cover along the CRe. | Changes in functional groups due to flooding has not yet been studied in the CRe, but current work is examining aspects of this.<br><br>Continue work using flow-response guilds to examine likely functional group changes due to different flow regimes and likely functional group changes that impacted historic sandbar change (two current projects).           |
| Functional group cover   | Base flows                       | Strong | Unknown         | Low | Theory and evidence from other rivers in the southwest indicate that increased base flows should alter the functional composition of vegetation cover due to different selective pressures. We expect higher base flows to select for species that are less drought tolerant. However, the effects of altered base flows on functional group cover have not yet been studied in the CRe. Current work is examining aspects of this. As noted in the Status & Trend table, further, clear objectives do not yet exist for functional group cover along the CRe.                                  | Changes in functional groups due to higher base flows have not yet been studied in the CRe, but current work is examining aspects of this.<br><br>Continue work using flow-response guilds to examine likely functional group changes due to different flow regimes and likely functional group changes that impacted historic sandbar change (two current projects). |
| Area of woody vegetation | Past vegetation restoration      | Weak   | Positive Effect | Low | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.   | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>See Experimental & Management Actions table.  |

|                          |                                  |        |         |        | RIPARIAN VEGETATION   |   |  |
|--------------------------|----------------------------------|--------|---------|--------|---|---|--|
|                          |                                  |        |         |        |   |   |  |
| Area of woody vegetation | Magnitude and duration of floods | Strong | Unknown | Medium | Prior to river regulation, the magnitude and duration of floods, and the length of time between extreme floods, were dominant drivers shaping woody riparian vegetation cover along the CRe and all other rivers in the southwest. Even with river regulation, flows equivalent to the 1983 flows (>90,000 cfs) can still remove > 50% of riparian vegetation, including woody vegetation. In contrast, present-day HFE's are not of sufficient magnitude and duration to remove substantial vegetation. HFE's may deposit nutrients, which could increase vegetation, but this has not been studied. Other disturbances (e.g., from wild and prescribed fire) can also affect total vegetation cover in ways that may resemble the effects of flood scouring. The driver thus has the potential to strongly affect total vegetation cover, but the experts express less confidence that this potential can be realized. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate whether removal of riparian vegetation would be regarded as a "good" or "bad" effect of flooding, from the standpoint of riparian community integrity. Natural scouring events were a natural feature of riparian community dynamics prior to river regulation, but the community is now part of a highly managed system. | We are confident that very large floods are capable of removing vegetation and that the current HFE's are not large enough or long enough to remove vegetation. We are not confident about if vegetation is benefited by a nutrient pulse delivered by HFE's. | Although, we do not know how long an individual flood needs to be to drown vegetation, previous studies indicate that over multi-year time periods, inundation for more than 10 % of the given time frame should keep vegetation cover below 12% (i.e., keep vegetation cover relatively low). It is possible, but not certain, that inundating the riparian area for at least 10% of each year may reduce or stop expansion of riparian vegetation. |
| Area of woody vegetation | Base flows                       | Strong | Unknown | Medium | Inter- and intra-annual variation in base flows was a natural feature of riparian community dynamics prior to river regulation, but the community is now part of a highly managed system. Multiple studies show that present-day base flows result in increased vegetation within the new floodplain. Specifically, increased base flows (discharge greater than in pre-dam base flows throughout the year) support an expansion of riparian vegetation – including woody vegetation – below the 45,000 cfs shoreline. The driver thus has the potential to strongly affect total vegetation cover, but the experts express less confidence that this potential can be realized. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate whether the expansion of vegetation below the 45,000 cfs shoreline would be regarded as a "good" or "bad" effect, from the standpoint of riparian community integrity.  | Current flows have been shown in multiple studies to increase woody vegetation within the new floodplain.   | Although, we do not know how long an individual flood needs to be to drown vegetation, previous studies indicate that over multi-year time periods, inundation for more than 10 % of the given time frame should keep vegetation cover below 12% (i.e., keep vegetation cover relatively low). It is possible, but not certain, that inundating the riparian area for at least 10% of each year may reduce or stop expansion of riparian vegetation. |

| RIPARIAN VEGETATION                      |                                  |          |                 |        |  |  |
|--|----------------------------------|----------|-----------------|--------|--|--|
|  |                                  |          |                 |        |  |  |
| Area of herbaceous marsh habitats        | Past vegetation restoration      | Weak     | Positive Effect | Low    | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites, although such work requires supplementing substrates with fine grain substrates (see separate driver) and careful attention to the amount of inundation. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.   | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>See Experimental & Management Actions table.   |
| Area of herbaceous marsh habitats        | Proportion of silt in substrate  | Moderate | Positive Effect | Low    | Marsh habitats seem to need silts to retain moisture, although this relationship has not been studied in detail in the CRe. Long-duration floods increase percent of sand and decrease silts. The driver thus has the potential to affect herbaceous marsh habitat abundance and quality in the CRe, but the lack of studies of this matter in the CRe limit understanding of the strength of the effect. As noted in the Status & Trend table, further, rehabilitation to achieve objectives for herbaceous marsh habitats would need to be guided by clear objectives for this resource characteristic – objectives that do not yet exist.   | This has not been studied in detail.   |
| Area of herbaceous marsh habitats        | Magnitude and duration of floods | Strong   | Unknown         | Medium | Flooding of the riparian corridor – including its herbaceous marsh habitats – was a natural feature of riparian community dynamics prior to river regulation, and such floods would have both scoured and replenished silt substrates needed by marsh vegetation (see separate driver) as well as shaped the abundance and distribution of geomorphic settings for marsh habitat. Multiple observations record that the regulated flows between 1965 and 1991 increased herbaceous marsh habitat. Unfortunately, there are not sufficient data to quantify the present extent of these habitats and how that extent relates to flows since 1991, including HFEs, although there is some indication that flows after 1991 have led to reduced marsh area. | Although we know that there were more marsh habitats in Grand Canyon as of the early 1990's, we do not know their current extent and how that relates to recent flows.   |
| Vegetation structure (vertical layering) | Past vegetation restoration      | Weak     | Positive Effect | Low    | Vegetation rehabilitation can be effective at altering this resource characteristic at the scale of individual restoration sites. However, too little restoration has taken place so far to significantly strongly affect this resource characteristic along the CRe.  | Riparian vegetation restoration is an established practice in the southwest but does not have a long history in the CRe and effects to date on this resource characteristic are unknown.<br><br>Develop a science-based vegetation management (e.g., restoration, rehabilitation, or other active management) plan with measurable goals. Allocate time and money based on goals to track success. |

|  |                                  |          |         |        |   | RIPARIAN VEGETATION |  |
|--|----------------------------------|----------|---------|--------|---|---------------------|--|
|  |                                  |          |         |        |   |                     |  |
| Vegetation structure (vertical layering) | Magnitude and duration of floods | Moderate | Unknown | Medium | Flooding of the riparian corridor was a natural feature of riparian community dynamics in the CRe prior to river regulation, and such disturbances (inundation of roots, erosion and deposition of sediment) would have removed some riparian vegetation and/or affected succession, affecting the vertical structure of the vegetation. However, no data are available to assess how changes in woody and herbaceous cover brought about by changes to the flood regime have specifically altered riparian vegetation vertical structure in the CRe. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate what changes in vertical structure would be regarded as a "good" or "bad" effect, from the standpoint of riparian community integrity.   |                     | If this is considered important to study, we would have to add another riparian vegetation river trip or double the size of the current river trip in order to collect this data. Extra staff would need to be hired to collect/enter/manage/analyze the extra data. |
| Vegetation structure (vertical layering) | Base flows                       | Strong   | Unknown | Medium | Inter- and intra-annual variation in base flows was a natural feature of riparian community dynamics prior to river regulation, but the community is now part of a highly managed system. As noted for other drivers (e.g., see Area of woody vegetation), multiple studies show that regulated base flows are greater than pre-dam base flows throughout the year and have resulted in an expansion of riparian vegetation – including woody vegetation – below the 45,000 cfs shoreline. However, no data are available to assess how changes in woody and herbaceous cover brought about by changes to base flows have specifically altered riparian vegetation vertical structure in the CRe. As noted in the Status & Trend table, further, objectives do not yet exist for this resource characteristic, to indicate what changes in vertical structure would be regarded as a "good" or "bad" effect, from the standpoint of riparian community integrity. |                     | If this is considered important to study, we would have to add another riparian vegetation river trip or double the size of the current river trip in order to collect this data. Extra staff would need to be hired to collect/enter/manage/analyze the extra data. |

|                  |   |          |         |        | RIPARIAN VEGETATION   |           |       |   |  |
|------------------|---|----------|---------|--------|---|-----------|-------|---|--|
| Species richness | Sediment erosion/deposition disturbance interval and timing | Moderate | Unknown | Medium | INTERMEDIATE  |           |       |   |  |
|                  |   |          |         |        | Strength  | Direction | Notes |   |  |
|                  |   |          |         |        | <p>Intermediate amounts of disturbance often result in the highest amounts of richness/diversity, per ecological theory. However, this relationship has not been studied in Grand Canyon and "intermediate" for this study area is as yet undefined. Further, species richness can change due to many factors, not just flow regulation affecting hydrologic disturbance. Increases and decreases in richness may not be tied only to dam operations but may be also be affected by other disturbance processes such as fire, insect invasions, air temperatures (affecting ET), and so forth.</p> <p>Note 1: The original assessment team assessed strength and direction as "unknown" for this and many other drivers because of a lack of clear objectives for resource condition.</p> <p>Note 2: The Knowledge Assessment guidance defines the Riparian Vegetation resource as follows: "Integrity of native vegetation communities and wildlife habitat, stand maturity, species diversity, overall abundance, and recruitment." Ratings for strength and direction thus should incorporate this definition and not consider how any given driver may affect other resource values such as recreation (campsite area) or archaeological site condition. The statements of the original assessment team indicate that disturbance interval and timing "often" have the potential to affect species richness. This suggests a rating of "Moderate" for strength, if one takes a broad definition of disturbance (i.e., not confined to</p> |           |       | <p>This has not been studied in Grand Canyon, and knowledge of what is "intermediate" for this study area is unknown.</p> |  |

|                         |   |          |         |        | RIPARIAN VEGETATION  |           |       |   |
|-------------------------|---|----------|---------|--------|--|-----------|-------|---|
| Community heterogeneity | Sediment erosion/deposition disturbance interval and timing | Moderate | Unknown | Medium | RIPARIAN VEGETATION  |           |       |   |
|                         |   |          |         |        | Strength   | Direction | Notes |   |
|                         |   |          |         |        | <p>Intermediate amounts of disturbance often result in the highest amounts of community heterogeneity, per ecological theory. However, this relationship has not been studied in Grand Canyon and "intermediate" for this study area is as yet undefined. Further, community heterogeneity can change due to many factors, not just flow regulation affecting hydrologic disturbance. Increases and decreases in community heterogeneity may not be tied only to dam operations but may be also be affected by other disturbance processes such as fire, insect invasions, air temperatures (affecting ET), and so forth.</p> <p>Note 1: The original assessment team assessed strength and direction as "unknown" for this and many other drivers because of a lack of clear objectives for resource condition.</p> <p>Note 2: The Knowledge Assessment guidance defines the Riparian Vegetation resource as follows: "Integrity of native vegetation communities and wildlife habitat, stand maturity, species diversity, overall abundance, and recruitment." Ratings for strength and direction thus should incorporate this definition and not consider how any given driver may affect other resource values such as recreation (campsite area) or archaeological site condition. The statements of the original assessment team indicate that disturbance interval and timing "often" have the potential to affect community heterogeneity. <u>This suggests a rating of "Moderate" for</u></p> |           |       | <p>This has not been studied in Grand Canyon, and knowledge of what is "intermediate" for this study area is unknown.</p> |