

ASSESSMENT OF
HAZARDS AND RISKS
ASSOCIATED
WITH THE RECOVERY OF
NECHAKO
WHITE STURGEON



RECOVERY INITIATIVE

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Disclaimer

This document is intended for use in the recovery of Nechako River white sturgeon. It was prepared in consultation with a number of recovery team members from this and other provincial white sturgeon recovery initiatives. It does not necessarily represent the official positions of the agencies or views of individuals involved in the recovery process. The discussion provided here is meant to inform an adaptive management process and is subject to change as new information becomes available, as well as to constraints associated with program budgets and biological realities.

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BACKGROUND

Worldwide, sturgeon (Acipenseridae) populations are extremely sensitive to over harvest and have responded poorly to major changes in their habitat. Water regulation and impoundment have been identified as major sources of habitat alteration, and many populations in impounded rivers have been extirpated or are in serious decline (Bemis et al. 1997; Birstein et al. 1997 and references therein; Birstein 1993). Resulting from similar developments, white sturgeon (*Acipenser transmontanus*) have been categorized as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2003). In British Columbia, recent government-led research and monitoring of Fraser River white sturgeon aimed at determining the status of local populations revealed that the Nechako stock group (SG-5) is distinct from other Fraser River stock groups (SG's 1-4) (see RL & L 2000 for SG definitions) and faces a high risk for extirpation. Studies of mitochondrial DNA haplotype frequency distributions and microsatellite DNA (Smith et al., 2002; Nelson et al. 1999), migration, and stock dynamics (RL&L 2000) have clearly supported these conclusions. Despite rigorous sampling in the Nechako River system very few juveniles (pre-spawners generally <25 yrs of age) have been observed (Carrier Sekani Tribal Council 2003, RL&L 2000, Dixon 1986). Further analysis of stock dynamics by Korman and Walters (2001) established that a steep decline in recruitment occurred during the 1960's following impoundment and flow regulation of the Nechako River in 1952. Recruitment failure has led to an ageing population with a high probability of extirpation within two to three decades. The BC Conservation Data Center has therefore "Red Listed" Nechako white sturgeon resulting in their identification as "critically imperilled" under provincial legislation.

INTRODUCTION

As a result of this critical stock status, the Nechako White Sturgeon Recovery Initiative was implemented in January 2001 and the Nechako White Sturgeon Recovery Team (hereafter referred to as the Recovery Team) was established with the goal to ensure the persistence and viability of a naturally-reproducing population of white sturgeon in the Nechako system and restore opportunities for beneficial use, if and when feasible. Three objectives of the Recovery Team outlined in the Recovery Plan (NWSRT Recovery Plan, 2004) are: 1) in the short term to continue assessing the population status and prevent further reductions in white sturgeon distribution, abundance, and genetic diversity within the Nechako system; **short-term** refers to the next 5 years (2003 to 2007) and 2) in the medium term to identify recruitment bottlenecks and establish technically feasible measures that reduce or eliminate these limitations; **medium-term** refers to the next 10 years (2003 to 2012). 3) in the long term to re-establish a natural population age structure and reach target abundance levels; **long-term** refers to the next 50 years (2003 to 2052).

Within the objectives set out for the recovery process there are two possible options for Nechako white sturgeon recovery: 1) Re-establish recruitment through natural means or 2) Re-establish recruitment through a combination of natural means and releases from a recovery facility. At present the specific cause or causes of recruitment failure remain unknown, although the Recovery Team is continuing efforts to research and understand this problem.

Due to the longevity and late maturity of white sturgeon, particularly for northern fish, it will take at least one generation (40-50 years) to establish a mature founder population. Considering population decline and the current small population size (n=571 in 1999 RL&L 2000) it is critical that the genetic diversity of the Nechako population be maintained until natural recruitment can be re-established and sustained.

Recovery through a breeding program has therefore been recommended by the Recovery Team as an important interim measure to reverse population decline, and to guide and aid the development of research to identify causes of recruitment failure. However, such a program cannot be undertaken without assessment of potential genetic hazards and risks in the context of the benefits to the populations involved. Hazards, as discussed here, will include the potentially adverse consequences of an activity or event and risk will include the qualitative probability of that hazard occurring (i.e. no risk, low, moderate, high). Following a discussion of uncertainty and species recovery, this document will outline the potential genetic hazards and assess the risks and benefits to Nechako (SG-5) and Fraser River stocks (SGs 3-4) in the context of the probable extinction of the Nechako stock. It must be stressed that this document seeks to address hazards and risks associated with the operation of a recovery facility which is only an interim portion of the recovery equation aimed at the short term preservation of the genetic integrity of Nechako white sturgeon. The re-establishment of sustained natural recruitment is a long-term objective of the Recovery Team and is addressed in the Recovery Plan (NWSRT Recovery Plan 2003).

UNCERTAINTY AND SPECIES RECOVERY

The conservation of imperilled species is subject to uncertainties that are not normally encountered while managing healthy populations (Anders 1998). Uncertainties in species conservation usually result from the need to make long-term decisions about recovery efforts with less than ideal levels of biological information, within short time frames. Uncertainty and risks associated with management may be compounded when dealing with organisms such as sturgeon because it can be difficult to measure or obtain the results of management prescriptions in the short term. Therefore to reduce the risk associated with uncertainty, it is critical that the best scientific information, experience and expertise be used in any recovery effort. Accordingly, the methods used for recovery are adaptive and use current, scientifically defensible principals based on conservation biology to address causes and potential risks of extinction or extirpation (Anders 1998).

The recovery approach currently employed for Nechako white sturgeon, follows a conservation and recovery model that is being applied to endangered populations of white sturgeon on the Kootenay River and Columbia River. The Kootenay and Columbia river projects are international, multi-agency efforts involving substantial expertise in white sturgeon biology and management. Success for the proposed Nechako white sturgeon recovery program will draw upon the expertise gained in Columbia and Kootenay river recovery programs and on the rigorous application of current scientific knowledge. It must be stressed that sturgeon recovery programs use carefully considered methods that often differ greatly from traditional enhancement-based hatchery practices. Enhancement practices which have been historically used for other species (principally salmonids) are known to have had deleterious effects on the natural genetic composition for recipient as well as adjacent stocks in part because the genetic implications of these practices have typically been ignored (Brannon 1993, Levin 2002, Orr *et al.*

2002,). Consequently, the proposal to embark upon species recovery for white sturgeon within the Nechako system has been thoroughly scrutinized, and will follow principles for the maintenance and conservation of genetic and ecological integrity that are specific to white sturgeon rather than principles for enhancement for harvestable surplus.

Within the scope of conservation of Nechako white sturgeon, the Recovery Team has considered interspecific impacts and intraspecific genetic hazards including potential genetic hazards for both the Nechako and Fraser river white sturgeon stocks. Interspecific (between species) genetic hazards and risks within the Nechako River system are considered to be low to negligible for two reasons: 1) there are no other sturgeon species within the Nechako River and 2) releases of Nechako white sturgeon from the recovery facility will be designed to restore the stock to historical population levels. Thus, interspecific competition (i.e. between white sturgeon and other fish species) is not expected to be higher than historic levels. Therefore, for the purposes of this discussion it is useful to split the genetic hazards into those that may affect Nechako white sturgeon and those that may affect other Fraser River white sturgeon stock groups.

GENETIC INTEGRITY OF NECHAKO WHITE STURGEON

Genetic hazards to Nechako white sturgeon can be categorized generally into two main components: 1) *Extinction* and *genetic variation*: genetic hazard resulting from the current demographic trend for Nechako white sturgeon, and 2) *Species Recovery* and *genetic variation*: genetic hazards resulting from a recovery program.

Extinction and Genetic Variation

Currently the main genetic hazard to Nechako white sturgeon is extinction; given what is currently known about the demographics of the Nechako stock, the risk is very high. Waiting for more research, delaying recovery efforts or avoiding the use of a recovery facility will not diminish the likelihood of demographic extinction of the Nechako stock within 20-30 years. Moreover, delays in recovery will seriously reduce the probability of the success of any future recovery efforts (Secor *et al.* 2002, Paragamian *et al.* In Review). Extirpation of this stock would represent the loss of a unique genetic component for white sturgeon as a species. Genetic studies of BC white sturgeon have led to the conclusion that Nechako white sturgeon form a separate breeding population within the Fraser River watershed that merits status as an evolutionary significant unit (ESU) (Smith *et al.* 2002, Nelson *et al.* 1999).

Recent estimates for the Nechako population indicated that in 1999 approximately 571 white sturgeon remained (95% CI 421-890) (RL&L 2000). Franklin (1980) suggested that an effective population size (N_e) of at least 500 individuals would be necessary to maintain the long-term adaptive potential for a

population. As a population declines, factors such as random genetic drift and inbreeding depression become increasingly important factors for greater extinction risk (Soulé and Mills 1998). Considering the current low population size, the ongoing lack of recruitment, the unique genetic structure and the limited number of adults maturing annually, each sturgeon mortality within the Nechako population represents a potential permanent loss of genetic information, including rare alleles. Loss of genetic information would result in a loss of adaptive potential for the local population as well as for white sturgeon as a species. As the effective population size for the Nechako declines through natural mortality and reproductive senescence over the next two or three decades, there will be an accelerating increase in the risk of population extinction (Figure 1 in Anders 1998). This phenomenon is known as the “extinction vortex” (Gilpin and Soule 1986). The re-establishment of recruitment at an earlier stage of decline is therefore clearly needed for this population. Waiting for more information or further study will only lead to the loss of genetic variation and exacerbate genetic problems associated with small population demographics (Anders 1998), while decreasing the probability of success for future recovery efforts (Secor *et al.* 2002, Paragamian *et al.* In Review). Clearly, recovery efforts including a breeding program in an appropriately designed facility can act to maintain genetic variation and reduce the high risk of the extinction hazard. However, improperly designed recovery programs can introduce a different series of genetic hazards that must be addressed.

Species Recovery and Genetic Variation

Loss of within population genetic variation is the main genetic hazard of poorly planned recovery activities. Genetic swamping, inbreeding/founder effects or domestication of the founder population are all potential threats. However, these genetic hazards may be mitigated by the use of well defined breeding and release protocols that consider genetics and life history strategies; consequently the level of risk can be managed to a low level. In terms of breeding for recovery, many of the life history traits of white sturgeon help reduce the relative risk of genetic hazards when compared with other cultured fish such as salmonids. White sturgeon use an evolutionarily stable strategy for reproduction that acts to maximize effective population size and minimize the genetic effects of small population demographics (Anders 2003). Multiple spawning opportunities (iteroparity), overlapping generations, differential sex specific

ages at maturity, differential sex specific spawning periodicity and spawner aggregations, communal courtship and spawning with multiple males are all strategies that may act to maximize gene flow between and among generations within white sturgeon populations. For Nechako white sturgeon, a properly designed breeding plan and recovery facility can similarly act to minimize the loss of within population genetic variation, maximize within population gene flow and in the short term mitigate risk of extinction due to the current recruitment failure and the current demographic trend.

Accordingly, the Nechako breeding plan (NWSRT Breeding Plan 2003) carefully considers the genetic hazards of culturing a founder population while addressing a suite of technical issues that could impede the success of the program. The Nechako breeding plan is largely based on the Upper Columbia River breeding plan (Pollard 2002) which in turn was an update of the Kootenay River white sturgeon breeding plan (Kincaid 1993), and considers a broad spectrum of recent sturgeon research and technical expertise. One major feature of the more recent plans is that, in the face of rapidly declining populations, the primary goal is to preserve the remaining genetic diversity of these populations. A secondary goal will be to minimize genetic swamping as the result of over-contribution of particular families or cohorts. Finally, issues such as inbreeding and domestication of the founder population are also considered in the breeding plan. Inbreeding can be avoided by the use of techniques to track individuals in the founder population so that they are not bred with related individuals. Domestication can be prevented by the avoidance of techniques or methods that artificially select for certain traits or individuals.

To establish a genetically diverse founder population for the Nechako River the associated breeding plan has set a goal of an ultimate minimum population size of 2,500 based upon World Conservation Union Red List criteria (IUCN 2001). This target is consistent with the Recovery Plan (NWSRT Recovery Plan 2004) and may be adjusted based on habitat capacity and any new research on sturgeon ecology and genetics. The Nechako White Sturgeon Breeding Plan (NWSRT Breeding Plan, 2003) uses the target of 2500 individuals as a benchmark upon which a series of breeding scenarios are based. The mating schedules for each scenario are designed to achieve the target population size over one generation (approximately 40-50 years) while maximizing the likelihood of achieving the primary recovery goal which is the preservation of remaining genetic material in the founder population. A range of scenarios was developed to maximize the

likelihood of achieving this goal in the face of technical issues related to brood stock availability as well as expected survival of reared juveniles in the recovery facility. Each breeding scenario ensures that the genetic contribution from the available brood stock is equalized where possible.

As part of the secondary goal, the breeding plan considers family equalization at release to prevent over contribution from any given family or hatchery cohort. The plan is to equalize family numbers within 20% of each other at release. Unfortunately, this goal may at times be incompatible with the primary objective of the breeding program, which is to preserve the remaining genetic diversity of the Nechako stock. For example, low survival in one family could, after equalization of all families, result in insufficient total release numbers to achieve the desired target population of 2500. Several factors including variability in family survival, difficulties with brood stock capture and release needs for research into the cause(s) of natural recruitment failure will affect whether equalization is achieved for any given year. The potential problems with equalization are discussed more in depth in the breeding plan (NWSRT Breeding Plan 2003). Overall, the breeding plan seeks to maximize the likelihood of maintaining the current pool of natural genetic variation within the founder population while secondarily minimizing the genetic over-contribution of individuals or individual families in the recovery program.

By following the breeding plan the hazard of genetic swamping within the Nechako founder population will be comparatively low. However, considering the current demographic trend of the Nechako population and the ongoing lack of recruitment, one outcome of the recovery program is that the released founder population will be much larger than the pool of wild juveniles. This scenario could be thought of as genetic swamping, however, given the current state of the natural population and the virtual absence of juveniles the impact of genetic swamping of wild fish in the absence of natural recruitment is negligible.

Releasing too many juveniles if and when natural recruitment is re-established could however result in genetic swamping. Alternatively, releasing too few individuals in the absence of natural recruitment will result in extinction of the Nechako white sturgeon population. For the Nechako stock, these issues will need to be evaluated in terms of both the remaining population size and the level of natural production if and when natural recruitment is re-established, while considering empirical survival rates for both wild and reared juvenile Nechako white sturgeon.

Presently, the greatest genetic hazards to the Nechako stock are extinction followed by loss of within population genetic variation. In the absence of natural recruitment, both of these hazards result in a high risk that there will be too few fish to sufficiently maintain the long term genetic integrity of the population. The use of an appropriately designed and implemented recovery facility and breeding program can act to mitigate the high risk associated with these hazards.

GENETIC INTEGRITY OF FRASER RIVER WHITE STURGEON

Genetic hazards for Fraser River white sturgeon stocks could result from the potential displacement of Nechako River white sturgeon into the Fraser River, and subsequent interbreeding of different stocks. Overall, the risk of genetic mixing of the different stock groups is considered low, as will be described. However, mixing of these stock could cause outbreeding fitness depression for the receiving stock. Outbreeding depression typically results from the disruption of co-adapted gene complexes through the interbreeding of historically isolated populations; however the degree to which this would be a problem for white sturgeon is probably low. At least five factors could have a significant bearing upon this hazard: 1) the natural level and frequency of gene flow between stocks, 2) geographic isolation based on the proximity of suitable sturgeon habitat in the Nechako and Fraser rivers, 3) genetic distance or degree of relatedness between stocks, 4) degree of differences in biogeophysical templates (habitat) and resulting natural selection pressure differentials between the two systems, and 5) the number of fish being released. In considering this hazard it is important to remember that the possibility of such mixing already exists as there are no absolute migration barriers between these two systems. Indeed, over evolutionary and shorter time scales mixing likely contributed to the distribution of genetic types that are currently being observed (Anders and Powell 2002), therefore a low level of temporally and geographically variable mixing could be expected between populations. However based on current information it is apparent that the different groups have maintained their reproductive isolation for an unknown, but extended period (McKay *et al.* 2002). Without perturbations such as alterations to Nechako River flows and the implementation of a recovery

program with subsequent white sturgeon releases, one might expect that reproductive isolation would be maintained through natural means. Given changes due to impoundment and flow regulation in the Nechako and the potential changes introduced by recovery releases, it is possible that historic patterns may have been or may be altered.

The potential for any influence of Nechako fish upon the genetic composition of stock groups directly upstream or downstream of the Nechako confluence in the Fraser River is presently considered low based on known movement data and the genetics of the upper Fraser River stocks. Thus any potential influences should be limited by the relatively low number of fish released per family from the recovery facility (NWSRT Breeding Plan 2003). Release goals in the breeding plan are set so that 50 white sturgeon from each cohort survive to maturity for each year that sturgeon are released. The Upper Fraser River stock (SG-4) is estimated to support 815 fish >5 yrs of age (Lheidli T'enneh 2002) with an estimated seven percent (57) of these fish being mature adults. Therefore, even though release numbers are low, if a substantial proportion of released Nechako juveniles were to make their way to the Upper Fraser, and eventually interbreed successfully, they could potentially affect the genetic composition of SG-4. For SG-3 the estimated population is larger (3745 CI 3064 to 4813) (RL&L 2000) than for the Upper Fraser. Assuming a similar proportion of adult fish, there would be 262 potential breeders in SG-3. In base cases the hazard is considered high but the probability of occurrence low. For SG-3 the risk is substantially lower, based upon the larger population size. At present, additional knowledge of the genetic composition, the relative annual production capability, including early juvenile mortality, maturity schedules and fecundity for other Fraser stock groups would be required to complete a full analysis of risk associated with the emigration of Nechako white sturgeon released from the recovery facility. To date, measurement of these parameters for white sturgeon in general has not been achieved by researchers from a variety of jurisdictions over the entire species' range as a result of the great difficulty and high cost of studying this species. Thus, efforts to understand the movements and potential mixing of Nechako founder population with other stock groups will be part of the ongoing monitoring and evaluation portion of the recovery program.

After considering population size effects, the factor having the greatest influence on the risk of genetic mixing is whether fish released into the Nechako would move in significant numbers into the upper or middle Fraser River. Although release locations in

the Nechako system have not been identified at present, release locations would most likely be in areas where white sturgeon currently exist, or in suitable habitat upstream from such areas. Assuming that their current distribution is reflective of habitat suitability, this suggests that juveniles would have to pass through a minimum of 60 km of poor habitat prior to entering the Fraser River. Release locations further upstream or in other watershed location off the main stem Nechako River could increase the distance fish would need to move to hundreds of kilometres. In addition, while larval white sturgeon do pass through a marked downstream dispersal phase, it is much less likely that fish of 1 year of age and older will actively move downstream in large numbers if suitable habitat is available in the Nechako system. Auer (1996) noted that fish typically migrate to optimize feeding, habitat and reproductive success. In theory, juveniles released into the Nechako should remain within suitable habitats, rather than embarking on energetically costly migrations through unsuitable habitat. Preliminary sampling from the Columbia River recovery program indicates relatively little movement from release locations. Continued monitoring should provide a good indication of the distances that one year old fish move in a riverine environment relative to habitat quality once they are released. Evidence from other established white sturgeon programs suggests that migrations following stocking are limited. Immature white sturgeon (< 1m forklength) transplanted from riverine to lacustrine sections of the lower Columbia River tended to move less than 10 km from the release point over a five year period (Rien and North 2002).

Despite the fact that movement of large numbers of juveniles out of the Nechako River appears unlikely, it is still reasonable to assess the risk posed by such movement. Current empirical evidence from studies of white sturgeon in the Nechako and Upper Fraser River watersheds also suggests that the risk of genetic mixing of stocks is low. Sampling the Fraser River from the Nechako River confluence downstream (RL&L 2000) resulted in few white sturgeon being caught within the first 320 km. The few white sturgeon caught in this section were located at the confluence with the Cottonwood River 135 km downstream from the Nechako River. In an upstream direction on the Fraser River, Lheidli T'enneh, (2002) identified white sturgeon through the first 40 km upstream of the Nechako River confluence, and then another concentration in a smaller area 80 km upstream of the confluence. In slight contrast to this, RL&L (2001) sampled a small number of white sturgeon in the confluence area; they found larger concentrations about 20 km upstream of the confluence (using about ½ the effort of Lheidli T'enneh 2002). If

these distributions are indicative of habitat suitability within the Fraser River, then fish moving from the Nechako system would have to travel a fair distance downstream, through apparently poor habitat, in order to overlap with the mid-Fraser group. These two groups have a higher potential for mixing in the Fraser River above the Nechako River confluence.

Based upon the population size and the proximity of fish to the Nechako confluence, SG-4 fish appear to have a greater potential than SG-3 fish for physical mixing with Nechako fish. The one variable that cannot be assessed at this time is whether Nechako white sturgeon would stay in the Fraser River until mature and successfully interbreed with fish from either of these areas. While a conservative approach might assume that interbreeding is likely if there is overlap in the distribution of reproductively active fish, this assumption may not hold. Recent radio-tracking information from the Nechako River program demonstrated that two white sturgeon, a male and a female (likely post-spawning but not confirmed) moved into the Fraser River and were tracked to a location about 20 km downstream of the Nechako River confluence (Golder 2003, M.W.L.A.P unpublished data). The female was later located about 135 km downstream of the Nechako River confluence near the Cottonwood River. A third white sturgeon was captured initially in the lower Nechako River 500 metres upstream from the confluence of the Fraser River in 2000. A year later it was captured 125 km upstream in the Nechako River (Lheidli T'enneh, 2001, Golder 2003). It is still unclear whether these are anomalous behaviours or typical movements, however, they are indicative of range overlap. In spite of these documented movements into the Fraser River, the existing genetic evidence indicates significant reproductive isolation between these groups of fish (Nelson *et al.* 1999). It therefore remains unclear whether fish would interbreed if they were physically located within the same area during the reproductive period. Current genetic evidence indicates that they do not do so at levels that would suggest a single population within the upper Fraser and Nechako systems (Smith *et al.* 2002).

Overall, the hazard of genetic mixing of stocks is considered moderate based on current genetic distances and the uncertain outcome if fish were to mix; whereas the risk of genetic mixing is considered low based on empirical movement and genetic data. A conservative approach would include monitoring the movements of cultured fish in both rivers. Indeed monitoring and evaluation will be an integral part of the recovery strategy and is summarized in the following section.

ASSESSMENT OPTIONS AND OUTCOMES

Addressing the above hazards will be an ongoing process that will change as information becomes available. While the Nechako program has the advantage of experience gained from the Kootenay and Upper Columbia river programs, concerns about downstream mixing of white sturgeon with other distinct populations are unique to the Nechako. With respect to the assessment of fish movement, the Columbia River program is at least 2 years ahead, and should provide some very useful information. Monitoring will also be a definite part of any strategy to release juveniles into the Nechako system. As part of that strategy, all released fish will be permanently marked to facilitate monitoring. Assessment of survival rates, habitat use within the Nechako system, and movements within and out of the Nechako system are important components of the monitoring plan. To assess whether fish have moved into the Fraser River, areas upstream and downstream from the Nechako River confluence will be monitored as part of this sampling program.

A variety of actions could be taken if monitoring indicates a significant risk of genetic exchange between Nechako and Fraser river fish. These range from alterations of juvenile release timing or location, which would diminish the likelihood of movement into the Fraser River, to a more extreme option, which would be the termination of the conservation culture program. Another option that deserves mention is the potential to recapture individuals once they are released into the wild. High empirical recapture rates of released fish in the Kootenay River suggest this may be a relatively feasible option. Given the late maturity of white sturgeon, removing fish from specific areas prior to them becoming reproductively active is a potential means to decrease the risk of genetic exchange. This may also allow fish to be removed from the population if the contributions from one year or one family are ultimately deemed excessive as a result of higher than expected survival rates. While recapture of significant numbers of fish would be a challenge, the longevity and late

maturity make this option more reasonable for white sturgeon than for most other species.

CONCLUSION

Overall, the Recovery Team believes the genetic hazards associated with culturing white sturgeon can be managed. Careful consideration and implementation of appropriate and adaptive breeding, monitoring and evaluation plans minimize risks to the genetic structure of the Nechako and upper Fraser River stock groups. At present, risks to the genetic structure of other populations appear to be low although monitoring of juvenile movements following release will be used as a conservative measure. The greatest genetic hazard appears to be the loss of the Nechako stock. In the face of a continual decline in the number of mature females, the high probability of extinction within the next two decades and while considering the risks and benefits of fish culture, the Recovery Team has concluded that a recovery and breeding facility is an immediate, necessary component of the recovery process.

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