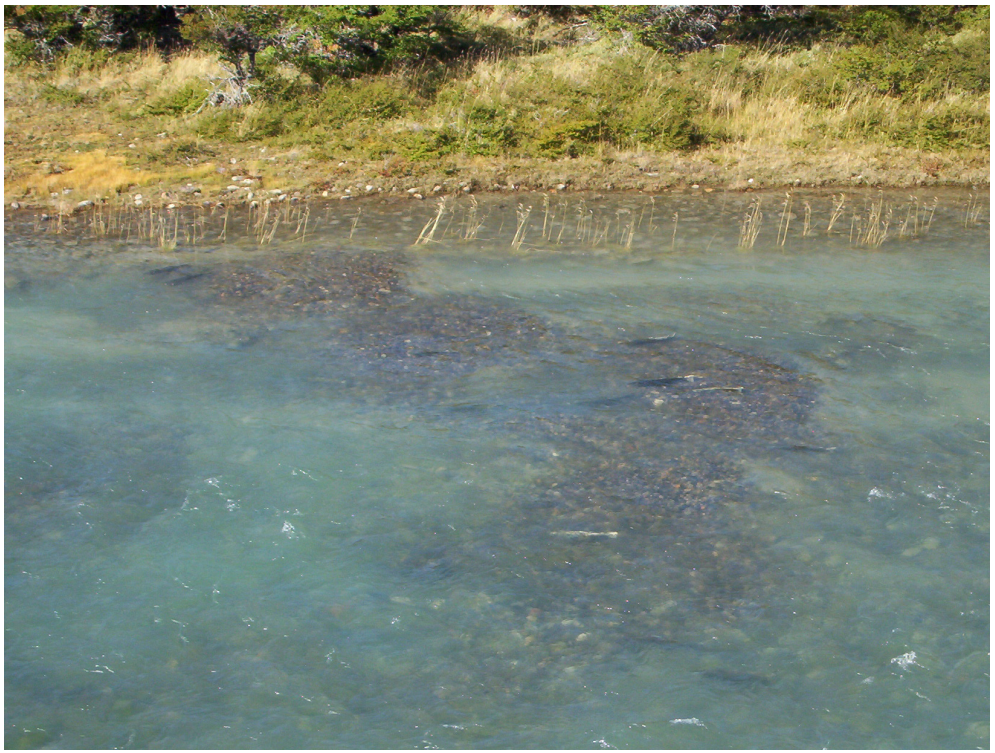
Reintroduction of Spring-Run Chinook Salmon to the San Joaquin River: Genetic Management Techniques



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NOAA Fisheries
National Marine Fisheries Service

The San Joaquin River

- Second longest river in California, nearly 400 miles, drains into San Francisco Bay/Delta. North flowing counterpart of Sacramento River in Central Valley
- Historically southernmost populations of Chinook salmon
- Estimated at 15,000 annually in 1930s. May have been more abundant.
- Construction of Friant Dam in 1942, and almost total lack of ensuing releases, caused ~65 miles of the San Joaquin to go dry in most years.

Central Valley Spring Run Chinook Salmon

- Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit (ESU) was listed as Threatened under the US Endangered Species Act in 1999
- Historically likely the most abundant salmon run in the Central Valley, with annual abundance estimates from early inland fisheries at 700,000
- Currently extirpated from most of the historic range, including all of the San Joaquin River and its tributaries
- Persistent populations in the Feather River, Butte, Mill and Deer creeks
- Small numbers of spring running fish in other tributaries, including reestablished populations in Battle and Clear creeks.

Evaluation of potential donor stocks

•Program seeks to create self-sustaining populations that are “robust” and representative of the genetic and phenotypic diversity of the donor stock(s)

•Technical Advisory Committee recommended use of Butte Creek spring-run stock, due to larger current census size and lack of hatchery influence.

• Agencies determined that only Feather River fish could be used as donor stocks at this time, due to risk of extinction of naturally spawning stocks and uncertainty about habitat availability in the San Joaquin River.

•Genetic evaluation determined that Feather River Spring-run Chinook salmon are the most diversity, but also introgressed with fall run

•Genetic evaluation of phylogeographic affiliation of small populations of spring running fish found colonizers generally come from proximate sources.

Comparative Evaluation of Genetic Diversity in Central Valley Spring-run Population

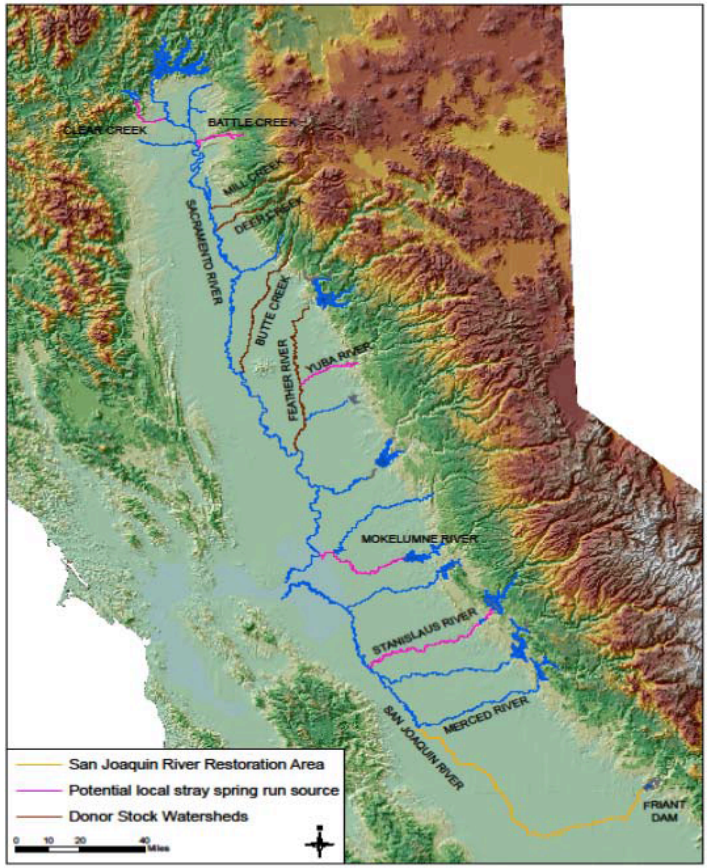
Data Source	20 microsats[1]		169 SNP loci[2]		7-10 microsats[3]		Mean size 1970-2009[4]	Census Size last 3 years[4]	Census size lowest 3 years[4]
Stock	A_R	Ho	K	Ho	K	Ho			
Butte Creek	9.76	0.74	1.88	0.26	6.18	0.62	116	7154	238
Mill/Deer combined	11.01	0.77	1.91	0.29	6.6	0.61	906	4274	1546
Feather River	11.25	0.78	1.91	0.31			776	1679	637

1) Garza et al. 2008 2) Clemento and Garza unpublished 3) Banks et al. 2000 4) Grand Tab

Banks et al. 2000 did not study Feather River spring stock.
Mean census sizes are harmonic and for Feather River do not include in-river spawning component.
A_R= allelic richness; Ho= observed heterozygosity

Genetic analysis of spring-running populations

- Since late 1990s, a generally increasing number of salmon with a spring phenotype have been documented in Battle and Clear creeks
- Small numbers of spring arriving fish have also be documented in other Central Valley tributaries, including several in San Joaquin
- Genetic stock identification with 96 SNPs (Clemento et al. 2014) used to identify their origin.



Genetic stock identification spring running fish from non-persistent populations

	Sample size	Assigned to Fall/ Feather Spring	Assigned to Natural Spring
Battle Creek	188	31	156
Clear Creek	171	12	159
Yuba River	43	43	0

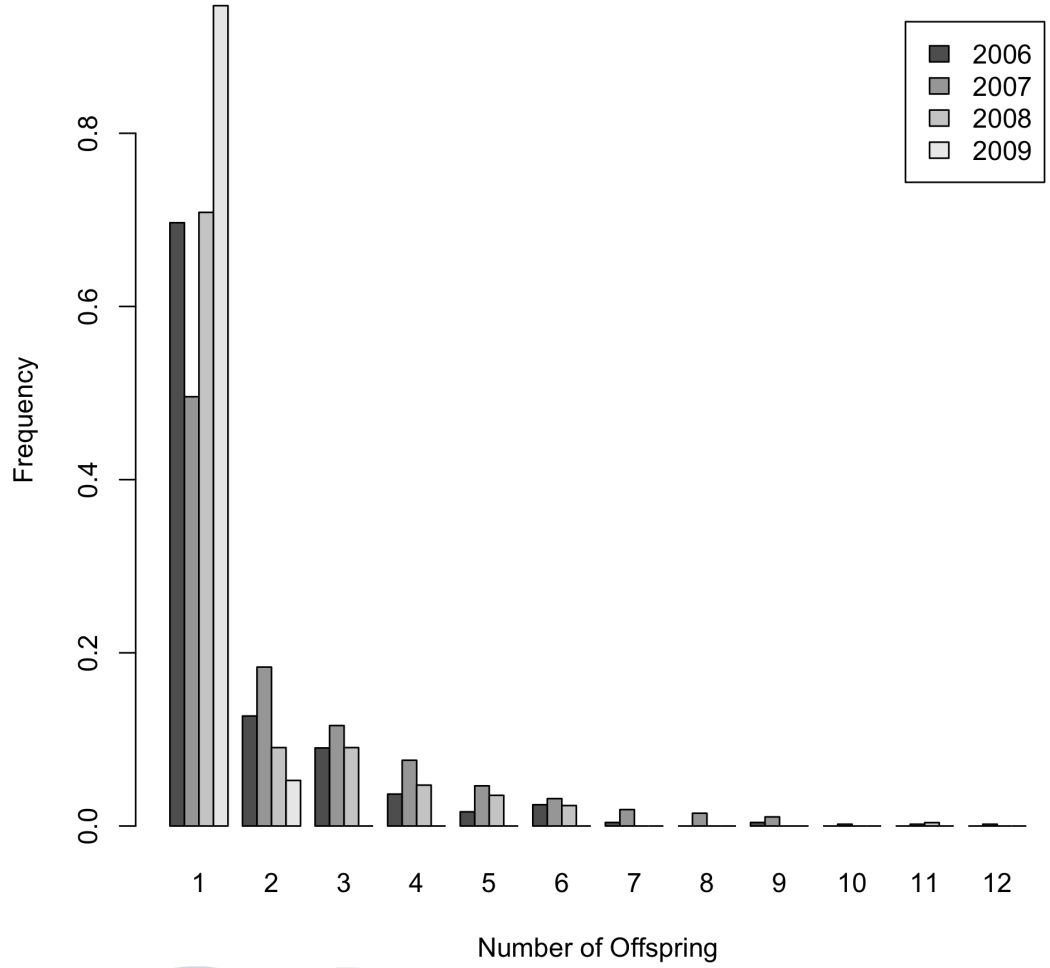
Both Battle Creek and Clear Creek populations contain similar numbers of fish that assign to both of the two natural spring-run populations

Key question emerges about whether they are assortatively mating or not.

Genetic Management of Reintroduction

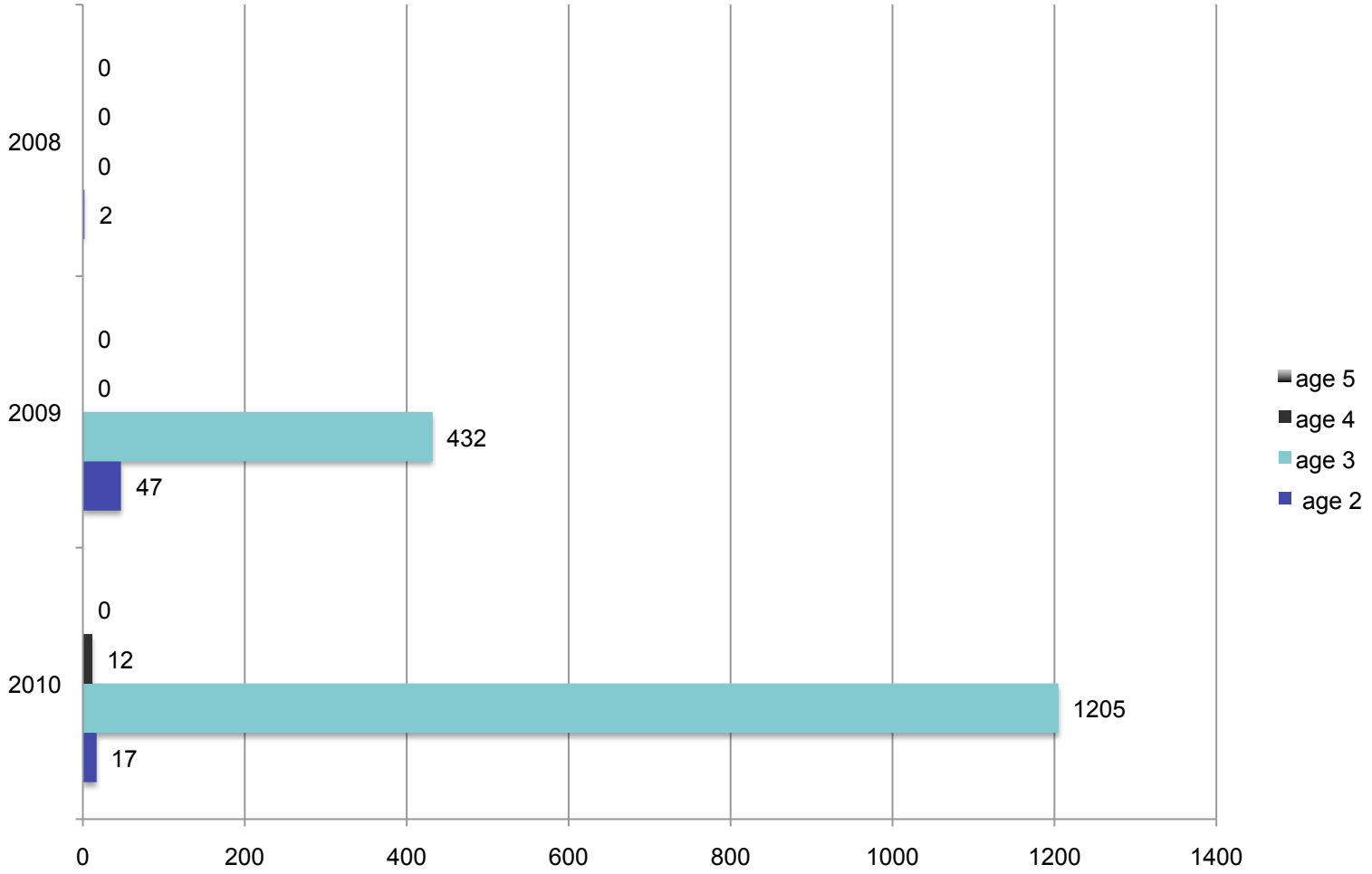
- Stock identification of potential donor individuals
- Identification of siblings and other close relatives to minimize inbreeding when selecting donor stock
- Identification of siblings and other close relatives to minimize inbreeding when spawning donor stock
- Genetic monitoring and stock ID for fish volitionally entering the SJR
- Genetic tagging to provide unambiguous identification of all program/supplemental fish and their progeny anywhere, including at salvage facility and in ocean fisheries
- Evaluation of relative survival/reproductive success in multi-stock donor strategy, and of all natural spawners, program and volitional.

No. Offspring/parent pair, Feather River Spring Chinook



Clemento 2013

Age distribution, Feather River Spring-run Chinook



Clemento 2013

Genetic Management of Reintroduction

- Identification of siblings and other close relatives to minimize inbreeding when selecting donor stock
- In 2012, of 128 parents, 20% had at least one full sibling in the broodstock; 19 pairs of full siblings, four sibships of size four and 1 full sibship of size five
- Effective size of broodstock at least 10% less, and opportunity for inbreeding in program much greater, than expected.

Genetic Management of Reintroduction

- Identification of siblings and other close relatives to minimize inbreeding when spawning donor stock
- Annual creation of spawning “matrices”-genetic marker based estimation of relatedness/inbreeding coefficient of potential spawning pairs.

Genetic Broodstock Management

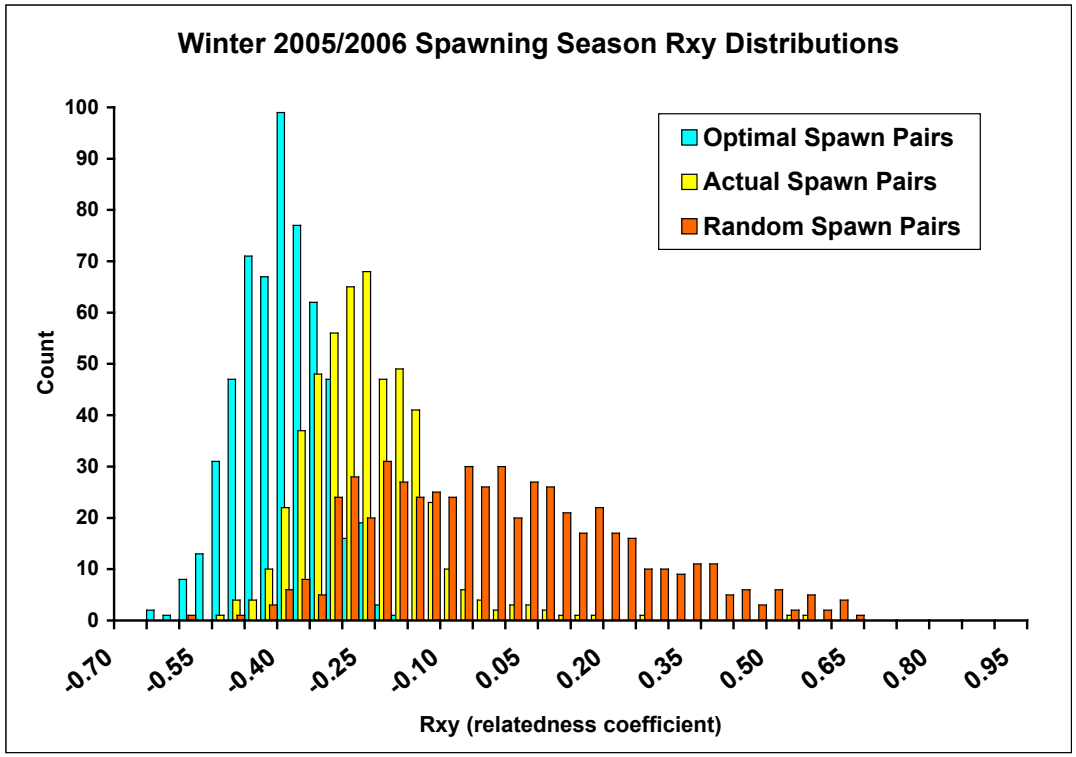
Replacing mate choice in hatcheries

Relatedness coefficients (r_{XY}) derived molecular genetic data derived

All males ranked by r_{XY} to focal female with best mates, top of list, least related to focal female

Avoid mating pairs related at half-sibling or greater

In use in Scott Creek and Russian River coho salmon programs since inception and begun in Iron Gate Hatchery coho salmon program in 2010



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M_829234**	M_81C34B	M_8189C6**	M_81DAC3**	M_8250C4**	M_81A933**	M_8257B8**	M_82A599**	M_817623**	M_811C32**
M_8129B2**	M_8265D7	M_823A30**	M_8197CE**	M_60C809**	M_829F7E**	M_823588**	M_823588**	M_820983**	M_823A30**
M_7ACE0D**	M_813645	M_8175BD**	M_3C03A4**	M_820983**	M_825498**	M_8197CE**	M_8180B5**	M_496D4F**	M_820983**
M_812B1D**	M_60C1E4	M_822746**	M_82ACF1**	M_823A30**	M_8189C6**	M_81872D**	M_8135B6**	M_8197CE**	M_825470**
M_817FDC**	M_82494C	M_824FEE**	M_81DEDA**	M_823002**	M_823002**	M_823A30**	M_81BBA6**	M_8194E4**	M_8197CE**
M_8189C6**	M_825905	M_81A933**	M_8175BD**	M_817FDC**	M_60C809**	M_81E30C**	M_80F3D4**	M_823A30**	M_829F7E**
M_60D0AF**	M_817939	M_60D0AF**	M_812B94**	M_81BBA6**	M_496D4F**	M_7ACE0D**	M_82498A**	M_81C81B**	M_813C16**
M_822746**	M_8296A9	M_823EEF**	M_818927**	M_81E30C**	M_7ACF5F**	M_81824F**	M_81A933**	M_60FB04**	M_8189C6**
M_60FB04**	M_823D9B	M_60C607**	M_817C04**	M_8129B2**	M_8197CE**	M_823EEF**	M_8257B8**	M_81A933**	M_813D6E**
M_81A933**	M_82AA30**	M_813C16**	M_827BBD**	M_827BBD**	M_813D6E**	M_812B1D**	M_826C67**	M_822746**	M_81C280**
M_823790**	M_827EFC**	M_8257B8**	M_825470**	M_81872D**	M_824EA3**	M_60FB04**	M_824EA3**	M_823EEF**	M_81C81B**
M_823588**	M_82115D**	M_814F58**	M_496D4F**	M_814F58**	M_823790**	M_811DD2**	M_813645**	M_8189C6**	M_81E30C**
M_81E30C**	M_829F71**	M_8199D3**	M_8199D3**	M_81C81B**	M_60C607**	M_829234**	M_8275D0**	M_811C32**	M_60B441**
M_81BBA6**	M_828C16**	M_823790**	M_816625B**	M_60B441**	M_813C16**	M_81BBA6**	M_81C34B**	M_60C809**	M_81625B**
M_824FEE**	M_60DE22**	M_824EA3**	M_81E30C**	M_82ACF1**	M_823EEF**	M_8175BD**	M_82509A**	M_60E810**	M_825498**
M_81872D**	M_815752**	M_496D4F**	M_813C16**	M_813D6E**	M_811C32**	M_825470**	M_829CD9**	M_824EA3**	M_8199D3**
M_8257B8**	M_823D74**	M_3C03A4**	M_60C607**	M_824EA3**	M_823588**	M_496D4F**	M_82A818**	M_60D0AF**	M_60C607**
M_824EA3**	M_828B0C**	M_823588**	M_829F7E**	M_8184D5**	M_823A30**	M_81DAC3**	M_829C36**	M_8280A1**	M_814F58**
M_8194E4**	M_82A04B**	M_82509A**	M_813174**	M_3C03A4**	M_8221CC**	M_817623**	M_812E28**	M_81BBA6**	M_8221CC**
M_823002**	M_820925**	M_825470**	M_824FEE**	M_8221CC**	M_814F58**	M_8194E4**	M_8249DA**	M_8257B8**	M_7ACF5F**
M_60C809**	M_81D91E**	M_820983**	M_823790**	M_496D4F**	M_81C81B**	M_60C809**	M_826263**	M_823002**	M_813865**
M_496D4F**	M_8258D1**	M_8280A1**	M_60B441**	M_812B94**	M_81BBA6**	M_823790**	M_823C23**	M_823588**	M_827BBD**

Russian River, Spawn 2004/2005

Moving forward

- Program goal is a multiple stock reintroduction strategy, with simultaneous introduction of fish from more than one source, when available, using a planned conservation hatchery as an intermediary
- Intensive monitoring and evaluation will evaluate whether there are fitness differences that are stock specific
- Monitoring and evaluation will use intergenerational genetic tagging
- Multiple stock reintroduction strategy will depend upon status of donor stocks. Current demographic status of naturally spawning stocks complicates take
- Fundamental question of whether Restoration Goal is Spring-run or spring running population, overwhelmed by current status of donor stocks
- Debate about whether spring run stocks should be intentionally crossed in the reintroduction program. Ongoing evaluation of patterns of mating in Battle and Clear creeks may clarify if fish naturally outbreed or not.
- Adaptive management backed by strong monitoring, evaluation and oversight will be needed to determine success in a program that will likely cost more than $1 billion over the next twenty years.