Delta Landscape Metrics

Creating a Spatial Framework to Inform Restoration Planning

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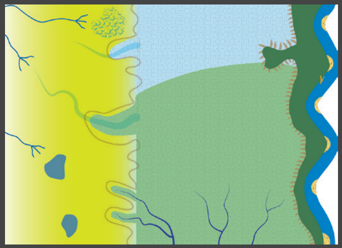


San Francisco Estuary Institute-Aquatic Science Center

Bay-Delta Science Conference
October 29, 2014

AQUATIC SCIENCE CENTER

The Delta Landscapes Project

Management Tools for Landscape-Scale Restoration

Funded by the Ecosystem Restoration Program

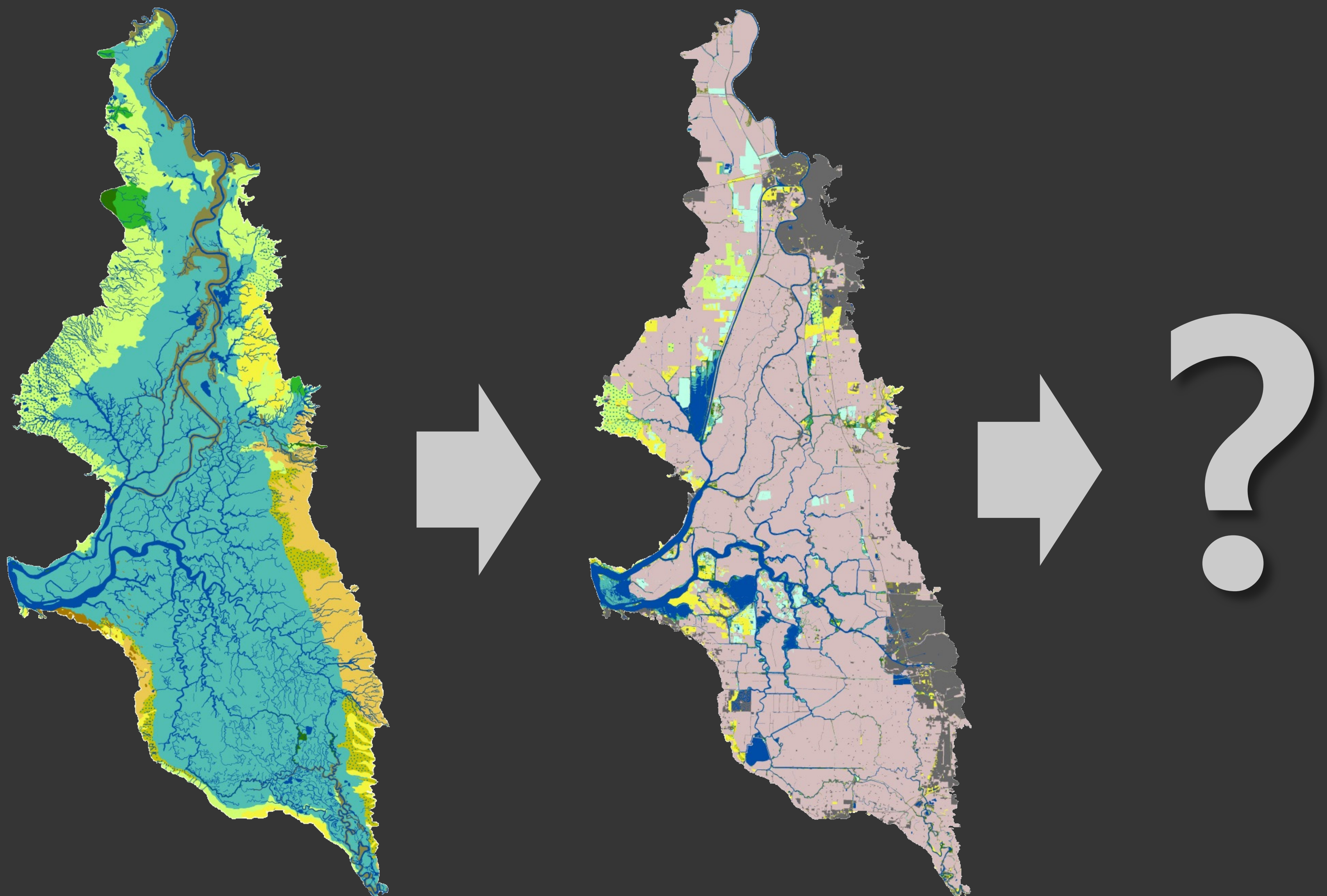
A DELTA TRANSFORMED

ecological functions, spatial metrics, and landscape change

IN THE SACRAMENTO–SAN JOAQUIN DELTA

SAN FRANCISCO ESTUARY INSTITUTE
AQUATIC SCIENCE CENTER
SFEI
A•S•C

How do we create ecologically functional, resilient *landscapes*? (not just nice projects)



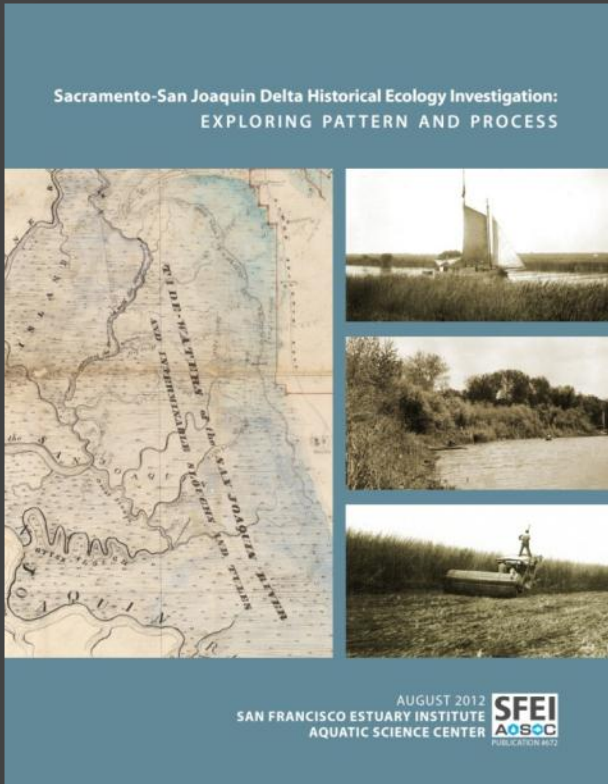
1. **Provide a framework that helps individual projects add up to a larger functional landscape** (pieces of the puzzle)

2. **Provide guidance for what kinds of projects make sense where** (avoid one-size-fits-all)

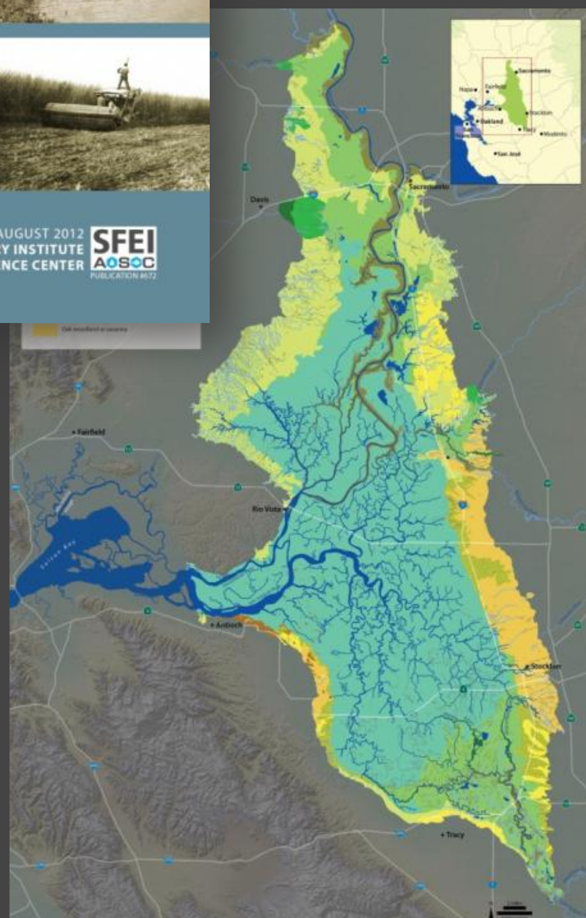
3. **Reduce conflicts and mistakes** (shared understanding of priorities and current science)

4. **Make better use of long-term physical/climatic trajectories** (work with processes, not against them)

5. **Meet landscape-scale species needs** (connectivity, migration for multiple species)



Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process



- Funded by Ecosystem Restoration Program (CDFG, NOAA, US FWS)
- Final Report/GIS Available: www.sfei.org/DeltaHEStudy
- Collaboration with KQED QUEST and Stanford's Bill Lane Center for the American West: science.kqed.org/quest/delta-map/

1. Define target ecological functions
2. Identify associated system attributes (spatial metrics)
3. Quantify landscape change metrics
4. Describe subregional potential (physical drivers, opportunities)
5. Create conceptual Operational Landscape Units (e.g. “archetypes”)
6. Produce restoration guidelines and potential performance metrics

Landscape Interpretation Team (LIT)

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Ted Sommer (DWR)

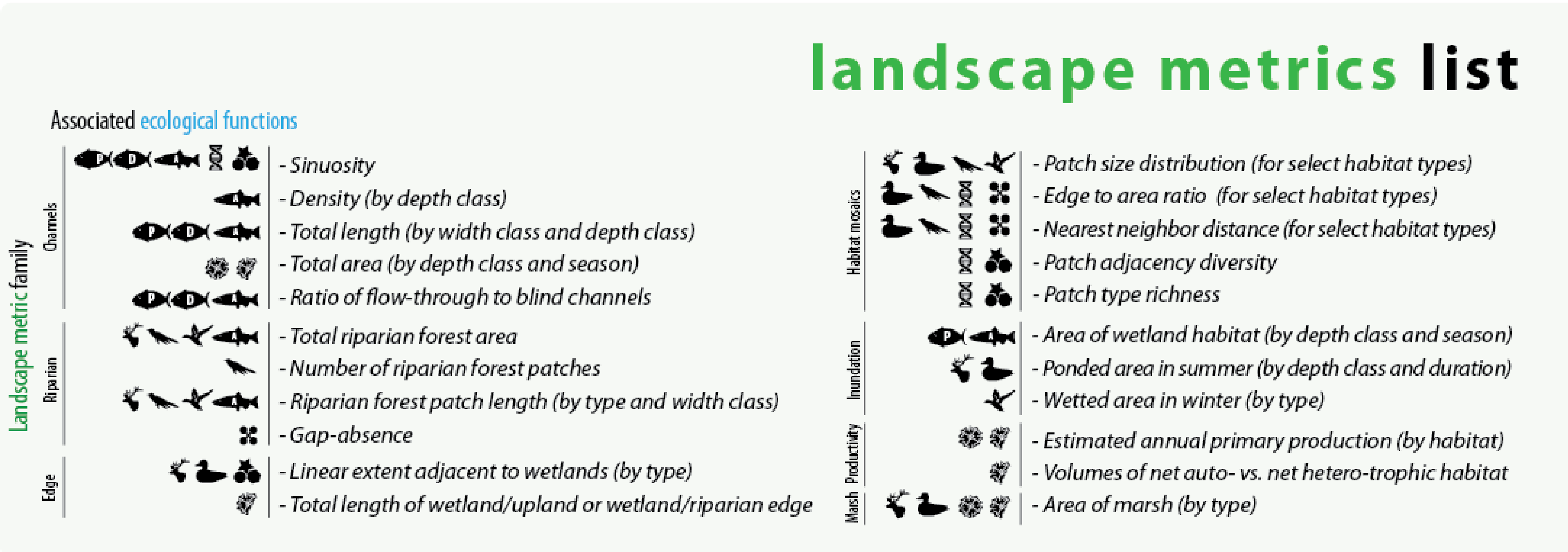
LEVEL	POPULATION						COMMUNITY	
THEME	Life history support					Adaptation potential	Food webs	Biodiversity
FUNCTION	Provides habitat and connectivity for fish	Provides habitat and connectivity for marsh wildlife	Provides habitat and connectivity for waterbirds	Provides habitat and connectivity for riparian wildlife	Provides habitat and connectivity for marsh-terrestrial transition zone wildlife	Maintains adaptation potential within wildlife populations	Maintains food supplies and nutrient cycling to support robust food webs	Maintains biodiversity by supporting diverse natural communities
METRICS	Inundation extent, duration, timing, and frequency	Marsh area by patch size (patch size distribution)	Ponded area in summer by depth and duration	Riparian habitat area by patch size	Length of marsh-terrestrial transition zone by terrestrial habitat type	To be addressed with qualitative conceptual models in Task 4.	Expected to be addressed with a related project.	To be addressed with qualitative conceptual models in Task 4.
	Marsh to open water ratio	Marsh area by nearest neighbor distance	Wetted area by type in winter	Riparian habitat length by width class				
	Adjacency of marsh to open water by length and marsh patch size	Marsh core area ratio						
	Ratio of looped to dendritic channels (by length and adjacent habitat type)	Marsh fragmentation index						

Ecological Functions list (Task 3)

ecological functions list

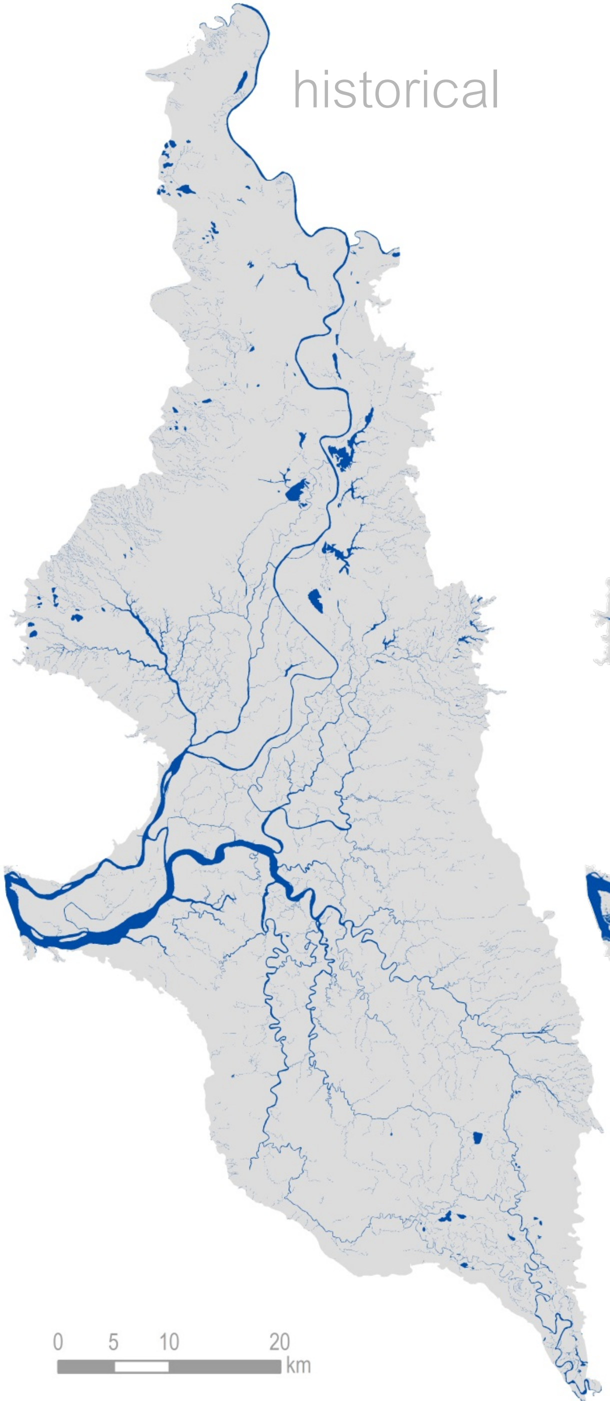
Habitat and connectivity for pelagic fish	Habitat and connectivity for resident mammals	Habitat and connectivity for native plants	Maintain genetic/pheno typic diversity	Nutrient movement and recycling
Habitat and connectivity for demersal fish	Habitat and connectivity for marsh birds	Habitat and connectivity for anadromous fish	Maintain connectivity for fragmented populations	Gross food supply
Habitat and connectivity for littoral fish	Habitat and connectivity for riparian birds	Habitat and connectivity for migratory waterfowl	Maintain diverse native communities	Net food supply

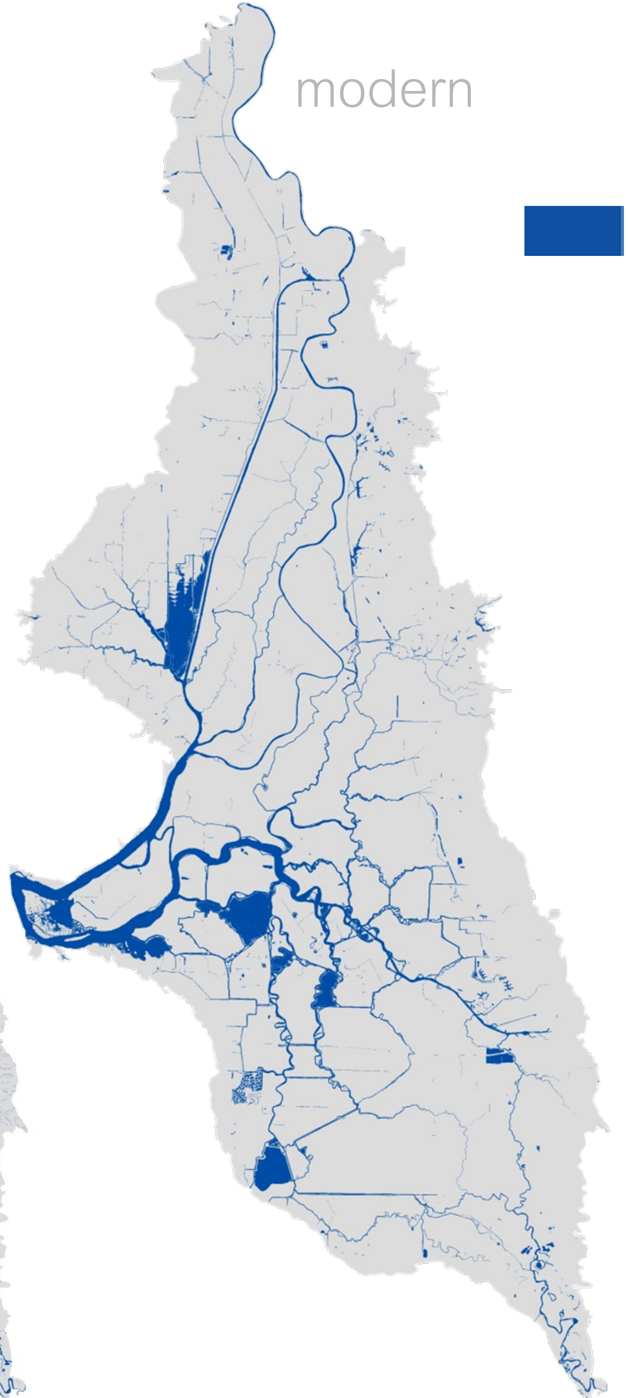
Landscape Metrics list (Task 3)



There has been a 73-fold reversal in the ratio between marsh and open water in the Delta, affecting the character and quality of aquatic habitats.

support for native fish

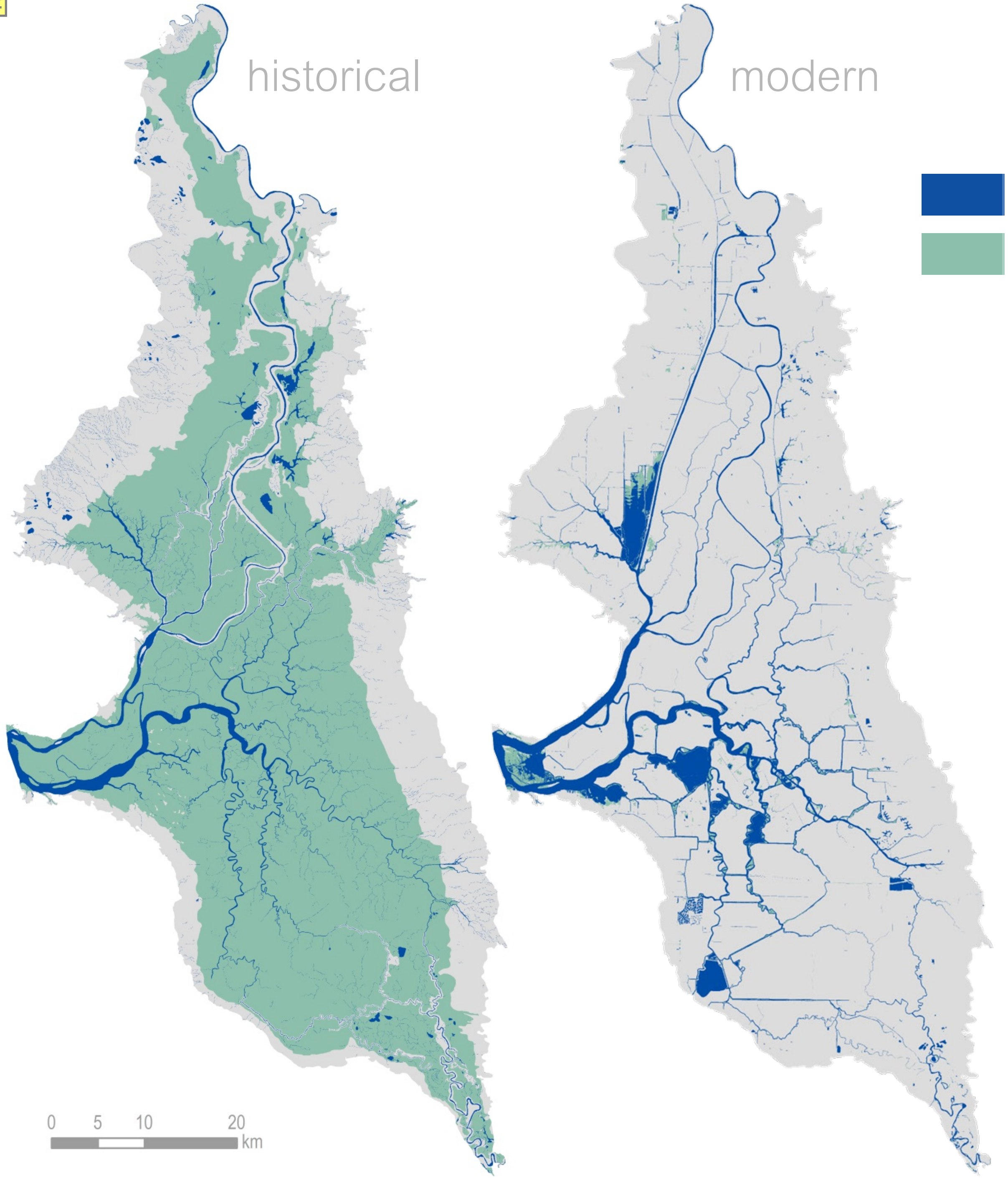




	historical	modern
open water	16,300 ha	26,600 ha

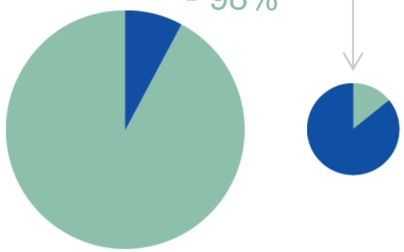
+ 63%

support for native fish



	historical	modern
open water	16,300 ha	26,600 ha
marsh	193,200 ha	4,300 ha

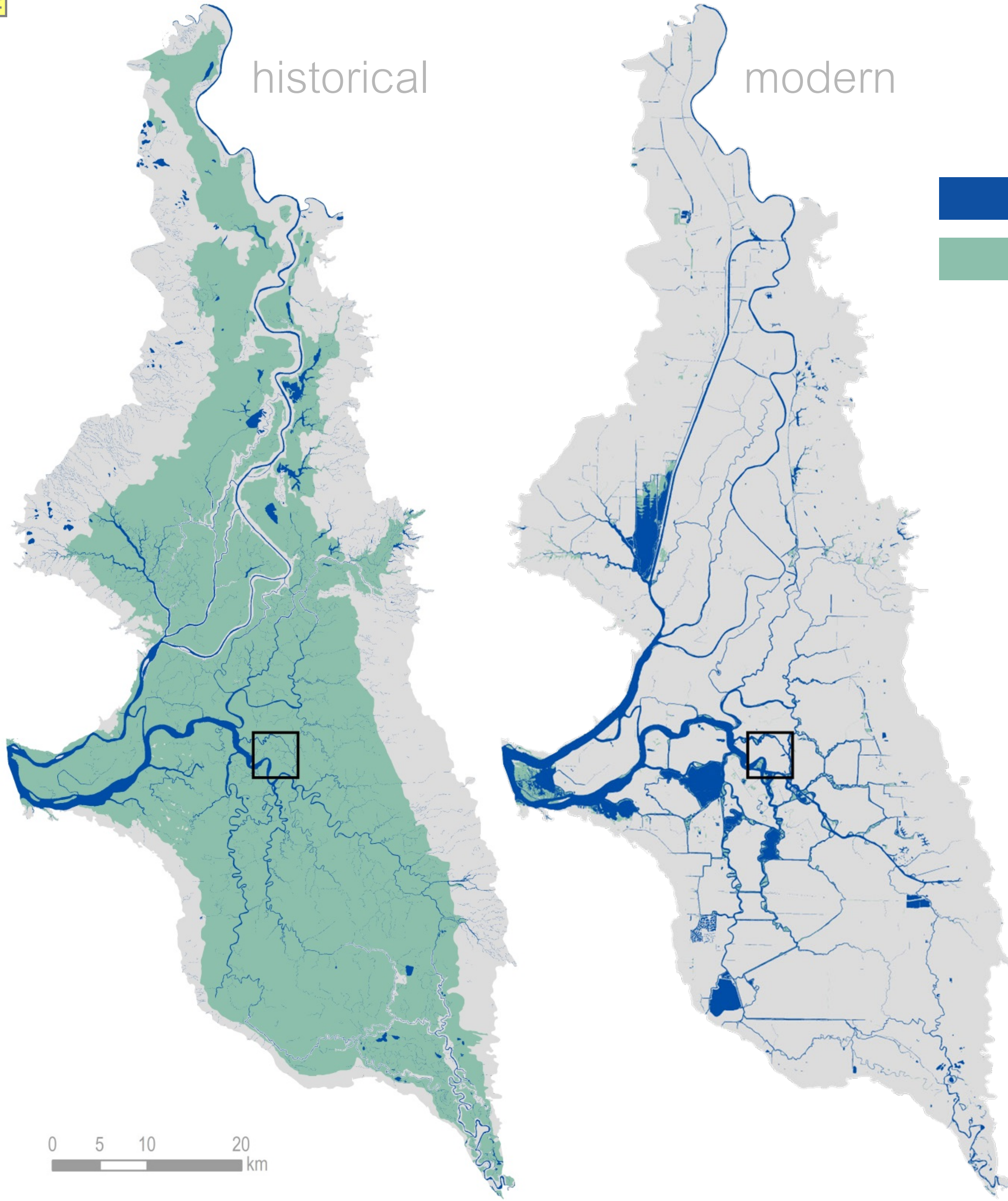
- 98%



100 : 1,182 | 100 : 16

74x decrease in marsh to open water ratio

support for native fish



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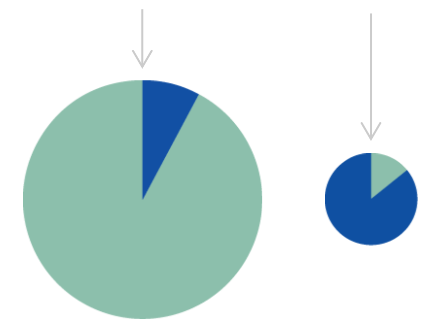

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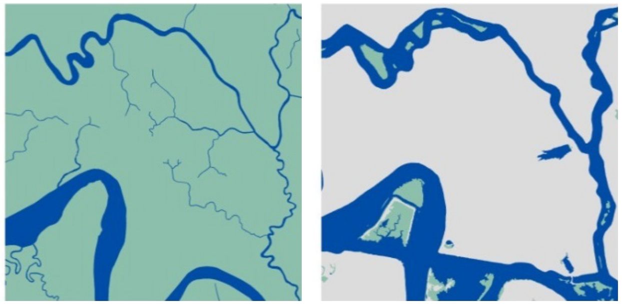
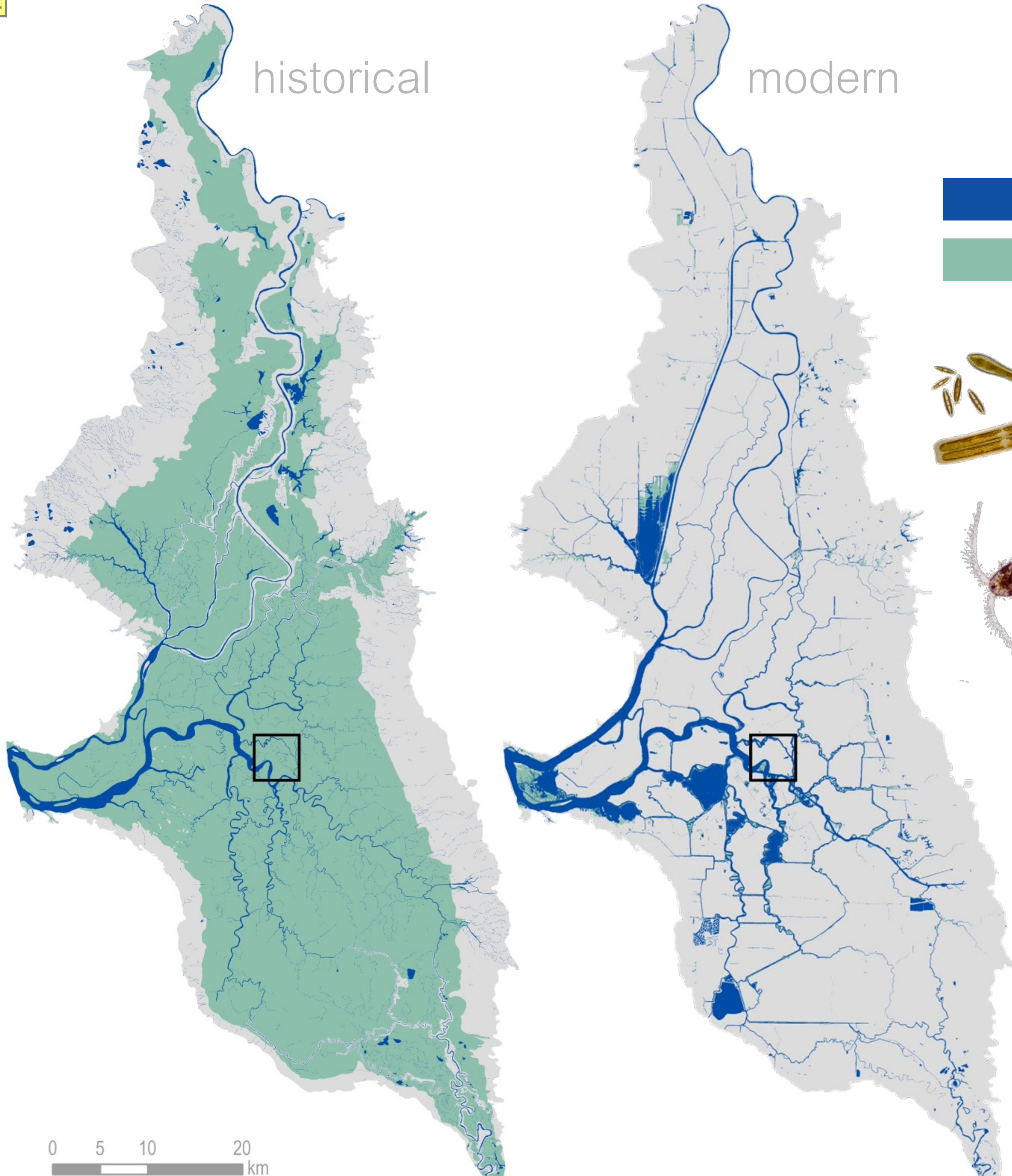
74x decrease in marsh to open water ratio

"channels in marsh" → "marsh in channels"



support for native fish



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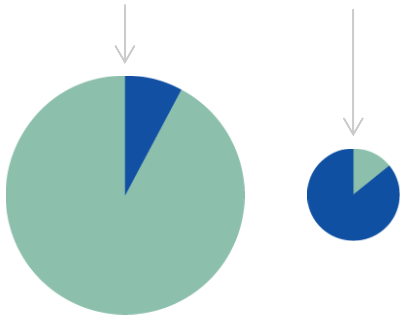

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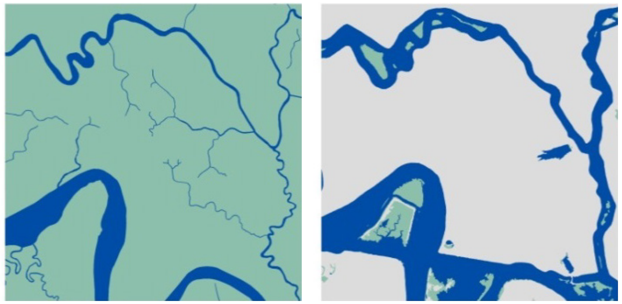
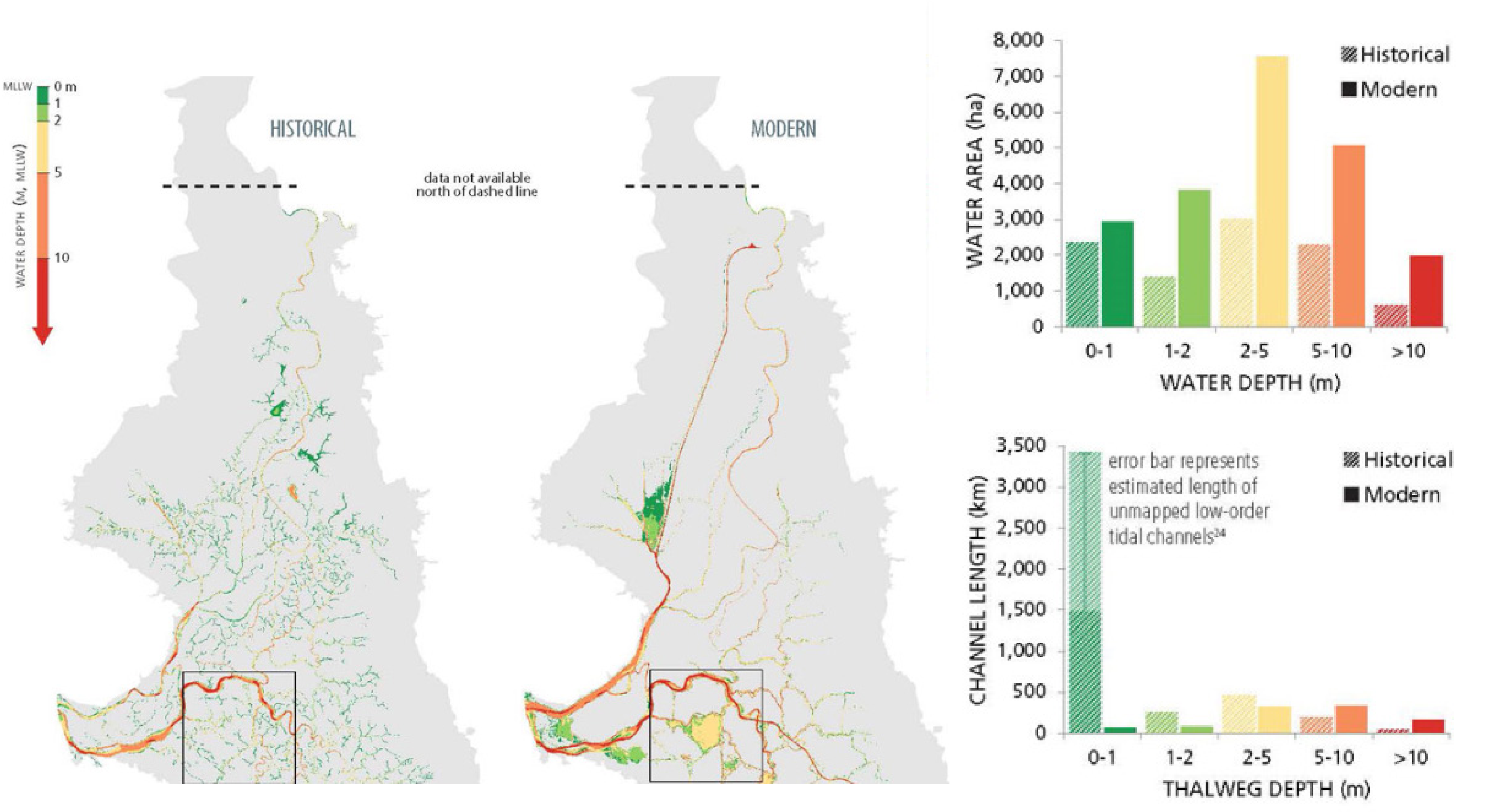
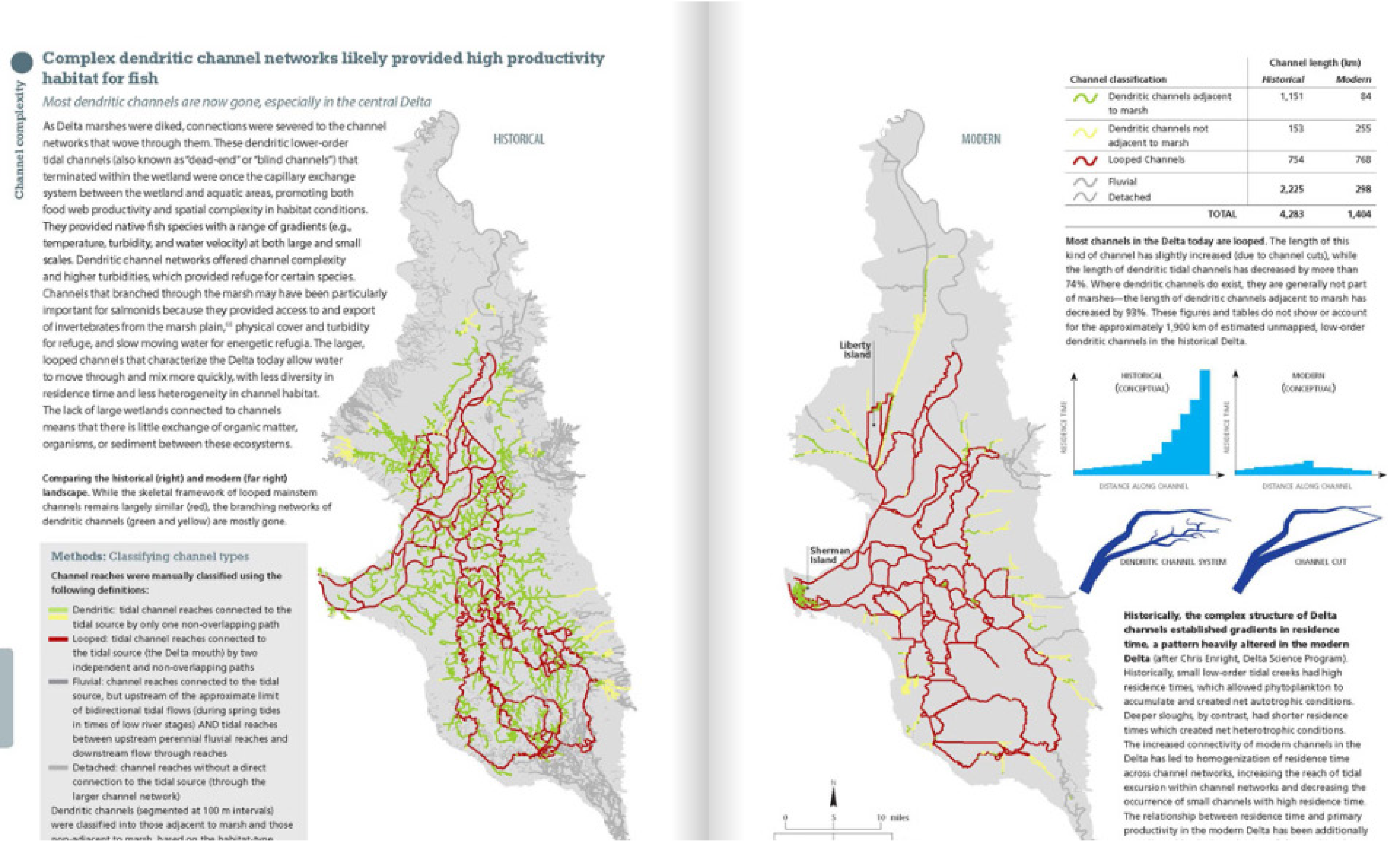


There is twice as much shallow-water habitat (<2m) in the Delta today as there was historically.



Historical DEM co-developed with UCDavis CWS (Fleenor, Whipple, Bell, et al.)

Complex dendritic channel networks likely provided high productivity habitat for fish.



Channel complexity

Complex dendritic channel networks likely provided high productivity habitat for fish

Most dendritic channels are now gone, especially in the central Delta

As Delta marshes were diked, connections were severed to the channel networks that wove through them. These dendritic lower-order tidal channels (also known as "dead-end" or "blind channels") that terminated within the wetland were once the capillary exchange system between the wetland and aquatic areas, promoting both food web productivity and spatial complexity in habitat conditions. They provided native fish species with a range of gradients (e.g., temperature, turbidity, and water velocity) at both large and small scales. Dendritic channel networks offered channel complexity and higher turbidities, which provided refuge for certain species. Channels that branched through the marsh may have been particularly important for salmonids because they provided access to and export of invertebrates from the marsh plain,[55] physical cover and turbidity for refuge, and slow moving water for energetic refugia. The larger, looped channels that characterize the Delta today allow water to move through and mix more quickly, with less diversity in residence time and less heterogeneity in channel habitat. The lack of large wetlands connected to channels means that there is little exchange of organic matter, organisms, or sediment between these ecosystems.

Comparing the historical (right) and modern (far right) landscape. While the skeletal framework of looped mainstem channels remains largely similar (red), the branching networks of dendritic channels (green and yellow) are mostly gone.

Methods: Classifying channel types

Channel reaches were manually classified using the following definitions:

- Dendritic: tidal channel reaches connected to the tidal source by only one non-overlapping path
- Looped: tidal channel reaches connected to the tidal source (the Delta mouth) by two independent and non-overlapping paths
- Fluvial: channel reaches connected to the tidal source, but upstream of the approximate limit of bidirectional tidal flows (during spring tides in times of low river stages) AND tidal reaches between upstream perennial fluvial reaches and downstream flow through reaches
- Detached: channel reaches without a direct connection to the tidal source (through the larger channel network)

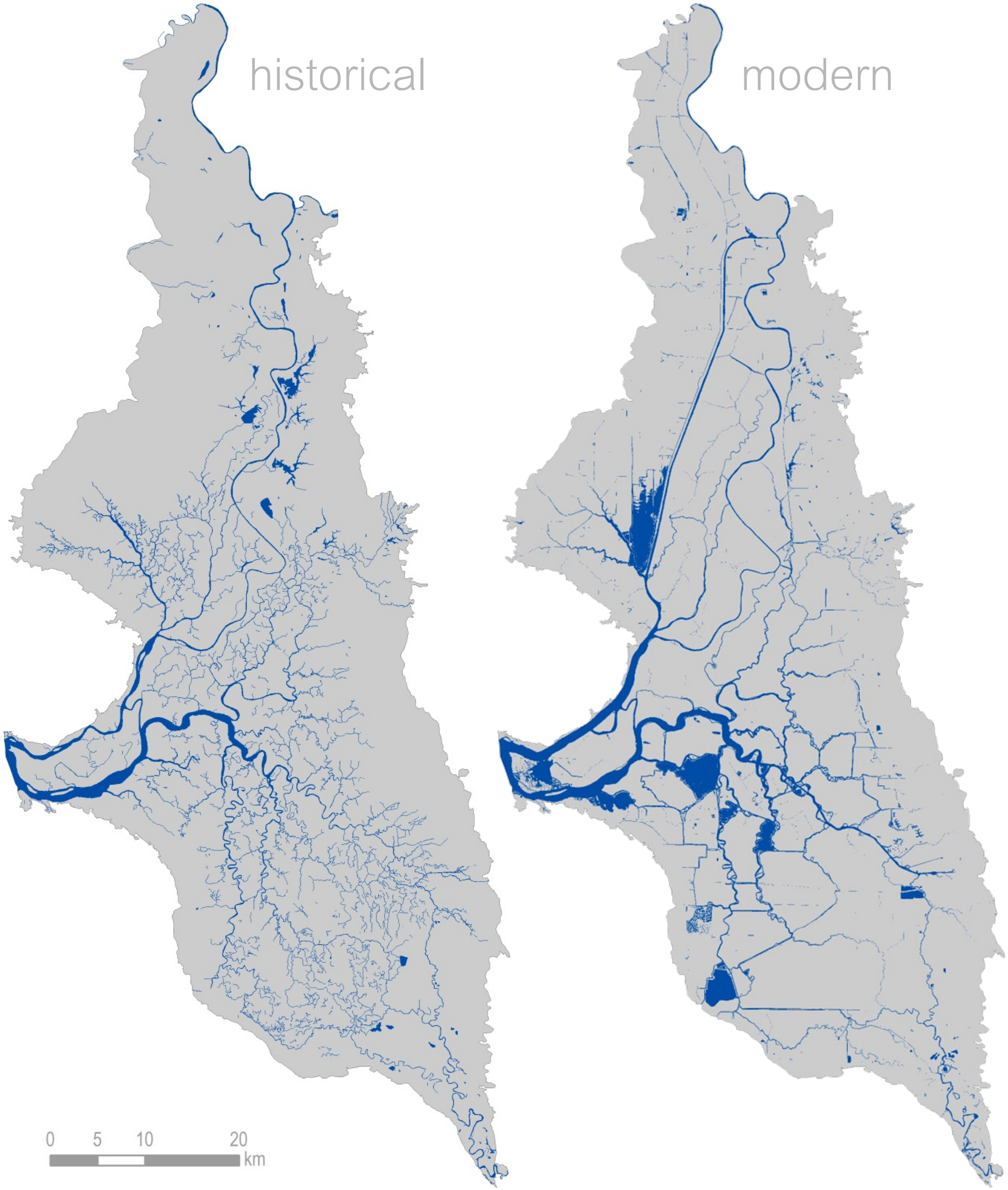
Dendritic channels (segmented at 100 m intervals) were classified into those adjacent to marsh and those non-adjacent to marsh, based on the habitat-type

Channel classification	Channel length (km) Historical	Modern
Dendritic channels adjacent to marsh	1,151	84
Dendritic channels not adjacent to marsh	153	255
Looped Channels	754	768
Fluvial / Detached	2,225	298
TOTAL	4,283	1,404

Most channels in the Delta today are looped. The length of this kind of channel has slightly increased (due to channel cuts), while the length of dendritic tidal channels has decreased by more than 74%. Where dendritic channels do exist, they are generally not part of marshes—the length of dendritic channels adjacent to marsh has decreased by 93%. These figures and tables do not show or account for the approximately 1,900 km of estimated unmapped, low-order dendritic channels in the historical Delta.

Historically, the complex structure of Delta channels established gradients in residence time, a pattern heavily altered in the modern Delta (after Chris Enright, Delta Science Program). Historically, small low-order tidal creeks had high residence times, which allowed phytoplankton to accumulate and created net autotrophic conditions. Deeper sloughs, by contrast, had shorter residence times which created net heterotrophic conditions. The increased connectivity of modern channels in the Delta has led to homogenization of residence time across channel networks, increasing the reach of tidal excursion within channel networks and decreasing the occurrence of small channels with high residence time. The relationship between residence time and primary productivity in the modern Delta has been additionally

Most of the temporarily flooded habitat available to fish in the Delta has been lost.



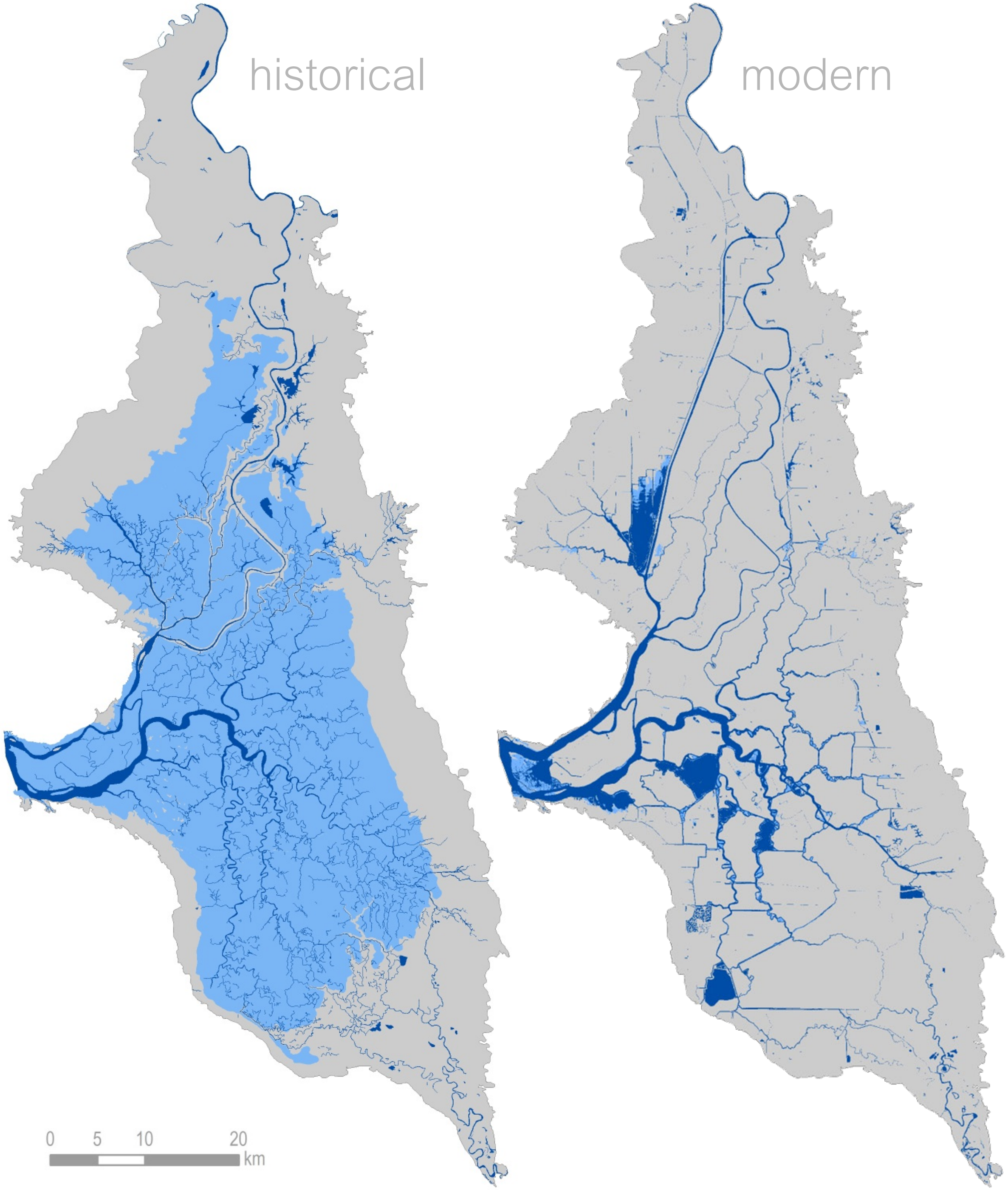
support for native fish

PONDS, LAKES, CHANNELS, FLOODED ISLANDS

Mostly perennial open water features

- variable depth

support for native fish



PONDS, LAKES, CHANNELS, FLOODED ISLANDS

Mostly perennial open water features

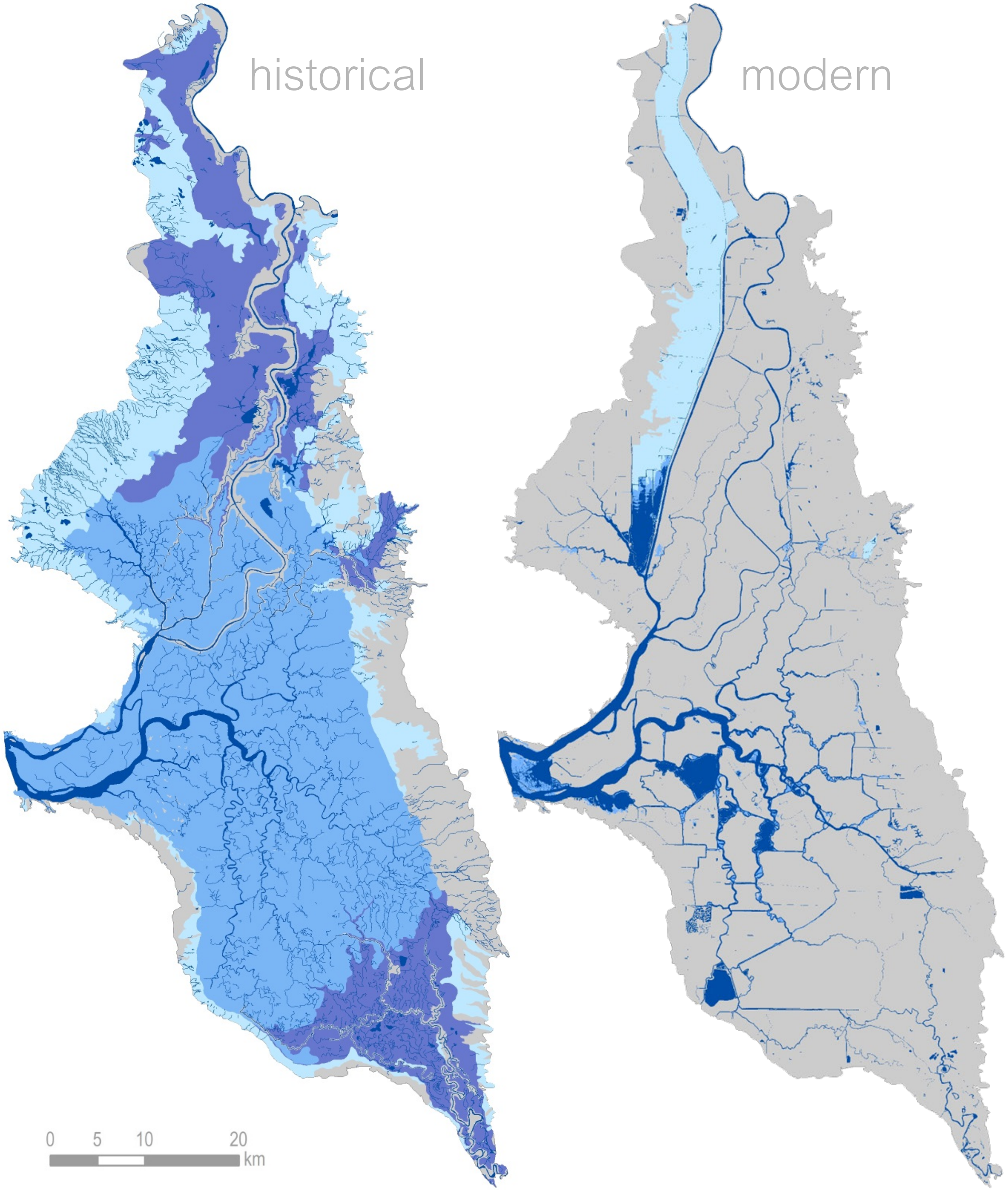
- variable depth

TIDAL INUNDATION

Diurnal overflow of tidal sloughs into marshes

- high recurrence (2x daily to monthly)
- low duration (< 6 hrs per event)
- low depth ("wetted" up to .5 m)

support for native fish



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Diurnal overflow of tidal sloughs into marshes

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SEASONAL LONG DURATION FLOODING

Prolonged inundation from river overflow into flood basins

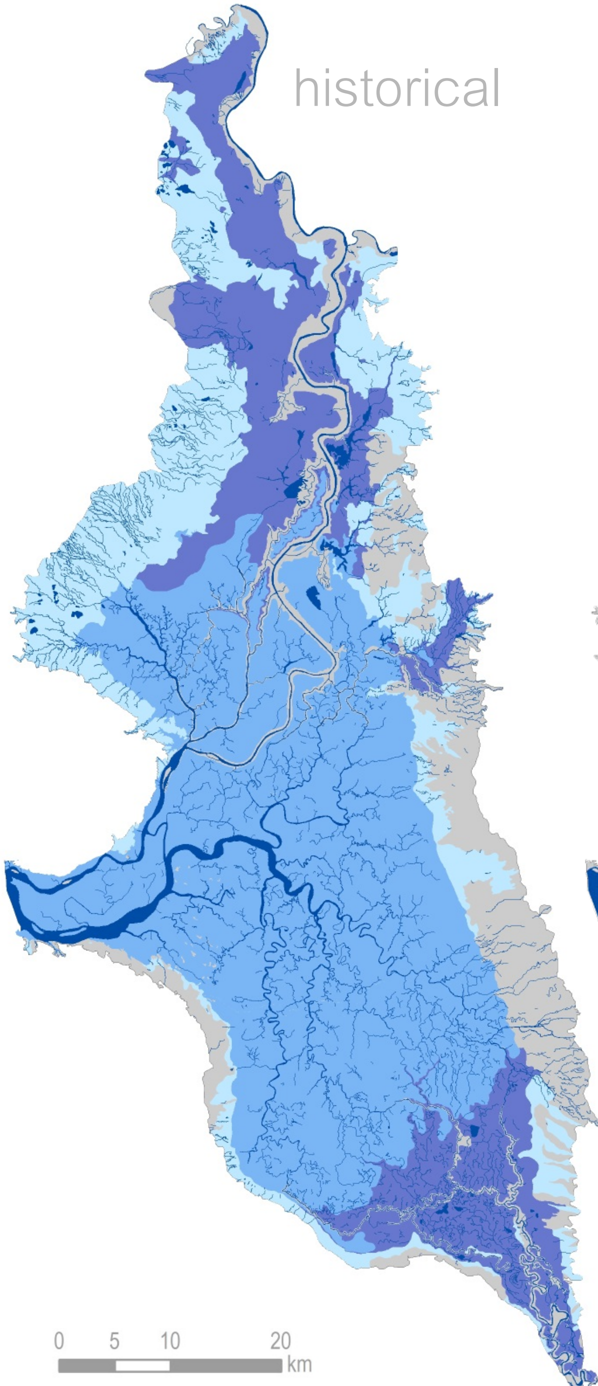
- low recurrence (~1 event per year)
- high duration (persists up to 6 month)
- generally deeper than 'seasonal short-term flooding'

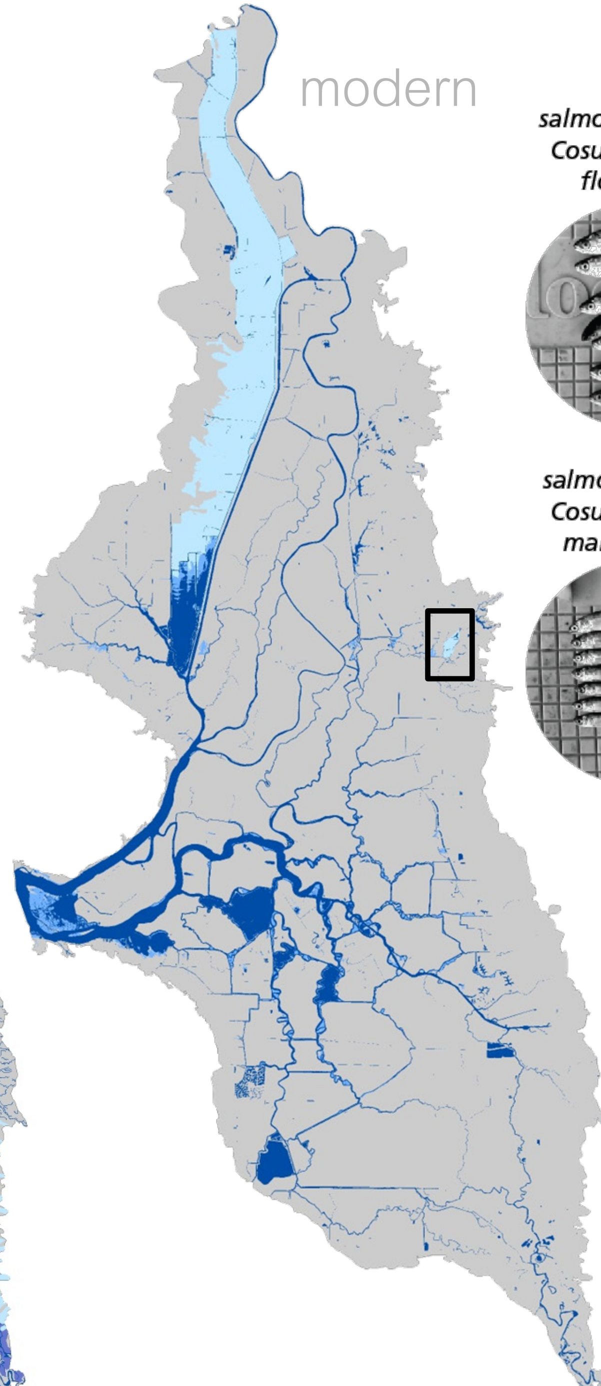
SEASONAL SHORT-TERM FLOODING

Short-term fluvial inundation

- can be multiple events per year
- low duration (days-weeks per event)
- generally shallower than 'seasonal long duration flooding'

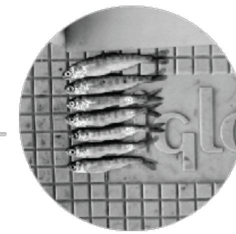
support for native fish

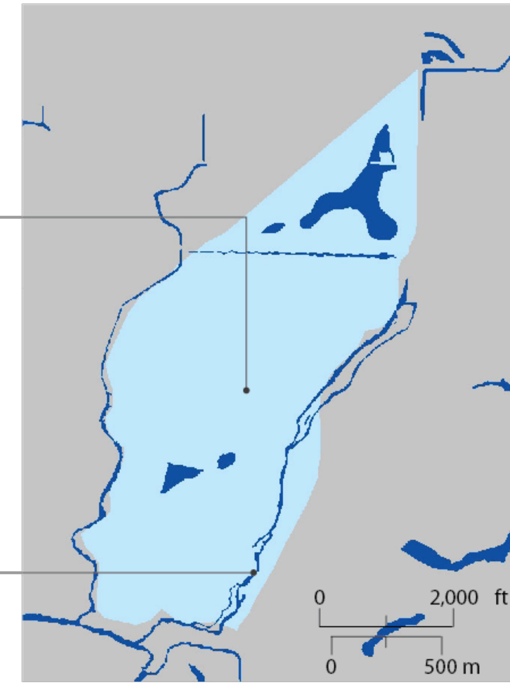




salmon reared on Cosumnes River floodplain

salmon reared in Cosumnes River main channel





photos by Jeff Opperman, 2006

Juvenile salmon reared in ephemeral floodplain habitats of the Cosumnes River have been found to grow significantly larger than juvenile salmon reared only within the Cosumnes River (Jeffres et al. 2008).

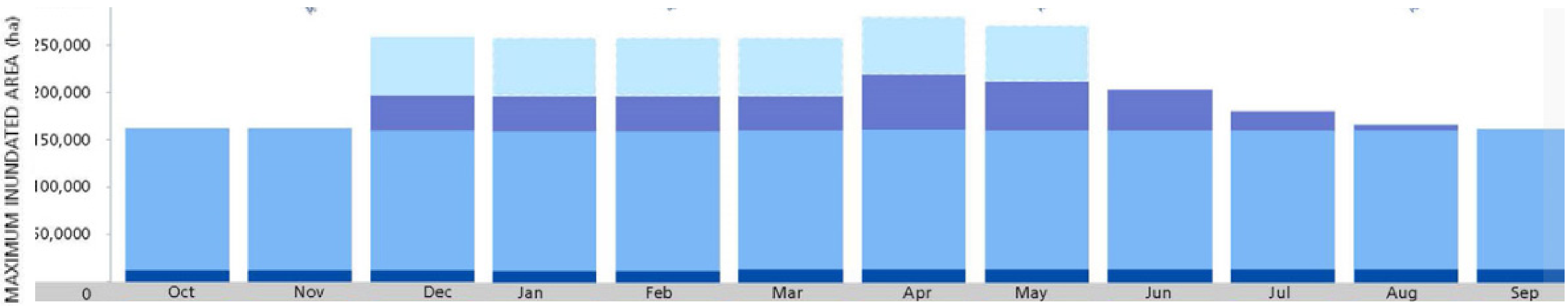
PONDS, LAKES, CHANNELS, FLOODED ISLANDS

TIDAL INUNDATION

SEASONAL LONG DURATION FLOODING

SEASONAL SHORT-TERM FLOODING

Native fish are adapted to a complex, variable landscape with extensive aquatic resources throughout the year.



SEASONAL SHORT-TERM FLOODING
Short-term fluvial inundation
- intermediate recurrence (~10 events per year)
- low duration (days to weeks per event)
- generally shallower than seasonal long-duration flooding

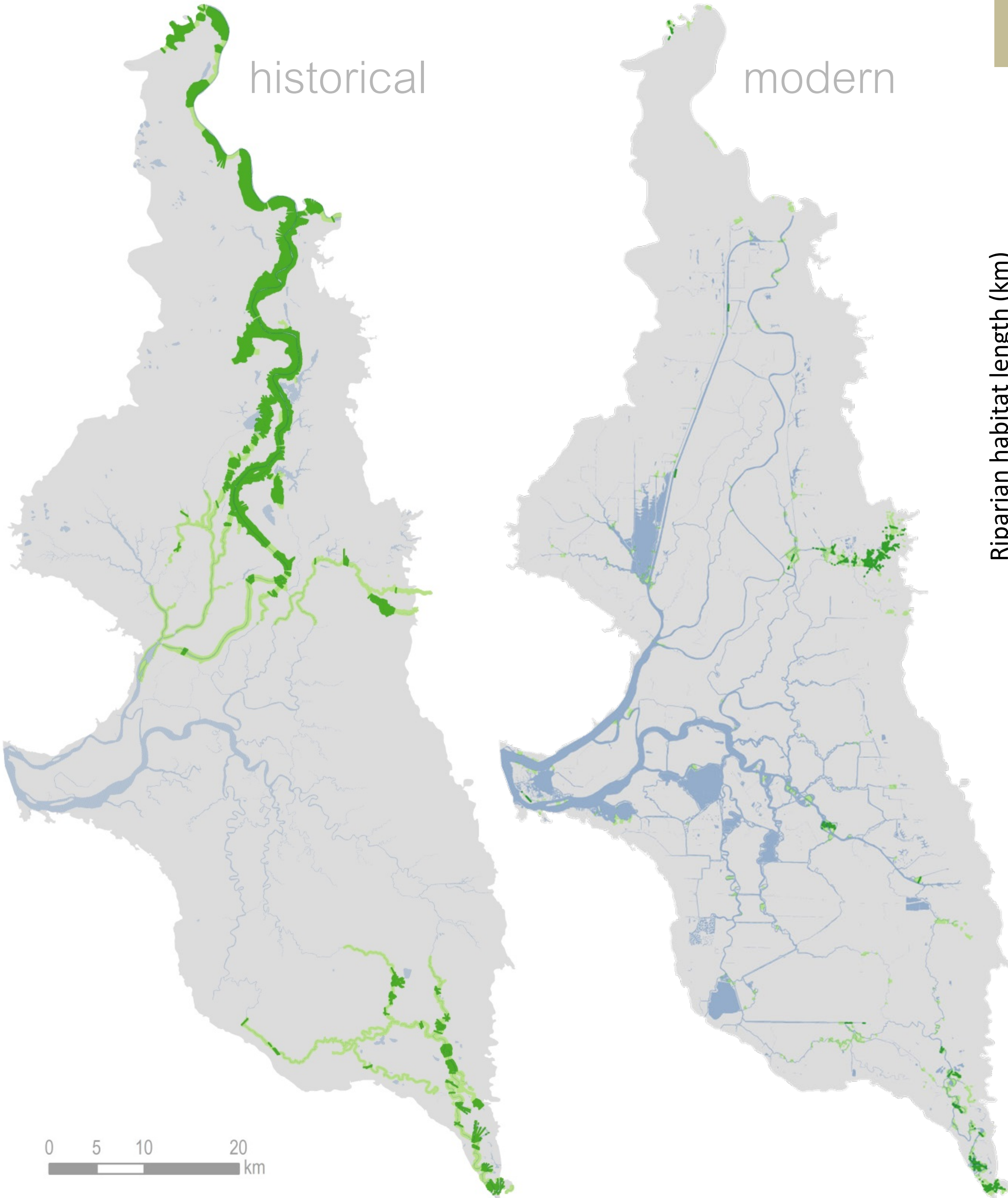
SEASONAL LONG-DURATION FLOODING
Prolonged inundation from river overflow into flood basins
- low recurrence (~1 event per year)
- high duration (persists up to 6 month)
- generally deeper than seasonal short-term flooding

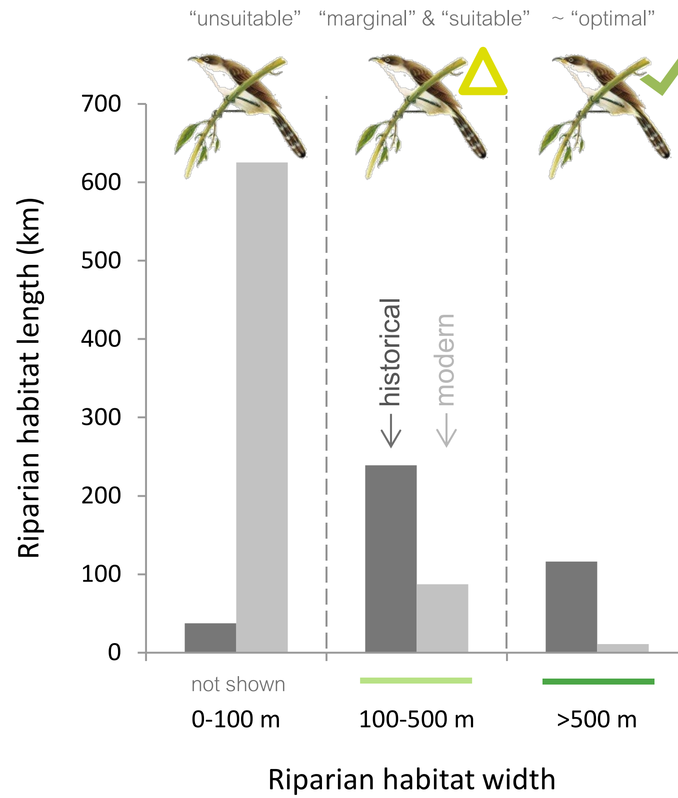
TIDAL INUNDATION
Diurnal overflow of tidal sloughs into marshes
- high recurrence (twice daily)
- low duration (<6 hrs per event)
- low depth ("wetted" up to 0.5 m)

PONDS, LAKES, CHANNELS, & FLOODED ISLANDS
Perennial open water features (with the exception of historical intermittent ponds and streams)
- recurrence not applicable (generally perennial features)
- high duration (generally perennial features)
- variable depth

There are a number of additional elements to a complete Delta ecosystem.

support for riparian wildlife





Majority of riparian habitat today is of "unsuitable" width to support yellow billed cuckoos (Laymon & Halterman 1989). Length of forest of "optimal" width has decreased by 91%

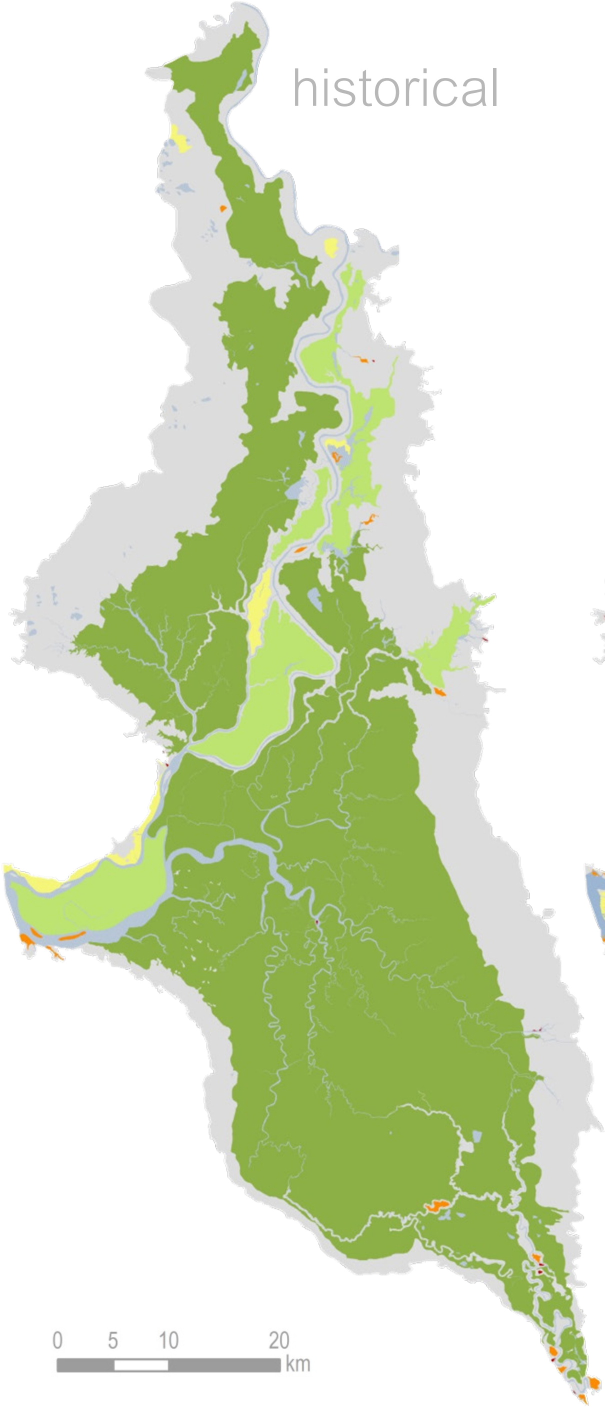
riparian forest width (transects)

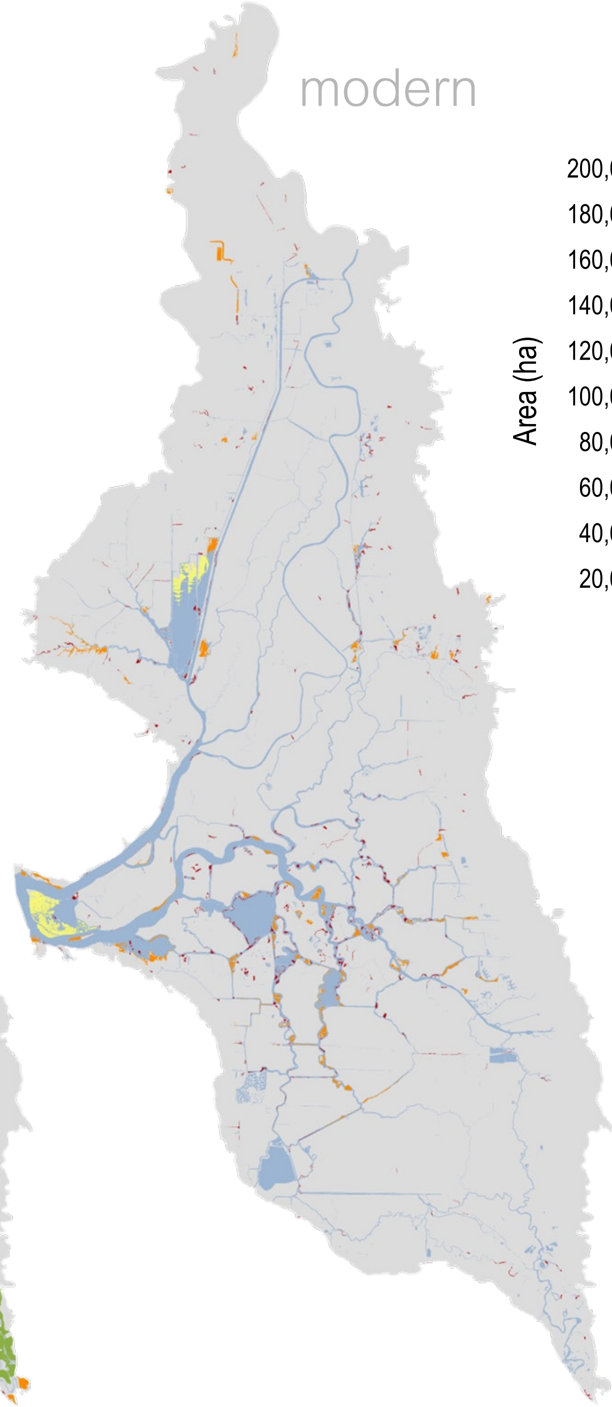
> 100 m wide

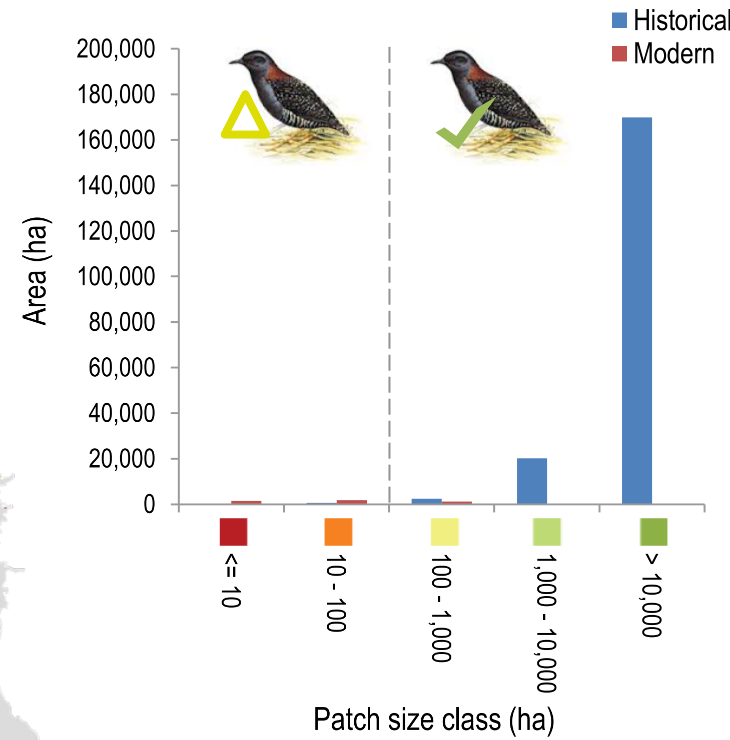
> 500 m wide

riparian forest < 100 m wide not shown

support for marsh wildlife







Marsh in patches large enough to fully support rails
(based on Liu et al. 2012, Spautz & Nur 2002):

Historical: 192,000 ha

Modern: 1,000 ha

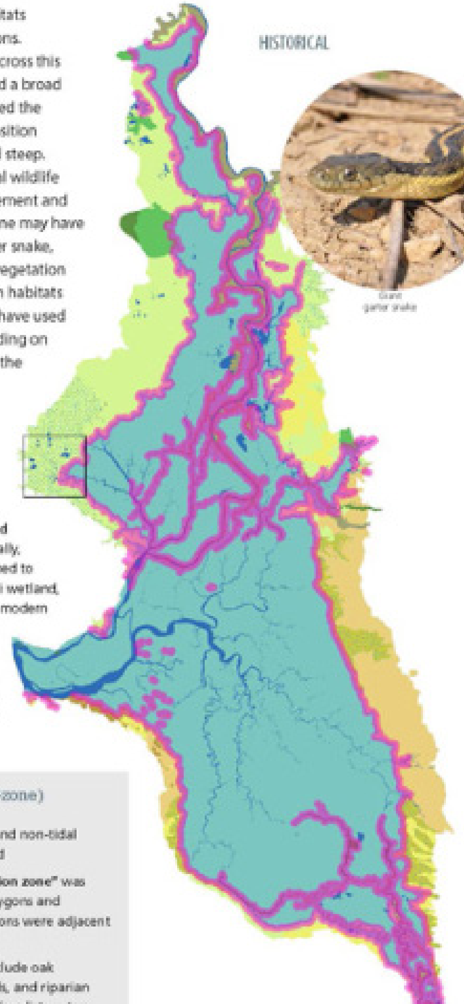
marsh patch size class (hectares)

- <= 10 ha
- 10 - 100
- 100 – 1,000
- 1,000 – 10,000
- > 10,000

The historical marsh-terrestrial transition zone was continuous and gradual

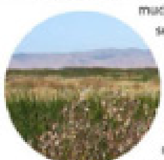
Today's marsh-terrestrial transition zones are fragmented

The transition zone between marsh and terrestrial habitats supported many wildlife species and ecological functions. Animals, organic matter, sediment, and water moved across this wide, complex, and heterogeneous area that supported a broad moisture gradient. Continuous transition zones bordered the Delta periphery and major riparian corridors. Most transition zones were wide and gradual, yet some were short and steep. This continuity and variability allowed diverse terrestrial wildlife to access wetland habitat, and was critical for the movement and dispersal of transition-zone obligates. The transition zone may have been particularly important to the endemic giant garter snake, which used aquatic habitats dominated by emergent vegetation from early spring to mid-fall, and drier, higher-elevation habitats during winter dormancy. Foraging birds and bats may have used seasonal wetlands at different times of the year depending on inundation and food production. In the modern Delta, the terrestrial edge is fragmented and narrow, providing less foraging access, cover, and movement corridors.



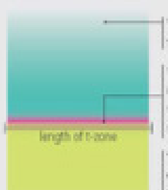
Giant garter snake

Marsh-terrestrial transition zones in the historical (right) and modern (far right) Delta, represented by pink lines. Historically, much of the marsh gradually transitioned to seasonal wetland, vernal pool, alkali wetland, or riparian forest. In contrast, the modern transition zone is discontinuous and rapidly shifts to mostly grassland. Modern grasslands are heavily altered habitats, and modern transition zones are often steep levees.



Marsh-terrestrial transition zone

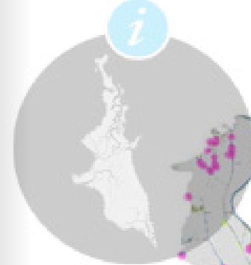
Methods: Marsh-terrestrial transition zone (T-zone)

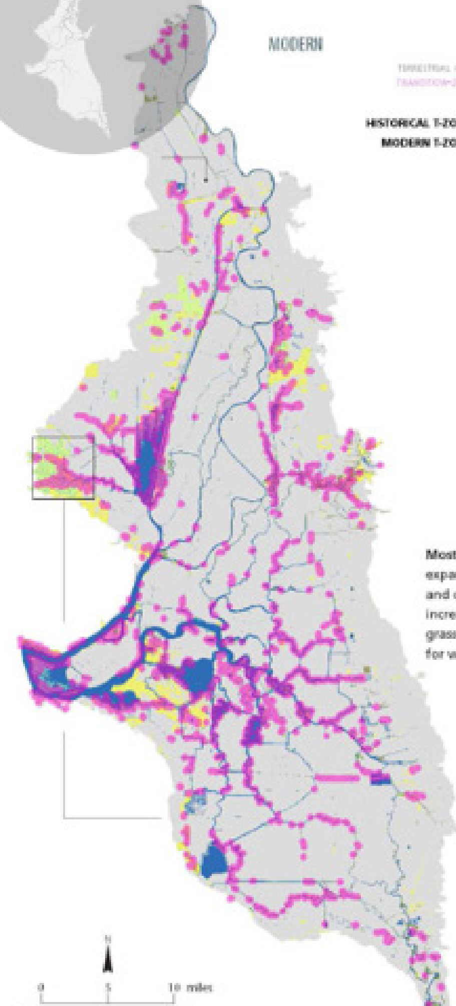


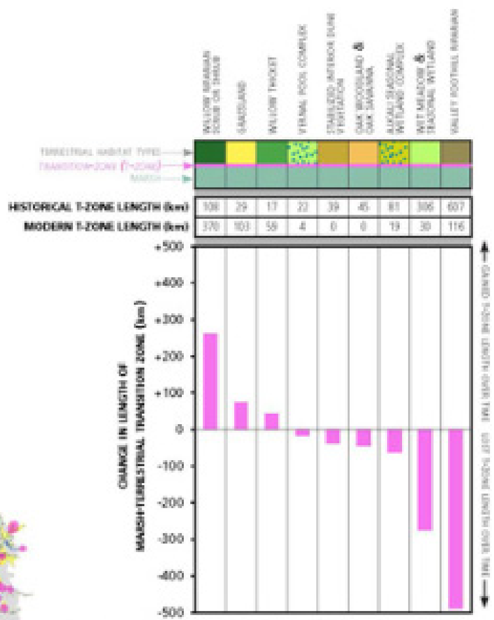
"marsh" includes both tidal and non-tidal freshwater emergent wetland

the **"marsh-terrestrial transition zone"** was mapped wherever marsh polygons and terrestrial habitat type polygons were adjacent to one another

"terrestrial habitat types" include oak woodlands, seasonal wetlands, and riparian habitat types, among others (see list on top-

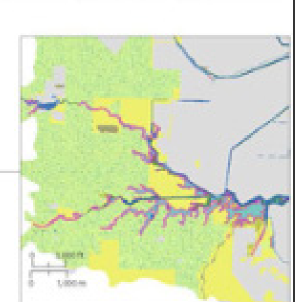






	WILLOW RIPARIAN SCRUB OR SHRUB	GRASSLAND	WILLOW THICKET	VERNAL POOL COMPLEX	STABILIZED INTERIOR DUNE VEGETATION	OAK WOODLAND & OAK SAVANNA	ALKALI SEASONAL WETLAND COMPLEX	WET MEADOW & SEASONAL WETLAND	VALLEY FOOTHILL RIPARIAN
HISTORICAL T-ZONE LENGTH (km)	108	29	17	22	39	45	81	306	607
MODERN T-ZONE LENGTH (km)	370	103	58	4	0	0	19	30	116

Most transition zone types are greatly reduced. A few types have expanded in quantity, but these tend to be relatively fragmented and disturbed. For example, although the extent of grassland has increased, modern grasslands are dominated by non-native annual grasses, which has changed the timing and availability of resources for wildlife.



The longest continuous unleveed marsh-terrestrial transition zone left in the Delta is along Lindsey Slough (above). This

THANKS

CDFW: Daniel Burmester, Carl Wilcox, Dave Zezulak

DSP: Peter Goodwin, Chris Enright, Anke Mueller-Solger, Cliff Dahm

Cache Slough Team: Bruce Orr, Noah Hume (Stillwater); Stuart Siegel (ESA)
Lower Yolo Team: Curt Schmutte, Val Connor
TNC MWT: Leo Winternitz, Rodd Kelsey

The LIT
CDFW, ERP, DWR, SFCWA , TNC for funding

http://sfei.li/deltametrics