SALTON SEA WATER IMPORTATION
SUBMITTAL REVIEW

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Technical Memorandum (TM) #8.1

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This Technical Memorandum (TM) was prepared as part of the Salton Sea Water Importation Proposal Review to provide information to support and reflect the Independent Review Panel's evaluation of submitted ideas to restore the Salton Sea by water importation and provide the Salton Sea Management Program (SSMP) with approaches that are feasible. Parts of this TM may be used in the Panel's Screening Report, Fatal Flaw Report, Feasibility Report, and/or Summary Report (Reports). In the event that any discrepancies are found between the Reports and this TM, the Reports shall take precedence.

1.0 Species

1.1 Fish

About 51 species of fish have been recorded in the Salton Sea since its formation (Riedel and Costa-Pierce, 2002; USFWS, 2008). The Desert Pupfish is the only endemic species to the Salton Sink Basin (CNRA, 2021). Some fish species lived in the historic Lake Cahuilla and entered the basin via the Colorado River. Of these, Rainbow Trout, Razorback Sucker, and Striped Mullet were recorded to still be present in 1929 (Riedel and Costa-Pierce, 2002). Thirty-three fish species were added to the Salton Sea for fishing or ecology purposes, such as insect control, between 1929 and 1956 (Riedel and Costa-Pierce, 2002). By 2000, fish populations were decreasing: Desert Pupfish and Longjaw Mudsucker were not recorded and Striped Mullet and Threadfin Shad were rare, but Sargo, Bairdiella, Orangemouth Corvina and California Mozambique Tilapia were common (Riedel and Costa-Pierce, 2002). By 2008, Carp, Red Shiner, Threadfin Shad, Channel Catfish, White Catfish, Largemouth Bass, Mosquitofish, and Sailfin Molly were only found in surrounding rivers, canals, and marshes, but not in the Salton Sea (USFWS, 2008). The California Mozambique Tilapia was the only fish found in the Salton Sea in 2008 (USFWS, 2008) and their current status within the Salton Sea is unclear (p7, Sheikh and Stern, 2021). A complete list of fish historically found in the Salton Sea is located in Microsoft Teams in the Support Channel in the Ecology folder.

1.1.1 NOTABLE SPECIES

Desert Pupfish (*Cyprinodon macularius*) – a State and Federally listed endangered species (CNDDB, 2021a). It is an endemic species to the Salton Sea region (CNRA, 2021). They were historically found in springs, slow-moving streams, and sloughs in the lower Colorado River in the Salton Sink Basin (Keeney, no date; Echelle and Echelle, 2021). Desert Pupfish consume insect larvae, detritus, vegetation and snails and are considered important in mosquito control (Keeney, no date). Their population began declining in the Salton Sea in the 1970s and ceased to exist in the Salton Sea proper in 2000 (Echelle and Echelle, 2021). Water quality decreases, salinity increases, habitat reduction, and non-native species reduced populations (CNRA, 2021). They still occur in some areas of the Salton Sink Basin, Colorado River Delta, and the Laguna Salada Basin (Keeney, no date). Five isolated populations exist near the Salton Sea region and another 5 are located near the Colorado River delta (Echelle and Echelle, 2021). Pupfish utilize the agricultural drainage creeks around the Salton Sea and only enter the Salton Sea to reach other populations for breeding (Nye et al., 2021). A map of some population locations is found in Attachment A.

California Mozambique Tilapia (*Oreochromis mossambicus × O. urolepis hornorum*) – a non-native hybrid species introduced to the Salton Sea sometime between the late 1960s and early 1970s (Riedel, 2016; UC Davis, 2021). They became the largest and most common fish species in the Salton Sea (Riedel, 2016) and were the last surviving species in 2008 (USFWS, 2008). A 2017 sample concluded that the tilapia's occurrence had decreased: 327 fish were recorded over three size classes, but no fry were found (CDFW and USFWS, 2017). The tilapia's occurrence in 2020 was unclear (p7, Sheikh and Stern, 2021). Tilapia are a food source for many fish-eating birds, including pelicans (Riedel and Costa-Pierce, 2002).

Razorback Sucker (*Xyrauchen texanus*) – a State and Federally listed endangered species (CNDDB, 2021a). Historically, the Colorado River periodically flooded the valley that currently contains the Salton Sea to form Lake Cahuilla during the wetter climate periods. The razorback sucker was an original Lake Cahuilla inhabitant brought in via the Colorado River that has not been recorded in the Salton Sea since 1929 (Riedel and Costa-Pierce, 2002). While they were once located throughout the Colorado River, habitat degradation has limited their range to smaller areas in Wyoming, Lake Mojave, Lake Mead, the Grand Canyon, the Green River, and the Yampa River (Langstaff, 2004).

1.2 BIRDS

The Salton Sea is an important stop on the avian migration pathway between the tropics and the Arctic known as the Pacific Flyway (Nye et al., 2021). Over 400 species of bird have been recorded at the Salton Sea and 46 have some level of State or Federal protection (Fish and Wildlife Service, no date; State of California, 2021). Many species utilize the Salton Sea as breeding or wintering grounds while others inhabit the region year-round (Fish and Wildlife Service, no date). Birds utilize the open water, marshes, shrubland, riparian vegetation, and beaches and mudflats that are directly connected to the Salton Sea, but also utilize the farmland and towns that surround the Salton Sea (Fish and Wildlife Service, no date). Sightings of fish-eating birds have decreased but insect-eating shorebirds and waterfowl populations are still supported at the Salton Sea (Jones, Orr, and Cooper, 2019). A complete list of birds historically and currently found in and around the Salton Sea is located in Microsoft Teams in the Support Channel in the Ecology folder.

Some areas of the Salton Sea are protected for conserving bird habitat. The Sonny Bono Salton Sea National Wildlife Refuge is a designated Important Bird and Biodiversity Area (IBA). IBAs are internationally recognized conservation areas that support globally threatened, range-restricted or biome-restricted species and serve as a congregation site to over 1% of a species' population (BirdLife International, 2021). A map of the Sonny Bono Salton Sea National Wildlife Refuge is in Attachment B.

1.2.1 Species of Concern

American White Pelican (*Pelecanus erythrorhynchos*) – 33% of the North American population has been recorded wintering at the Salton Sea. It is a State Species of Special Concern (Riesz, no date).

Black Skimmer (*Rynchops niger*) – Salton Sea is the only inland breeding location in Western US for this species. It is a State Species of Special Concern (Riesz, no date).

Black Tern (*Chlidonias niger*) – Salton Sea is an important migratory stopover location for this species. It is a State Species of Special Concern (Riesz, no date).

Double-crested Cormorant (*Phalacrocorax auritus*) – Salton Sea has the largest inland breeding population for this species. It is on the State Watch List (Riesz, no date).

Eared Grebe (*Podiceps nigricollis*) - Although not protected, 90% of California's population winters at the Salton Sea. The population has been declining with lack of fish and pile worms (Audubon, no date b; Riesz, no date; Kuperman et al., 2000).

Gull-billed Tern (*Gelochelidon nilotica*) – Salton Sea is one of two breeding locations for this species. It is a State Species of Special Concern (Riesz, no date).

Ruddy Duck (*Oxyura jamaicensis*) – Although not protected, the Salton Sea is the breeding location for the largest population of Ruddy Duck (Riesz, no date).

Snowy Plover (*Charadrius nivosus*) – The Salton Sea provides the largest inland wintering population for this species. It is a State Species of Special Concern (Riesz, no date).

Western Burrowing Owl (*Athene cunicularia ssp. hypugaea*) – Although they do not use Salton Sea proper, 70% of California's population inhabits drains and canals in the area (Riesz, no date), including within the Known Geothermal Resource Area. Some populations must be relocated for lithium extraction (Energy Source Mineral, 2021). It is a State Species of Special Concern (Riesz, no date).

Yuma Ridgway Rail (also known as Yuma Clapper Rail) (*Rallus longirostris yumanensis*) – This is a Federally listed endangered, State threatened, and State fully protected species (Riesz, no date).

Marshes near the Salton Sea house 80% of this species (Riesz, no date). Geothermal and lithium expansion that occur within Morton Bay where an established population resides requires mitigation to offset habitat loss (Shafique, 2021).

1.3 Invertebrates

Around 15 species of invertebrates have been noted to live within the Salton Sea (SDSU, no date; Coe et al., 2000; Kuperman et al., 2000). They consume algae and provide a food source to each other, fish, and shorebirds (SDSU, no date; Coe et al., 2000; Kuperman et al., 2000). Salinity controls invertebrate populations: species that can tolerate high salinities still exist in the Salton Sea while others are no longer found (SDSU, no date; Simpson and Hurlbert, 1998). Several species plummeted in 2005 (Anderson et al., 2007), but the water boatman (*Corixidae*) population has increased (Kirby, 2019). A list of Salton Sea invertebrates is located in Microsoft Teams in the Support Channel in the Ecology folder.

1.3.1 Species of Concern

Barnacle (*Balanus amphitrite saltonensis*) – shells provide an important habitat for amphipods and pile worms (Coe et al., 2000). Introduced in the 1940s (Coe et al., 2000), the barnacle population dropped in 2005 (Anderson et al., 2007).

Brine Shrimp (*Artemia franciscana*) and **Brine Fly** (*Ephydra*) – important food source for birds and other invertebrates, such as the water boatman (Cohen and Hyun, 2006; SDSU, no date). Brine shrimp and flies can withstand high salinities (Cohen and Hyun, 2006; SDSU, no date).

Pile Worm (*Nereis (Neanthes) succinea*) – an important food for fish and the primary food source for Eared Grebes (Kuhl and Oglesby, 1979; Kuperman et al., 2000). The pile worm population plummeted in 2005 (Anderson et al., 2007).

Water boatman (*Corixidae*) – important food source for fish (Kirby, 2019). Populations increased as fish decreased and have infested surround communities, such as in Salton City in 2019 (Kirby, 2019).

1.4 Mammals

About 38 mammal species have been recorded in the Sonny Bono Salton Sea Wildlife Refuge (USFWS, 2008; USFWS, 2011), none of which are protected (CNDDB, 2021a). Mammal species include 20 rodents, 12 bats, and 6 mid-size mammals including racoon, coyote, skunks, and desert kit fox (USFWS, 2008; USFWS, 2011). Smaller rodents are an important food source for raptors, herons, and egrets (USFWS, 2011). Muskrats play an important role in marsh habitat maintenance (USFWS, 2011). A list of Salton Sea mammals is located in Microsoft Teams in the Support Channel in the Ecology folder.

1.5 Reptiles & Amphibians

Four amphibians and 17 reptiles (2 tortoise, 6 lizards, and 9 snakes) have been recorded in the Sonny Bono Wildlife Refuge (USFWS, 2008; USFWS, 2011). Most amphibians are not found in saline habitats, but the Lowland Leopard Frog (*Rana yavapaiensis*), which was previously extinct in the region, now has a population in the refuge's wetlands and is a State Species of Special Concern (Parker, 2019; CNDDB, 2021b). Only the Desert Tortoise (*Gopherus agassizii*) is protected and is listed as Federally and State threatened species and a State candidate species for listing as an endangered species (CNDDB, 2021a). A map of the Desert Tortoise range is in Attachment C. A list of Salton Sea reptiles and amphibians is located in Microsoft Teams in the Support Channel in the Ecology folder.

2.0 Habitat Types

2.1 Habitat Types Associated with the Salton Sea

The best-studied and greatest biodiversity of the Salton Sea is in avifauna and much of the work on the Salton Sea has sought to categorize the different habitats that the birds of the Salton Sea utilize. Although the biodiversity at the Salton Sea extends beyond avifauna, these habitat descriptions can help to understand most species at the Salton Sea. Several different categorization schemes have been employed. For simplicity, this memorandum, presents the Jones 2016 classification of bird habitat which is the most current of these, and reflects a simplification of CDFW's classification and has clear physiographic taxonomy. This classification divides the Salton Sea habitat into playa, mudflats and shallow water, mid-depth water, deep water, and permanent vegetated wetlands. An additional habitat that is important especially to colonial nesting birds are the small islands in the Salton Sea. These islands provide protection, but many of them will soon or already have become connected to the mainland due to falling water levels (Bureau of Reclamation, 2007).

2.1.1 Playa

The playa is comprised of areas once inundated by water from the Salton Sea which are now exposed sand or alkali flats (Jones et al., 2016). Playa is the most abundant habitat type after open water. These areas are devoid of vegetation or sparsely vegetated with plants such as Iodine bush (*Allenrolfea occidentalis*). Small saline pools can form on the playa due to springs and seeps which are favored areas for foraging. The playa is primarily breeding, nesting, and overwintering habitat for small shorebirds such as the Snowy Plover (Shuford et al., 2000). Larger birds, such as American Avocets and Black-necked Stilts tend to favor areas where driftwood, vegetation, levees or other landscape features provide cover and security.

2.1.2 Mudflats and Shallow Water (0-15cm depth)

The mudflats and shallow water habitat type comprises the area directly around the Salton Sea that is influenced by its water up to a depth of 15 cm. This area along the shoreline is influenced by wind and waves and is home to many invertebrates and the species that feed on them. The area is largely devoid of vegetation. The Mudflats and shallow water comprised 26,100 acres in 1999 and 28,000 acres in 2015. Shorebirds such as dowitchers, sandpipers, and the American Avocet are typical of birds in this zone (Jones et al., 2016). Key areas for this habitat type include the western edge of the lake (zones 6-8 in Attachment D).

2.1.3 MID-DEPTH WATER (15-30CM DEPTH)

Mid-depth water is defined by Jones et al. (2016) as water between 15cm and 30cm deep. This zone is used by large wading birds such as egrets and herons and dabbling ducks. These birds are largely feeding on invertebrates and small fish. This zone is comprised 18,900 acres in 1999 and 19,900 acres in 2015.

2.1.4 DEEP WATER (30+CM DEPTH)

The deep water zone is where the water exceeds 30cm in depth. This zone is where Tilapia, the most abundant fish of the Salton Sea, spends most of its time. This zone is characterized by diving birds such as the fish-eating birds-cormorants and pelicans, and other important birds such as the eared grebe and ruddy duck feeding on invertebrates. Deep water also provides a pathway for desert pupfish to reach other breeding colonies located in agricultural drains and river mouths (Bureau of Reclamation, 2007). Continued increases in salinity may cut these breeding populations off form one another.

2.1.5 PERMANENT VEGETATED WETLANDS

Wetlands are areas where freshwater enters the Salton Sea and supports perennial vegetation that provides habitat to many animals. Most of these are on the north and south shores where the rivers and agricultural drains enter the Salton Sea. Important wetland vegetation types include Cattail (*Typha latifolia*), Common Reed (*Phragmites australis*) wetlands and Tamarisk (*Tamarix racemosa*) wetlands (Shuford et al., 2000). Tamarisk wetlands are particularly important as they provide roosts for colonial seabirds (Bureau of Reclamation, 2007). The area of wetlands was 2,500 acres in 1999 and 3,100 acres in 2015 (Jones et al., 2016). Wetlands are also important habitat for the desert pupfish and other fish species. The desert pupfish primarily occupies this zone. These drains often only connect to the Salton Sea in the winter when most of the precipitation in the region falls (Bureau of Reclamation, 2007).

2.2 HABITAT TYPE DISTRIBUTION

Important habitat areas are not evenly distributed around the Salton Sea (See attachments D and E). The areas at the north and south ends of the lake seem to be particularly important as they have the highest concentration of wetlands (Shuford et al., 2000; Jones et al., 2016). The Southeastern portion of the lake has the highest utilization by birds and the northeastern shore the least (Shuford et al., 2000).

3.0 Ecosystem Degradation

Increased salinity, decreased oxygen, and temperature changes will likely lead to ecosystem collapse under a no action scenario, decreasing viability of the Salton Sea for fish and migratory birds (Nye et al., 2021). Importing freshwater, lowering salinity, and increasing wetlands could restore, protect, and sustain the aquatic ecosystem and the species that rely on it (Nye et al., 2021).

3.1 Water Quality

A detailed review of Salton Sea water quality will be located in TM 4.4. Eutrophication, selenium concentrations, and thermal stratification are the primary aspects that harm the Salton Sea's ecosystem.

3.1.1 EUTROPHICATION

Eutrophication, the increase in nutrient loads (e.g., nitrogen and phosphorus), in the Salton Sea stem from agricultural runoff from the Imperial and Coachella Valleys and untreated sewage from Mexico (Nye et al., 2021; Sheikh and Stern, 2021). The increased nutrients promote the growth of algae, aquatic plants, and photosynthetic microorganisms (Nye et al., 2021). The decomposition of these species following death results in decreased dissolved oxygen, creating dead zones and decreasing fish populations (Nye et al., 2021). Eutrophication events will increase with rising salinity (Lyons and Hung, 2021).

Harmful Algal Blooms (HABs) also occur from eutrophication. Dinoflagellates and cyanobacteria primarily makeup HABs in the Salton Sea (Nye et al., 2021). These HABs produce neurotoxins that build up in fish, which are then consumed by birds (Nye et al., 2021). The cyanobacterial toxin has been linked the Eared Grebe deaths in the region (Nye et al., 2021). HAB occurrence will increase as the Salton Sea's elevation decreases and temperatures increase (Nye et al., 2021).

3.1.2 SELENIUM & OTHER CHEMICALS

Selenium is a naturally occurring element found within sediment in the Colorado River Basin and enters the Salton Sea in agricultural drainage inflows from adjacent lands irrigated with water from the Colorado River. Inflow has increased the concentration in the Salton Sea: a 2007-2008 study determined the inflow concentration to be between 0.00097-0.0645 mg/kg (p42, Lyons and Hung). The selenium has built up within the Salton Sea and is consumed by bacteria and algae, which are consumed by invertebrates, which are then consumed by fish and birds (Bureau of Reclamation, 2007). While necessary for metabolic function, high concentrations can be toxic, causing feather loss, reproduction harm, and death (Bureau of Reclamation, 2007). Selenium also suppresses avian immune systems, which may have contributed to 15,000 pelicans and other fish-eating birds died from botulism in 1996, which was partly contributed to the selenium concentrations in the region (p44, Lyons and Hung).

Other chemicals present in the Salton Sea from agricultural runoff include DDT and PCBs (Nye et al., 2021). Arsenic enters the ecosystem via geothermal and groundwater (Nye et al., 2021). Unsafe levels of these chemicals exist within the Salton Sea and in the Whitewater, New, and Alamo River wetlands at the perimeter of the Salton Sea (Nye et al., 2021). These chemicals pass through the food chain and harm birds and can kill fish by increasing cold susceptibility (Nye et al., 2021).

3.1.3 THERMAL STRATIFICATION

Thermal stratification occurs when a layer of warm, less-dense water forms over a cooler, denser layer of water (Bureau of Reclamation, 2007). This reduces mixing events that historically have occurred throughout the year to only occur for a short amount of time in the winter (Bureau of Reclamation, 2007). The less frequent mixing events build up hydrogen sulfide and ammonia concentrations (Bureau of Reclamation, 2007). When mixing does occur, gaseous ammonia and hydrogen sulfide are released, leading to annual fish die offs (Bureau of Reclamation, 2007). This also leads to pile worm population crashes, which in turn causes decreased food availability for Eared Grebes, leading to death (Anderson et al., 2007).

3.2 Salinity

See TM 4.1 for details on Salton Sea salinity. Species salinity tolerance will be detailed in TM 8.2.

Salinity influences the location of viable habitats and which species can be sustained in the Salton Sea. Rising salinity has removed almost all fish species from the Salton Sea proper, but fish have been found in the freshwater creeks that flow into the Salton Sea (USFWS, 2008; CDFW and USFWS, 2017). For instance, tilapia in 2017 were rarely found in the Salton Sea proper and were more likely to be found in the lower salinity regions where inflows meet the Salton Sea (CDFW and USFWS, 2017). Pupfish are adapted to both fresh and high salinities but enter the Salton Sea to move between the freshwater pools they reside in (Nye et al., 2021). Rising salinity, however, will likely stop pupfish from moving between these habitats in the future (Nye et al., 2021). Additionally, rising salinity alters which birds can be supported at the Salton Sea. The decrease in fish has decreased the occurrence of fish-eating birds at the Salton Sea (Jones, Orr, and Cooper, 2019). The pile worm can only reproduce in a maximum salinity of 45-50 ppt (Kuhl and Oglesby, 1979), which was surpassed in 2009 (Bureau of Reclamation, 2020), therefore limiting food availability for Eared Grebes (Kuperman et al., 2000). Water boatman are currently a primary shorebird and waterfowl food source, but rising salinities threaten these populations (Shafique, 2021). Microorganisms and arthropods that favor low oxygen and high salinity conditions may thrive while other invertebrate populations will crash, eventually limiting food for shore birds (Nye et al., 2021).

3.3 Habitat Loss

Rising salinity and temperature have driven fish to the fresher water regions near the tributary channels that enter the Salton Sea (e.g., where the New, Alamo, and Whitewater Rivers meet the Salton Sea) (Nye et al., 2021). The limited fish habitat has caused fish-eating birds to congregate in these regions (Nye et al., 2021). The increased density of species accelerates disease outbreaks. 150,000 Eared Grebes died in 1992 at the Salton Sea due to disease (Audubon, no date b; Riesz, no date) and an avian cholera outbreak killed 6,000 Ruddy Ducks in 2019 (Gregg, 2019).

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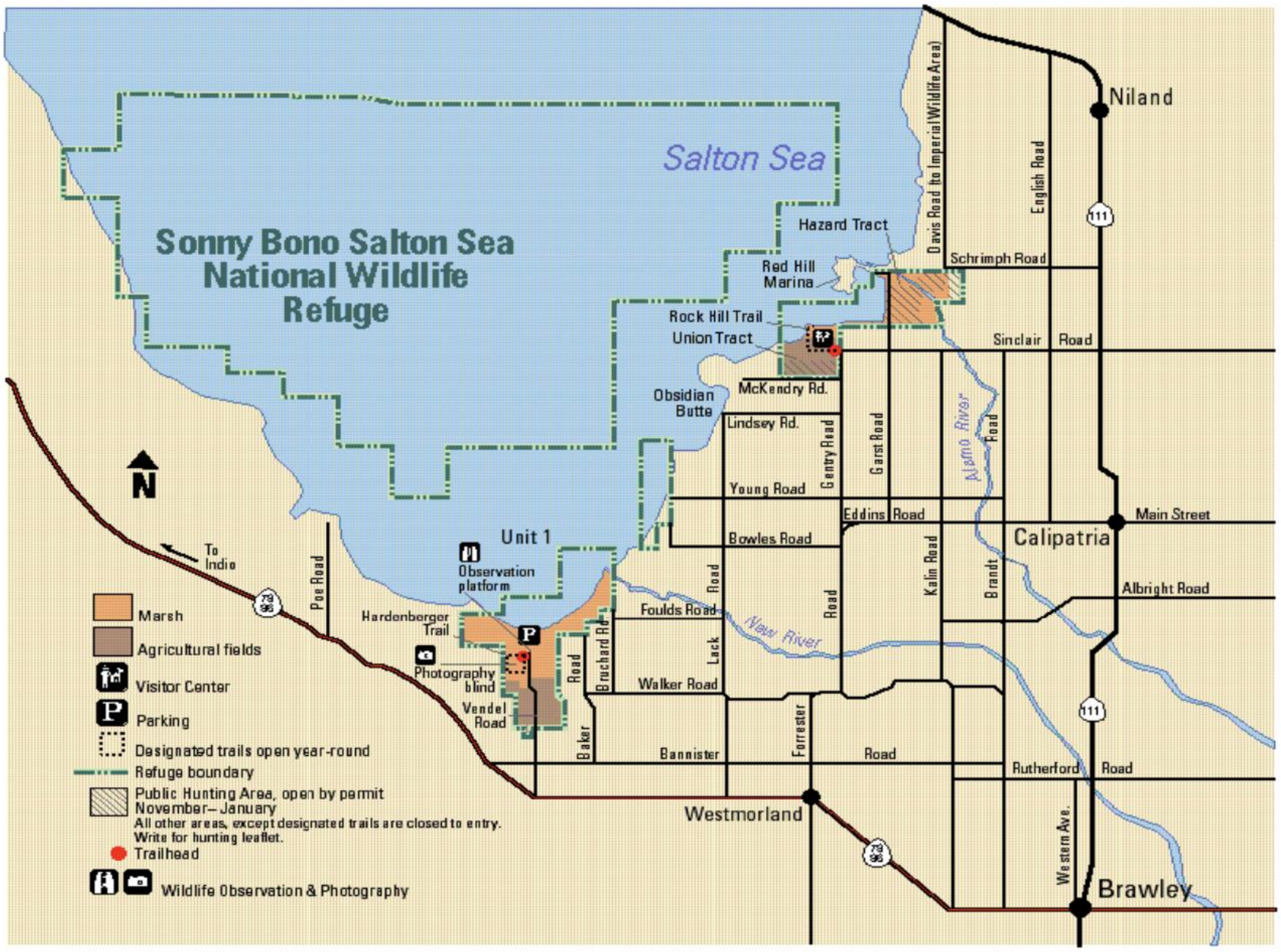
ATTACHMENT A

DESERT PUPFISH LOCATIONS SURROUNDING THE SALTON SEA (KEENEY, NO DATE).

Note: Map base image is from 2010 however map date is unknown. A more recent map is not publicly available. This map may be incorrect as a 2021 source states only 5 isolated populations exist around the Salton Sea (Echelle and Echelle, 2021). Another source states that pupfish reside in freshwater pools in the perimeter of the Sea and utilize the Sea to move between them (Nye et al., 2021).

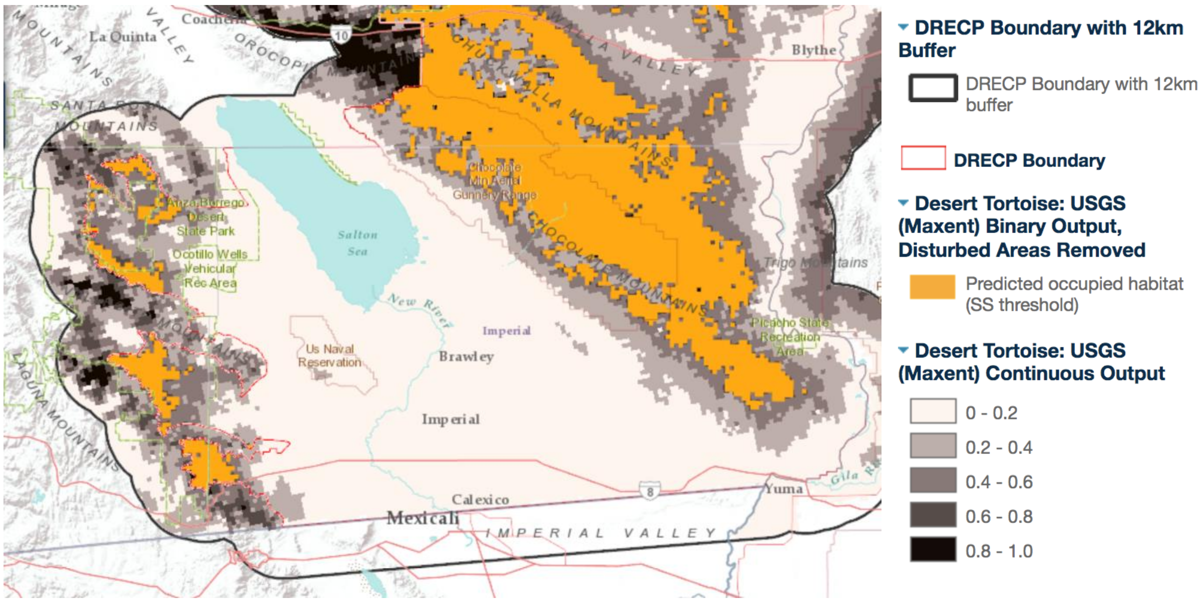
ATTACHMENT B

Sonny Bono National Wildlife Refuge map (Shafique, 2021).



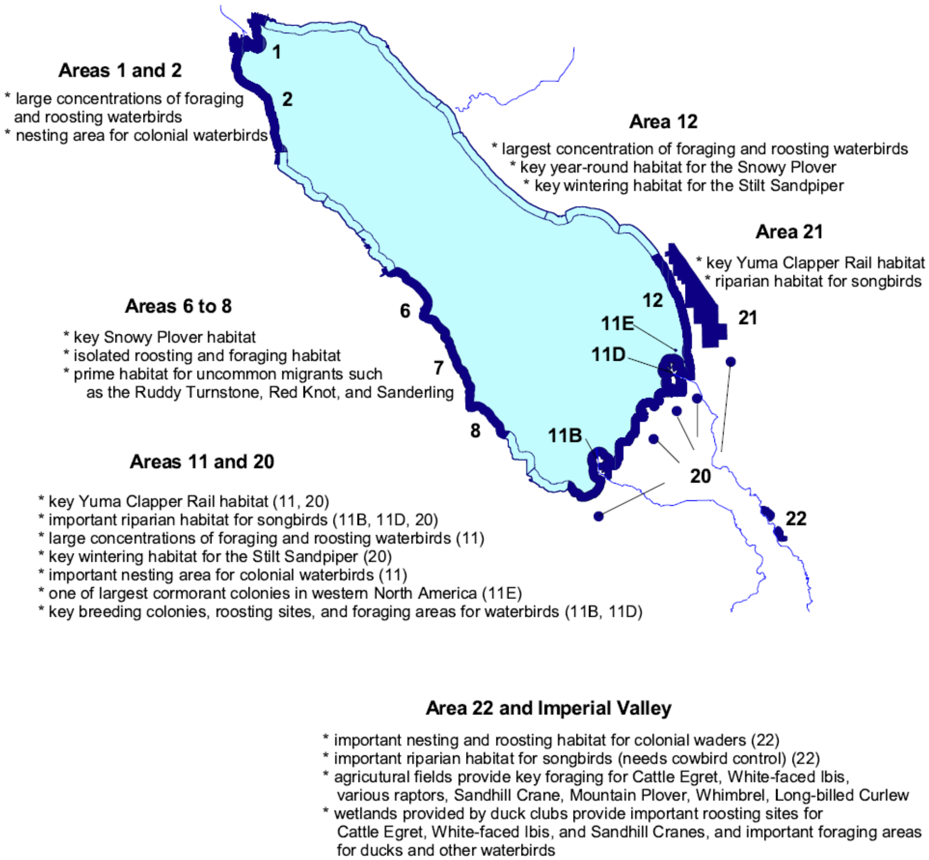
ATTACHMENT C

Desert Tortoise habitat range map (Conservation Biology Institute, 2013).



ATTACHMENT D

AREAS OF PARTICULAR IMPORTANCE TO BIRDS (SHUFORD ET AL., 2000).



Note: These data largely coroborated by Jones et al. (2016).

ATTACHMENT E

Waterbird Utilization of Salton Sea Locations (Shuford et al., 2000).

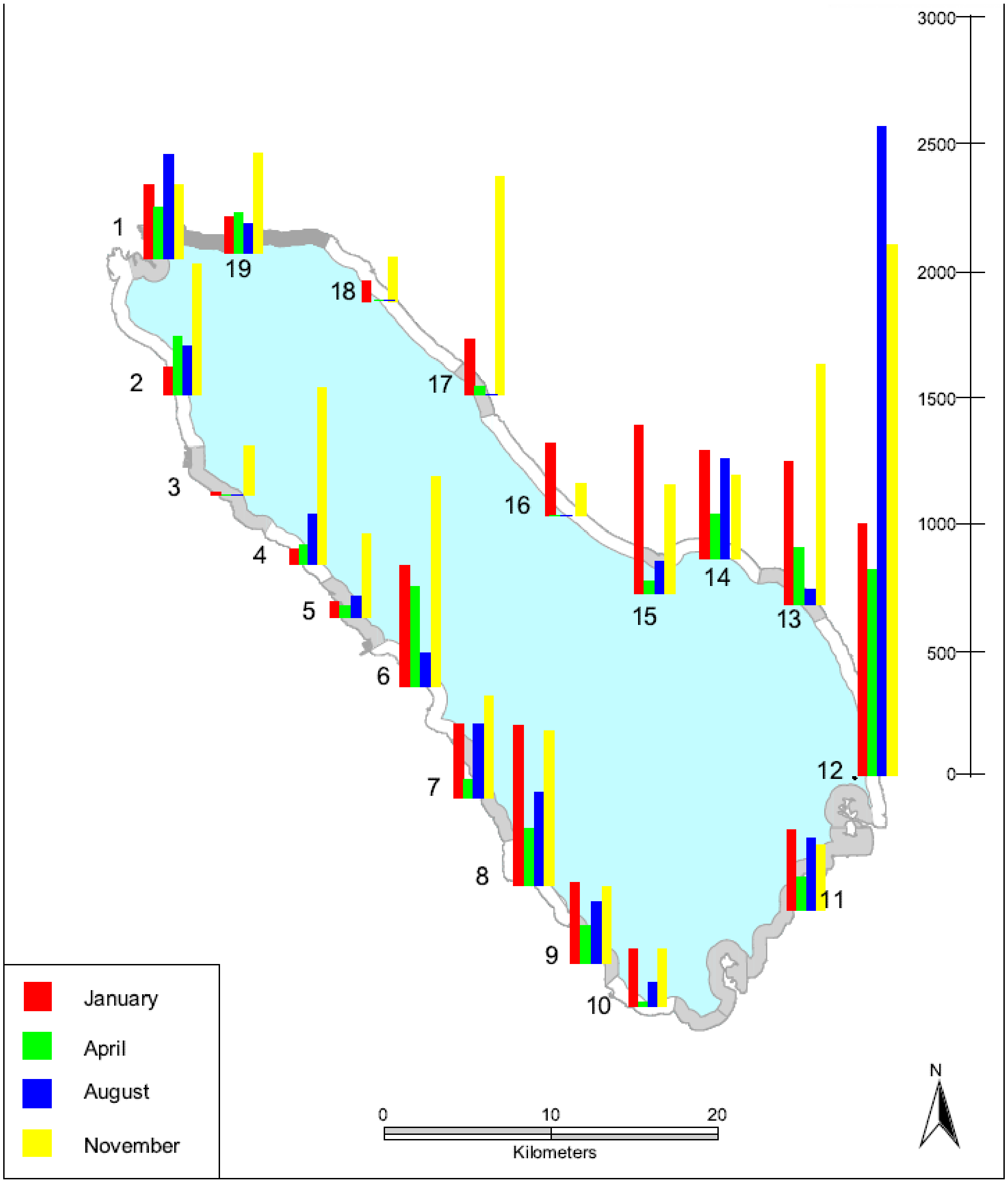


Figure 5 - 1b. Comparison of density (individuals/km) of waterbirds within 19 shoreline segments for four comprehensive surveys of the Salton Sea, California, in 1999.